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**DISCOUNTING ACROSS SPACE AND TIME**

**IN CLIMATE CHANGE ASSESSMENT**

A Dissertation in

Geography

by

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**Abstract**

Discounting is traditionally conceptualized as the comparison of the value of gains or losses that occur at different times. It endeavors to incorporate how humans trade off values to be received in the future versus value received immediately into economic analysis. Discounting has emerged as a key factor in assessments of climate change and other long-term environmental issues. However, the traditional time-only discounting neglects important spatial influences on how values are compared. This dissertation presents what is, to my knowledge, the most comprehensive effort to incorporate space into discounting as a theoretical, empirical, and applied concept. New discounting theory is presented that examines major reasons for discounting across time and finds that these reasons also hold for discounting across space. The theoretical work culminates in a new conceptualization of discounting that handles discounting across space as well as time while clarifying the philosophical basis for what is and is not discounting. New empirical research on discounting examines how humans discount across space and time and assesses the extent to which human values can be described in terms of discounting. This empirical research indicates that discounting by humans has strong spatial components and also that discounting is fundamentally limited as a paradigm for describing human values. Finally, new applied research illustrates how space-time discounting can advance our understanding of important societal issues through analysis of three cases of climate change adaptation. These cases – crop indemnity payments, the Commonwealth of Nations, and the nexus between climate change, migration, and conflict – show the importance of space-time discounting to cases of project evaluation, cooperation, and conflict. For example, the crop indemnity payments finds that when we do not account at all for space in project evaluations, or when we account for space with too coarse of a resolution, then our project evaluations can be significantly inaccurate. Taken together, this dissertation's theoretical, empirical, and applied work show the importance of space to discounting as both an intellectual construct and a concept with very tangible practical significance. In short, the inclusion of space into discounting suggests major transformations to both the science and policy of discounting.

**Table of Contents**

**List of Figures**

**List of Tables**

**Preface**

Chapters 3 and 4 serve as the basis for multiple-authored journal papers. In both cases, I am the first author.

The second author for Chapter 3 is Peter Howe. I developed the core ideas for this chapter and situated them within the existing literature. I designed the survey presented in this chapter with assistance from Howe as well as our colleagues Laura Wray-Lake and Jennifer Domagal-Goldman. Howe led the quantitative data analysis of our survey results; the qualitative analysis was performed jointly. I led the writing of the chapter. Howe made contributions to the writing throughout the chapter, in particular Sections 3.4 and 3.5 discussing our survey. Finally, Howe led the production of Tables 3.1-3.3.

The second author for Chapter 4 is William Easterling. I led the development of the core ideas for this chapter with extensive input from Easterling. I situated the ideas within the existing literature. I led the development of the three case studies. Easterling helped devise the crop indemnity case and identified the data used for this case. Finally, I led the writing of the chapter. Easterling made contributions to the writing throughout the chapter.

**Acknowledgments**

**Chapter 1: Introduction**

The purpose of this dissertation is to provide a comprehensive treatment of how space is relevant to the concept of discounting. An extensive literature already examines discounting across time, which in rough terms is the comparison of the values of gains and losses that occur at different times. But how gains and losses are valued depends on *where* they occur, not just *when* they occur. The small amount of prior work on discounting across space provides important starting points but does not fully integrate space into the discounting concept. This dissertation improves on the prior work mainly by providing a significantly more comprehensive account of the role of space in discounting. The dissertation covers each of three core aspects of discounting. First, the dissertation develops a theoretical foundation for space-time discounting, examining reasons for discounting across space and time. This theoretical work results in a new definition of discounting. Second, the dissertation explores space-time discounting as an empirical concept, analyzing how people discount across space and time and the extent to which human values can be described through discounting. This empirical work suggests major transformations to how descriptions of how people discount are used in policy analyses. Third and finally, the dissertation applies space-time discounting to three sets of problems that involve climate change adaptation. This applied work demonstrates the usefulness of space-time discounting to major societal issues. Taken together, the theoretical, empirical, and applied work presented in this dissertation offer a thorough treatment of the importance of space to discounting.

**1.1. The Need for Space-Time Discounting**

Why is space-time discounting important? Suppose we are Canadian policy makers considering how (if at all) to assist with efforts to adapt to the impacts of climate change. We must decide how much assistance to offer and how to distribute it. We are aware that some regions within Canada are expected to be more severely impacted by climate change than others, and that the most severely impacted regions are expected to be primarily in other countries, in particular certain lower-income countries. We are also aware that climate change is a dynamic process and thus that the impacts will change over time, quite often becoming more severe than they are now. Given the set of impacts as it is distributed across space and time, how should we – and how will we – decide how much assistance to offer and how to distribute this assistance?

Traditional policy research often approaches these questions with some form of cost-benefit analysis (Ackerman and Heinzerling 2004; Adler and Posner 2006; Fuggitt and Wilcox 1999). In simple terms, here the benefits of adaptation assistance are weighed against the costs of providing the assistance. When the benefits exceed the costs, then the assistance may be considered to be warranted. For any given region and time to which the Canadian government could provide adaptation assistance, it might favor the assistance whenever it finds that the benefits of assistance are worth the cost. Thus a cost-benefit analysis for each region-time could establish how the Canadian government would distribute its assistance. Likewise, the total amount of assistance it offers might be the total amount for which the benefits are believed to exceed the costs.

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Performance of cost-benefit analysis like the above requires all the costs and benefits to be in some common metric – known as the numéraire – so that their values can be compared. Often – though not always – money is used as the numéraire; other numéraires might include welfare, lives saved, or even a generic points system. For whatever numéraire is used, it will also be necessary to compare values across space and time. That is, it is not necessarily the case that one dollar, one life, or one unit of some other metric is worth the same in all regions and at all times. For example, in our adaptation scenario, the Canadian government might decide that lives of contemporary Canadians are worth more than lives of people at other times and in other countries. Lives in these other times and countries might also be valued differently from each other. Lives in the near future might be valued more than the distant future; lives in countries that share Canada's affiliation with the Commonwealth of Nations might be valued more than non-Commonwealth countries. Indeed, Canada has actively participated in intra-Commonwealth adaptation programs.

In this dissertation, the process of comparing the values of costs and benefits that occur at different times and places will be referred to as *discounting*. The discounting concept is one with a long history and a large body of ongoing research located mainly in economics, as well as ethics, psychology, and cognate fields. Roughly speaking, economics established and developed discounting as a theoretical concept and explored many of its implications; ethics has studied prescriptions (recommendations) for how we *should* discount; and psychology has studied descriptions (observations) of how we *do* discount. It is not necessarily the case that how we do discount is also how we should discount. However, description and prescription are commonly connected via the "descriptive approach" to discounting (Arrow et al. 1996), details of which are discussed below.

With rare exception, the discounting literature (and its usage in policy and other decision making) has focused exclusively on value comparisons across time. (See Section 1.2.2 for a survey of the literature.) Indeed, discounting is almost always assumed to refer exclusively to intertemporal comparisons. This includes treatments of discounting in each of economics, ethics, and psychology, as well as in the other fields that have studied discounting. Comparisons across space either are ignored, assumed to be unimportant, or in some cases handled through other means. Thus for our scenario of Canadian government assistance for climate change adaptation, and for many other scenarios as well, we know quite a lot about how we would and how we should value the costs and benefits as they occur at different times, but relatively little about the valuations across space.

The neglect of space in discounting comes despite the potential for space to be important to discounting. For example, the Canadian government could care deeply about where the benefits of its adaptation assistance accrue. It might care more about benefits that accrue to Canadians, because it is elected by Canadians. Or, it might care more about benefits that accrue to people who are overall worse-off (whether in Canada or elsewhere), or who are expected to be more severely impacted by climate change, out of

support for ethics which prioritizes the worse-off or more severely impacted. Finally, it might care more about benefits in some places simply because it is more effective at achieving these benefits due to the specifics of its ability to provide adaptation assistance. Other reasons for discounting across space could exist for this Canada adaptation scenario and for other scenarios as well. Thus the neglect of space is not due to some inherent irrelevance of space to discounting.

In this dissertation, I develop a conceptualization of discounting that readily handles discounting across both time and space. This conceptualization expands existing time-only discounting paradigms to include discounting across space, and perhaps across other dimensions as well. The conceptualization also accommodates the small amount of prior work on spatial discounting: the conceptualizations contained in the prior work constitute a subset of the conceptualization developed here. Including space in discounting constitutes a significant expansion of the discounting concept. As part of this exercise in expansion, this dissertation also systematically explores the limits of discounting (1) as a theoretical concept and (2) as a paradigm for describing human values. That is, the dissertation systematically explores (1) the breadth of ethical views that can in theory be expressed in terms of discounting, and (2) the extent to which observed human values fit within those views that can be expressed in terms of discounting. Given the prominence of discounting in environmental issues, special attention is paid to discounting in non-anthropocentric ethics, i.e. ethics in which the costs and benefits may have no connection to humans. Although most existing treatments of discounting are strictly anthropocentric, it is possible to extend discounting beyond anthropocentric ethics. However, there are other views on ethics to which discounting cannot be extended. Thus discounting, no matter how broadly defined, cannot handle all views on how we do and how we should make policy and other decisions.

The dissertation has three core parts, covering theoretical, empirical, and applied aspects of space-time discounting. Each part is written to be a stand-alone journal article. The first part (Chapter 2) develops the idea of space-time discounting as a theoretical concept. The Chapter 2 goal is to establish and refine the theory of space-time discounting, including the possibility for discounting to employ non-anthropocentric ethics. The second part (Chapter 3) explores descriptions of how people discount across space, time, and other dimensions, as well as limitations to how well human values can be described in terms of discounting. The Chapter 3 goal is to review and extend our understanding of how humans discount across space and time as well as the limits to how well human values can be described in terms of discounting. The third part (Chapter 4) applies the concept of space-time discounting to three cases in climate change adaptation: crop indemnity payments, adaptation projects sponsored by the Commonwealth of Nations (many of which feature Canada's involvement), and the hypothesized connection between climate change, forced migration, and violent conflict. The Chapter 4 goal is to demonstrate the usefulness of the space-time discounting concept to real-world scenarios. Thus although the dissertation is divided into three distinct parts, each part has considerable relevance to the other, and when taken together the three parts present a unified case for including space in discounting.

Throughout the dissertation, I do not advocate for any particular ethical view on how we should or should not discount. However, I do engage in some advocacy and other normative activity. In most general terms, I aim to "improve" our understanding of what discounting is and how this concept can be used. I put "improve" in scare quotes here to emphasize the normativity inherent in this term. I am making a normative argument in this dissertation, but it is a subtler – and, I believe, weaker and more readily accepted – argument than the sorts of arguments made for or against various views on discounting. In particular, I am arguing for, and working towards, intellectual virtues such as clarity of thought, consistency of reasoning, and accuracy of analysis. I believe such virtues to be held widely – perhaps universally – by those engaged in research on discounting, regardless of the specific views on discounting that these individuals might hold. We might or might not view these virtues as being important or valuable for their own sake, but we probably at least believe them to be important or valuable as precursors to whatever it is that we do consider to be important or valuable for its own sake.[1] Thus when I make a claim like "we should include space in discounting," I am appealing to these intellectual virtues and not to the sorts of ethics used to pick sides in debates on how we should discount.

At several points in the dissertation, I refer to the idea of "analytical mistakes". This idea also has a normative element to it: in general, a mistake is considered to be a bad thing. As it appears in this dissertation, an analytical mistake is one specific type of mistake. Specifically, an analytical mistake is a piece of analysis that the analyst herself would disagree with if only she was aware of how this piece of analysis was mistaken. For example, if I include in an analysis work showing that one plus one equals three, then I would consider this to be a mistake, if only I was aware that I had done this, and I would agree that this mistake constitutes "bad" analysis. In the dissertation, I sometimes argue that neglecting space in discounting can lead to analytical mistakes. The assumption here is that analysts would agree that space should not be neglected if only they were aware of how space is being neglected and how this neglect alters the analysis. If this assumption does not hold – if a fully aware analyst would maintain that space should be neglected – then there would be no analytical mistake.

In this dissertation I make the normative claim that the concept of discounting *should* include space. This claim depends on an argument about semantics. In Chapter 2, and to a lesser extent in Chapter 4, I describe the several phenomena that are commonly cited as reasons for discounting across time. I further show how these phenomena – or close variants thereof – also exist across space. The question is whether the term "discounting" should be used to refer to these spatial phenomena just as the term is used is used to refer to the temporal phenomena. The only reason I can think of to not use discounting for these spatial phenomena is because the term "discounting" is inherently time-only. But this time-only restriction is both arbitrary and in conflict with colloquial uses of "discounting." In colloquial speech, to discount is to reduce the price, as in "the blue shirts are discounted to 10% less than their regular price." This use of discounting is not

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[1] The distinction between something being valuable for its own sake and being valuable for other reasons is a theme found throughout the dissertation. In the jargon of the dissertation, being valuable for its own sake means holding *intrinsic value*; being valuable for other reasons means holding *extrinsic value*. These two terms are discussed further in Section 1.2.1.

time-only.[2]  Why, then, should the other use of discounting be time-only?  I can think of no reason.  Finally, and perhaps most importantly, I find it clear, convenient, and useful to use the term "discounting" to refer to both the temporal and the spatial phenomena.  I would use "time discounting" or "temporal discounting" for the temporal phenomena and "space discounting" or "spatial discounting" for the spatial phenomena.  I understand that – for now, at least – many people will assume that "discounting" refers only to temporal phenomena.  Such is the nature of language and its evolution.  I am arguing for no less than a new understanding of an entrenched concept.  This will not occur overnight.  But, as I attempt to show in this dissertation, this new understanding is superior.

In Chapter 2 I also argue that the concept of discounting *should* include non-anthropocentric ethics.  The argument here directly parallels the argument for including space.  That is, the anthropocentric phenomena commonly referred to as discounting have non-anthropocentric equivalents or at least close approximations.  First, the same evaluative process that we call "discounting" when it is performed by humans can also be observed to be performed by at least some non-human entities, in particular sentient non-human animals.  This first form of non-anthropocentric discounting is referred to in Chapter 2 as *discounting by non-humans*.  Second, values involved in "discounting" can be non-human values just as they could be human values.  For example, in the case of Canadian government assistance for climate change adaptation could go to support Canadian humans or to the non-human portions of Canada – its ecosystems, livestock animals, etc.  This second form of non-anthropocentric discounting is referred to in Chapter 2 as *discounting for non-humans*.  In discounting by non-humans and discounting for non-humans, we have two major ways in which the discounting concept has parallels between the human and non-human realms.  Because of these parallels, it would be semantically arbitrary and unhelpful to exclude non-anthropocentric ethics from the term "discounting" just as it would be to exclude space.

Given the prominence of ethics in this dissertation, it is worth pausing to consider how this term is defined, especially since it is a term that can be understood in multiple ways.  In this dissertation, I use the term "ethics" broadly to refer to views or ideas about what is right and wrong, or good and bad, or what we should or should not do or be, as well as the study of these views and ideas.  As noted above, it is not my intent in this dissertation to argue for or against any of these views.  Instead, I endeavor to be inclusive of all views, including views that are only hypothetical in the sense that no one actually supports these views, and even including views that all or almost all of us will find horribly objectionable.  We may reject these views, but they are views nonetheless, and as such will not be excluded here.  Likewise, in this dissertation I intend broad definitions for what is within the domain of ethics.  Any view, decision, action, etc. that could at least hypothetically be considered to be about what is right and wrong or good and bad is here treated as an ethical view, decision, action, etc.  This may well include all views, decisions, and actions.  I would accept this result.  In contrast with some ethicists, I tend

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[2] These two uses of "discounting" are connected: merchants and lenders often offer a discount to customers or borrowers who make their payments early.  This practice has a long history, as seen in the Baba Metzia quote presented in Section 1.2.2.

to consider all decisions and actions to be at least potentially of at least some ethical significance.  Consider this passage from noted ethicist John Broome (2008:97):

> Not all "should" questions are ethical.  "How should you hold a golf club?" is not, for instance.  The climate question is ethical, however, because any thoughtful answer must weigh conflicting interests among different people.

If ethics is confined to situations of conflicting interests among different people, then how we should hold golf clubs could be ethical.  For example, I may face a decision of how hard to try to defeat you in a game of golf, which could pose conflicts between your interests and mine.  The decision could pose even broader conflicts if the game of golf is, as is often the case, a backdrop for business or political negotiation.  But even if I am golfing alone, how I hold my club can be of ethical significance.  For example, how I hold the club in general will affect my golfing performance, which in turn can affect how much I enjoy the game.  My enjoyment is of significance to those versions of utilitarian ethics (including, ironically, versions discussed in Broome 2008) that value such things as enjoyment, happiness, and wellbeing.  Thus according to these ethical views, how we hold our golf clubs can be of ethical significance.

Likewise, the intellectual virtues (such as avoidance of analytical mistakes) emphasized in this dissertation can also be treated as being within the ethical domain.  These virtues can be value from the perspective of ethical frameworks such as utilitarianism because, when we aspire to these virtues, we often are more successful at identifying which actions are better according to these frameworks.  On the other hand, the time spent in pursuit of intellectual virtues may often be spent on other tasks achieve more good per the ethical framework in effect.[3]  (On this, see Ord 2009.)  But the intellectual virtues can be considered as being within the ethical domain on their own, without appeal to separate ethical frameworks.  Schienke et al. (in press) refer to this as *intrinsic ethics*, i.e. ethics intrinsic or internal to research, which include "cognitive values such as simplicity, scope, internal consistency, consistency with other beliefs (conservatism), and empirical adequacy" (Schienke et al. in press:13).  Given the broad set of topics that can be considered as being within the domain of ethics and my intent here to not exclude particular views on ethics, I will maintain a broad view of ethics in this dissertation.

In the remainder of this Introduction, I further develop prior work relevant to space-time discounting and outline how this dissertation extends this work.

## 1.2. Prior Work On Discounting

As noted above, discounting is the subject of a large body of literature, mainly in economics but also with substantial contributions from ethics, psychology, and related fields.  Discounting has been especially prominent in discussions of long-term environmental issues such as climate change and hazardous waste storage.  A comprehensive review of the discounting literature here would be superfluous to the

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[3] By "in effect," I mean that these ethics are either actually correct or believed to be correct such that they serve as a guide for the actions or the lives of one or more (human or nonhuman) agents.

deeper treatment found in Chapters 2-4. Instead I provide a general overview of the literature relevant to the conceptualization of space-time discounting developed in this dissertation.

### 1.2.1 Costs and Benefits

Before reviewing the discounting literature, it is helpful to introduce some further background information about the concepts of costs and benefits, because discounting is (or at least can be considered to be) a subtopic within the realm of cost-benefit analysis. In particular, there are several ways of conceptualizing costs and benefits, each of which leads to a different understanding of discounting. I have developed these points more fully in a separate paper (Baum in press); here a short summary will suffice.

Most often, it is assumed that costs and benefits are monetary in nature, i.e. are measured with a numéraire of dollars, Euros, or other currency. Where costs and benefits are not initially in monetary form, they are often converted into a monetary numéraire, typically by estimating how much money people are willing to pay for them. This monetization procedure is found throughout the expansive cost-benefit analysis literature (cf. Ackerman and Heinzerling 2004; Adler and Posner 2000; 2006; Anderson 1993; Fuggitt and Wilcox 1999; Layard and Glaister 1994; Mishan 1975; Sagoff 2008; Soma 2006; Spash 2008; Sugden and Williams 1978). Such monetary costs and benefits are then often discounted across time. Sometimes, costs and benefits are interpreted in terms of human utility or welfare (Brekke 1997; Drèze and Stern 1987; 1990). Here costs and benefits may still be measured in a monetary numéraire, but, if they are, then the dollars would be weighted to account for the relationship between money and utility. The weighting captures the idea that one unit of money does not necessarily bring one unit of utility. In particular, it is often assumed that a dollar of consumption is worth more to the poor than to the rich, suggesting a diminishing marginal utility of consumption.

Interestingly, the discounting literature is much more likely to use non-monetary numéraires than is the cost-benefit analysis literature. For example, there is a substantial line of work exploring how people discount health (cf. Asenso-Boadi et al. 2008; Chapman 2002; Ganiats et al. 2000; Gravelle and Smith 2001). If cost-benefit analysis is restricted to monetary numéraires, then these non-monetary discounting studies fall outside the realm of cost-benefit analysis.

One attribute common to both the cost-benefit analysis literature and the discounting literature is that nonhuman phenomena (such as the environment or the welfare of nonhuman animals) are valued only to the extent that they are valued by or valuable to humans, as opposed to being valued for their own sake. If money is the numéraire, then it is humans' money in question, which is in some sense obvious because nonhumans do not generally handle money (but see Chen et al. 2006). If utility is the numéraire, then it is humans' utility in question, despite any evidence suggesting the existence of

nonhuman animal utility (cf. Chandroo et al. 2004; Lockwood 1987). If any other numéraire is used, then this numéraire would similarly be tied to some human attribute.[4]

When a cost-benefit analysis or discounting scheme values everything in terms of humans, it exhibits *ethical anthropocentrism*. Ethical anthropocentrism refers to the view that human interests should be prioritized within an ethical framework. The environment, the welfare of nonhuman animals, or any other nonhuman phenomena would be valued mainly or entirely to the extent that they are valued by or valuable to humans, as opposed to being valued for their own sake. If the nonhuman phenomena are mainly, but not entirely valued in human terms, then the corresponding ethical framework has *weak ethical anthropocentrism*; if the nonhuman phenomena are entirely valued in human terms, then the corresponding ethical framework has *strong ethical anthropocentrism* (Eckersley 1998). In saying that only humans are valuable for their own sake, the cost-benefit analysis and discounting literatures are using strong ethical anthropocentrism.

To say that only humans are valued for their own sake is to say that only humans hold *intrinsic value*. Intrinsic value is defined as that which is valuable for its own sake (Rønnow-Rasmussen and Zimmerman 2005). Intrinsic value stands in contrast with extrinsic value, which is anything that is valuable but is not intrinsic value (Bradley 1998). For example, if human welfare holds intrinsic value, then monetary consumption might hold extrinsic value because of the effect it has on human welfare. Or, if ecosystems hold intrinsic value, then soil nutrients might hold extrinsic value because of the effect they have on ecosystem flourishing. Thus, strong ethical anthropocentrism means that only humans hold intrinsic value; weak ethical anthropocentrism means that non-humans hold intrinsic value, but not nearly as much. In weak ethical anthropocentrism, when there is a trade off between human interests and non-human interests, one almost always decides in favor of the humans. The anthropocentrism found throughout the cost-benefit analysis and discounting literatures is strong ethical anthropocentrism. Likewise, throughout the dissertation, when the term ethical anthropocentrism is used without qualification, strong ethical anthropocentrism is intended.

In previous work (Baum in press; see also Sen 2000 for the only similar discussion that I am aware of), I argued that cost-benefit analysis can be expanded to include non-monetary metrics and non-anthropocentric ethics. Specifically, I argued that any negative or positive consequence of an action could be treated as a cost or a benefit. Here "negative" and "positive" can be defined in any way, i.e. relative to any definition of what holds intrinsic value as long as this intrinsic value can be a consequence of an action. In Chapter 2 of this dissertation, I advance a similar argument for discounting; in Chapter 3, I explore some empirical implications of this argument.

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[4] A possible example of a cost-benefit analysis that does not feature ethical anthropocentrism is the climate change mitigation analysis of McInerney and Keller (2008). As Schienke et al. (in press) discuss, McInerney and Keller (2008) include a term that may value natural systems for their own sake. However, the exact language of McInerney and Keller (2008) is ambiguous on whether natural systems are valued for their own sake or for their impact on humans.

While cost-benefit analysis can include a broad range of consequences, it would appear to only be able to include consequences. In other words, cost-benefit analysis inevitably exists within consequentialist ethics, which is ethics that holds that the consequences of our actions are the only ethically relevant phenomena. Other forms of ethics, such as deontology and virtue ethics (on which, see Section 3.2.3), appear to not follow any sort of cost-benefit structure. Following this logic, when these other, non-consequentialist forms of ethics are in effect, one cannot use cost-benefit analysis. As a caveat, it should be noted that non-consequentialist ethics is not explored in significant detail in this dissertation. Thus while I struggle to imagine non-consequentialist cost-benefit analysis, I cannot strictly rule it out.

## 1.2.2 The Discounting Concept

Discounting usually refers to some sort of comparison of the values of costs and benefits that occur at different times. This time-only discounting tradition is supported by a large interdisciplinary literature; major contributions include Ainslie (1974); Arrow et al. (1996); Frederick (2006); Frederick et al. (2002); Laslett and Fishkin (1992); Lind (1982); Loewenstein and Elster (1992); Portney and Weyant (1999); Price (1993); and the special journal issues introduced in Weisbach and Sunstein (2007) and Zeckhauser and Viscusi (2008). This literature emphasizes the importance of time discounting to long-term societal issues, illustrates the subtleties of how humans discount across time, and develops several competing views on how we *should* discount across time. Within this broad category of intertemporal value comparison, there are some differences between specific definitions of discounting.

Some definitions of discounting are very general. For example, at the beginning of one of the most thorough treatments of discounting available, Price (1993:4) defines discounting as "any process of revaluing a future event, condition, service or product to give a present equivalent." Similarly, in another prominent study, Frederick et al. (2002:352) "use the term time discounting broadly to encompass any reason for caring less about a future consequence." These definitions could readily handle non-monetary numéraires and non-anthropocentric ethics. (As is typical for the discounting literature, Price and Frederick et al. both consider non-monetary numéraires but not non-anthropocentric ethics.) As noted in Section 1.2.1, this could permit some discounting to fall outside the realm of cost-benefit analysis.

Other definitions of discounting explicitly define it in terms of cost-benefit analysis. For example, Sen (1982:326) holds that "the discount rate specifies the rate at which additional benefits in period $t + 1$ are converted into equivalent amounts of benefits in period t." This definition does not specify how costs and benefits are to be defined and thus could permit a broader interpretation of the terms. (The Sen 1982 paper employs a more typical narrow definition of costs and benefits, though Sen 2000 suggests that costs and benefits could be defined more broadly.) Meanwhile, Drèze and Stern (1990:29) define the social discount rate as "the rate at which the marginal social value of the numéraire is falling over time." This definition embeds discounting within a very specific form of cost-benefit analysis in which costs and benefits are defined in terms of

the welfare of human society. The definition follows from the welfare-based form of cost-benefit analysis that Drèze and Stern (1987; 1990) develop.

The definitions presented by Sen (1982) and Drèze and Stern (1990) both use the concept of the discount rate. The idea that the value of costs and benefits might decay over time at some fixed rate has a long history. This includes early academic work on discounting (e.g. Ramsey 1928; Samuelson 1937). This also includes the much longer history of interest and usury, which in many ways are conceptually antecedent to discounting. The histories of interest and usury can be traced to some of humanity's oldest known regulations, including the Code of Hammurabi and the Old Testament (Houkes 2004). For example, line 88 of the Code of Hammurabi reads:

> If a merchant [lent] grain at interest, he shall receive sixty qu of grain per kur as interest. If he lent money at interest, he shall receive one-sixth (shekel) six Fe (i.e. one-fifth shekel) per shekel of silver as interest (Houkes 2004:10).

Deuteronomy XXIII:19-20 reads:

> Thou shalt not lend upon usury (neshek) to thy brother; usury of money, usury of victuals, usury of anything that is lent upon usury; unto a foreigner (nokri) thou mayest lend upon usury; but unto thy brother thou shalt not lend upon usury (Houkes 2004:18).

The connection between interest, usury, and discounting can also be found in the historic regulations. For example, the Baba Metzia (V:2) from the Jewish Talmud includes the passage:

> A credit sale where the buyer, in return for the privilege of delaying payment, pays the seller a premium over the cash price is not permissible because it is usurious, but a discount for pre-payment is permissible (Houkes 2004:88).

Indeed, interest and usury are based on ideas about profit maximization and the time value of money which also underlie the commonly held view that discount rates should be matched to market interest rates. The idea of matching discount rates to market interest rates will be elaborated in Section 1.2.3.

One attribute that the above definitions of discounting all share is that they explicitly define discounting as a process for comparing values across time and not across any other dimensions. Indeed, the overwhelming majority of the discounting literature treats discounting as a strictly time-only phenomenon. However, a small amount of prior research has explored spatial discounting and related concepts, generally falling into two lines. One of the main lines of work here is the spatial discounting research lead by geographer Bruce Hannon (see Hannon 1987; 1994; 2005; Perrings and Hannon 2001). Hannon's spatial discounting research focuses on the idea that individuals favor being close to some phenomena and farther from others. In a rare break from the conventional ethical anthropocentrism, Hannon considers both humans and nonhumans. Thus for

example, "People prefer to live near school, church, and grocery store and far from sewage treatment and power plants, landfills and prisons" (Hannon 1994:157). Likewise nonhuman animals might prefer to be near food sources and far from predators.

The other main line of work on non-temporal discounting is the social discounting research lead by psychologists Howard Rachlin and Bryan Jones (see Jones and Rachlin 2006; 2009; Rachlin 2006; Rachlin and Jones 2008). Rachlin (2006:425) defines discounting as "the reduction of a quantity with the increase of some variable." This variable could be time but need not be. In Rachlin and Jones's social discounting research, the variable is social distance. The key idea here is that individuals (in this research only human individuals are considered, but perhaps nonhumans do this as well) tend to place more value on benefits that accrue to beings who are socially closer to them (such as close friends or family) than to people who are socially further away (such as mere acquaintances). Given that no two people can be at the same point in space-time, it follows that social distance can be mapped to space-time distance, although perhaps not in any simple pattern. It thus follows that social discounting can be represented in terms of space-time discounting.

Another instance of prior work on non-temporal discounting is that of Schelling (2000).[5] This work uses the phrasing "international discounting," though it also considers several phenomena that could be interpreted as intra-national discounting. (For further critique of Schelling 2000, see Sunstein and Rowell 2007:197-198.) Schelling emphasizes that certain reasons for time discounting have spatial components, rendering traditional time-only discounting inappropriate for assessments of issues such as climate change that feature substantial spatial heterogeneity. Schelling also describes spatial analogs for these reasons for time discounting. (Note that Schelling does not use the terms "spatial component" or "spatial analog." To my knowledge these terms are new to this dissertation.) The reasons Schelling discusses are, in the terminology of this dissertation, these reasons are welfare favoritism and consumption inequality. Note that, in contrast with the work cited in the above paragraphs from Hannon and from Rachlin and Jones, Schelling's work cited in this paragraph does not formally develop a conceptualization of non-temporal discounting but instead offers commentary on existing discounting debate.

Hannon's spatial discounting and Rachlin and Jones's social discounting research both provide important bodies of work on discounting across non-temporal dimensions. However, this work falls short of providing a systematic account of the theory of space-time discounting. In particular, each line of work focuses narrowly on a single reason for discounting across spatial or social distance. In Hannon's work, the reason is a desire to be close to or far from certain phenomena. In Rachlin and Jones's work, the reason is a desire for benefits to accrue to those more socially proximate. But there are other reasons for discounting across time, such as the opportunity to invest present money so as to gain more money in the future. These other reasons merit consideration for their relevance to spatial discounting. Furthermore, Rachlin and Jones's work is restricted to the human domain, as is most research on time discounting. These limitations point to significant

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[5] Schelling published several other documents on these aspects of discounting, but the documents are largely redundant with Schelling (2000) and thus are not cited here.

deficiencies in the literature with respect to the role of space in discounting. There is thus a need for an account of the theory of space-time discounting without ethical anthropocentrism. Such an account is presented in Chapter 2.

Finally, there are major lines of research on the concepts of utility functions and welfare weights in cost-benefit analysis (cf. Harberger 1978; Brekke 1997; Johansson-Stenman 2000; and the cost-benefit analysis literature cited in Section 1.2.1). These two concepts are not explicitly framed as spatial or space-time discounting but are nonetheless immediately relevant. The two concepts are sometimes conflated but in this dissertation will be defined separately. *Utility functions* are functions such that some units of consumption bring more utility (or welfare) than others. *Welfare weights* are weighting factors such that some units of welfare are weighted more than others within a social welfare function.

Utility functions and welfare weights are discussed throughout the cost-benefit analysis literature (as reviewed in Section 1.2.1), though they are not as widely used as time discounting is. This difference in usage is because most cost-benefit analysis is of the money-maximizing form (again see Section 1.2.1), which generally discounts money across time but does not employ utility functions or welfare weights. Indeed, many argue against the use of utility functions and welfare weights entirely, arguing instead that we should count all dollars equally (cf. Harberger 1978; note that this paper lumps the two concepts together into "distributional weights"). Others – in particular proponents of welfare-maximizing cost-benefit analysis – argue that such weights are important for cost-benefit analysis and should be used (cf. Drèze 1998, which also speaks in terms of a single "distributional weight" concept).

Just as there are multiple views on whether or not to use utility functions and welfare weights, there are also multiple views on which utility functions and welfare weights to use, given that they are to be used. Utility functions are most commonly formulated to feature diminishing marginal utility of consumption, which captures the idea that a unit of consumption is worth more to the poor than to the rich (e.g. Atkinson 1970). Another form of utility function that has garnered attention in the literature features relative wellbeing, which captures the idea that our wellbeing or utility depends on what our consumption levels are relative to others in society (e.g. Abel 1990). In particular, if our consumption levels are relatively low, then we may have lower utility levels due to such feelings as envy or jealousy, even if our consumption levels are high on an absolute scale. Perhaps the most common welfare weight scheme is the utilitarian weighting scheme, in which all units of welfare are weighted equally within a social welfare function (Boadway 2006). Another scheme is that receives extensive discussion is the Rawlsian scheme (named after Rawls 1971), in which the welfare of everyone except the worst-off in society holds zero weight within a social welfare function (Boadway 2006). Several utility functions and welfare weight schemes have been used in the climate change literature; these are discussed in Section 1.2.4.

While utility functions and welfare weights are commonly treated distinctly from discounting, I find that they are largely – though not entirely – equivalent. Utility

functions, combined with inequality in consumption across space and/or time, constitute one form of discounting; welfare weights, combined with any distribution of welfare across space and/or time, constitutes another (see Chapter 2).[6] Likewise, many of the views on how we should discount across time apply to how we should use utility functions and welfare weights across space, and vice versa. And just as it is not my intention in this dissertation to advocate for or against particular ethical views on discounting, it is also not my intention to advocate for or against the use of utility functions and welfare weights, or for or against any specific forms that utility functions and welfare weights may take. Instead, as with the discussion of discounting, I aim to help clarify the nature of these concepts and how the are and can be used. Though my focus is on discounting and not on utility functions and welfare weights, I believe that the discussion can be readily extended from the former to the latter.

Finally, it should be noted that, as with cost-benefit analysis, discounting appears to be confined to consequentialist ethics. This is because the values being compared in discounting are the values of the consequences of actions. For example, when we discount future impacts of greenhouse gas emissions relative to the cost of reducing emissions, we are comparing the values of the consequences of the actions of reducing (or not reducing) emissions. To be sure, I cannot rule out the possibility of non-consequentialist discounting. However, a more thorough examination of this possibility would require an inquiry into consequentialist and non-consequentialist ethics that is deeper than the space in this dissertation affords.

### 1.2.3 Descriptions of Discounting

The theory in Chapter 2 (and, as we will see, parts of Chapter 3) draws heavily on the Ramsey equation (named after Ramsey 1928; see Dasgupta and Heal 1979:296-297). This equation also structures much of the ongoing debate about discounting.

$$r = \rho + \eta * g \qquad (1.1)$$

Here, r and $\rho$ are the discount rates on money and on utility, respectively; they compare the values of money and utility that occur at different times. $\rho$ is essentially a welfare weight scheme. $\eta$ is the elasticity parameter; it defines the relationship between utility and consumption expressed in a utility function. In particular, $\eta$ sets how much more a dollar of consumption is worth to the poor than to the rich. Finally, g is the growth rate of per capita consumption, which represents how consumption changes over time. Note that Equation 1.1 neglects the effects of uncertainty.

There are two competing philosophies about how to define the four parameters in Equation 1.1. The philosophies are commonly known as the prescriptive approach to discounting and the descriptive approach to discounting (Arrow et al. 1996), though in previous work I have argued that these labels are inappropriate and misleading (Baum

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[6] Other forms of discounting exist besides these two, including investment opportunity (see Chapter 2) and stimulus magnitude (see Chapter 4).

2009). Both approaches set g by matching it to empirical observations of consumption growth rates; there is no significant disagreement here. Instead, the disagreement concerns the other three parameters: r, ρ, and η. The prescriptive approach begins by setting ρ based on an ethical judgment about how utility should be valued over time. The prescriptive approach also sets η either based on an ethical judgment about how much more we should value consumption for the poor vs. for the rich, or based on empirical inquiry into the actual relationship between consumption and utility. The prescriptive approach then calculates r from ρ, η, and g using Equation 1.1. In contrast, the descriptive approach matches r to market interest rates and then calculates ρ and η from r and g using Equation 1.1.[7] The descriptive approach thus solves for two variables (ρ and η) using one equation, meaning that there are multiple possible solution values for ρ and η. The descriptive approach is generally flexible on the precise values of ρ and η as long as Equation 1.1 is satisfied (Nordhaus 2007).

The use of market interest rates to define discount rates is a key point. There are two core reasons for matching monetary discount rates to market interest rates, as in the descriptive approach to discounting. The first reason derives from the concept of profit maximization mentioned above. In short, when we discount the value of the future monetized costs and benefits of a set of possible actions using market interest rates and then pick the action with the highest discounted value, we maximize the value of our discounted monetary benefits. Suppose that our two possible actions are a climate change policy and a market investment. Suppose further that a future benefit from the climate change policy was less than what we could get in the market. In this case, we could get more future money by investing in markets than by investing in this future benefit. With more money in the future, we could potentially compensate whoever would get the future benefits from the climate change policy and still have money left over. This gives us a reason for matching monetary discount rates to market interest rates. However, this reason has nothing to do with description but instead derives from the ethics of potential Pareto efficiency, which contends that we should implement policies precisely when this sort of compensation can potentially be made such that everyone is at least as well off (for further discussion of potential Pareto efficiency, see Adler and Posner 2006; Sen 1987).

The second reason for matching monetary discount rates to market interest rates is grounded in the concept of description. The core idea here is that in a cost-benefit analysis, analysts should use descriptions of how society discounts instead of imposing their own views about discounting on society. Market interest rates are thus used because they are an aggregate of many decisions by members of society about how to trade off present and future costs and benefits, i.e. decisions about whether to consume now or to invest in markets for future consumption. A problem with this reason, as I have explained previously (Baum 2009) is that market interest rates offer only one set of possible descriptions of how society discounts, and analysts must inevitably impose their own views about which description to choose.

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[7] Multiple market interest rates are available. In particular, different rates can be found for different financial instruments, such as equities and bonds. The significance of the existence of multiple rates for the descriptive approach to discounting is discussed in Baum (2009:202).

The possibility of multiple ways of describing how society discounts – and the potential for any of these descriptions to be used in policy via the descriptive approach to discounting – opens up broad opportunities for inquiry about how society discounts. Herein lies one core reason for studying the psychology of discounting: by more accurately understanding how people discount, we can more accurately implement the descriptive approach to discounting or more strongly critique existing implementations. Thus much of the research on the psychology of discounting has been oriented towards the questions of what discount rates people actually use and whether people even use conventional discount rates in the first place. Indeed, a central finding of the literature on the psychology of discounting is that there are many "anomalies" in how people discount which do not match with what the conventional discount theory would predict (cf. Frederick et al. 2002; Scholten and Read 2010; Thaler 1981). This finding suggests a need to revisit the descriptive approach to discounting so as to improve the accuracy of the descriptions.

There is one other problem with using market interest rates in the descriptive approach to discounting: the descriptions in markets are only of how people discount over time.[8] Thus analysts are imposing a view that time discounting by humans is the only relevant moral variable to describe. How people discount across other dimensions is completely ignored, as are those aspects of human (or nonhuman) values that cannot be expressed in terms of discounting. A fuller set of descriptions of multidimensional discounting and non-discounting values is explored in Chapter 3.

### 1.2.4. Climate Change Assessment

Options for how to respond to climate change generally fall into one of two categories: mitigation and adaptation. Mitigation refers to efforts to reduce or slow climate change either by reducing or slowing the greenhouse gas emissions that are driving climate change or by increasing or hastening the uptake of greenhouse gas molecules from the atmosphere. Examples of mitigation activities include switching from coal power plants to wind or solar power, switching from automobile transportation to bicycles and public transit, and reducing deforestation in the tropics. Adaptation refers to efforts to minimize the damages of climate change or to take advantage of new opportunities brought on by climate change. Examples of adaptation activities include switching to crops that are better suited to the new climate, building dykes and levees to protect against sea level rise, and migrating to regions with more suitable climates.

Discounting has factored prominently in assessments of climate change mitigation. Indeed, debates over what mitigation strategy we should pursue have often centered around issues of discounting. These debates are largely structured by the form of the Ramsey equation (Equation 1.1 above), with competing sides of the debates advocating either the prescriptive approach (e.g. Dasgupta 2008; Ramsey 1928; Stern 2007) or the

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[8] This critique also applies to studies using description-based arguments for the selection of spatial welfare weights, such as the discussion of Negishi weights found in Nordhaus and Yang (1996:746), except that these studies consider discounting across space as well as time. Note that these studies in general do not describe spatial welfare weights as "discounting."

descriptive approach (e.g. Anthoff et al. 2009; Bauer 1957; Nordhaus 2007) to setting the Ramsey equation parameters. These parameters are then used in integrated assessment models which integrate the global climate into a global economic model so as to identify (or at least to inform) what mitigation strategy would be optimal for society.[9] The optimization criterion is generally one of maximizing the total sum of time-discounted utility; here the time discount rate on utility and the form of the utility function are set by ρ and η in Equation 1.1.

In those integrated assessment models, the discounting parameters are commonly interpreted as the key variables in establishing optimal mitigation strategy. For example, Schultz and Kasting (1997) found that optimal mitigation strategy was significantly more sensitive to the choice of discounting parameters than to the specification of the global carbon cycle. The reason that discounting is so important here is simple: the impacts of climate change are expected to occur over a very long period: many centuries, or even many millennia. How we define the discounting parameters sets how much we care about these long-term impacts. If we care little (a lot) about them, then we have little (strong) reason for going out of our way to reduce emissions.

Many, though not all, assessments of climate change mitigation have neglected space. That is, the assessments have assumed that the impacts of climate change and mitigation efforts are uniformly distributed across the planet. Some integrated assessment models have handled space by crudely dividing the planet into some number of regions (generally in the range of 8 to 16 regions; cf. Hope 2006; Nordhaus and Yang 1996; Tol 2006), though as I and others have previously argued (Azar and Lindgren 2003; Baum 2007) this neglects important variation within regions. No model can handle all variation across a planet with several billion people, but more effort could be made to highlight and adjust for the inaccuracies introduced by clustering everyone into one or a small number of regions. One promising approach is that of Chakravarty et al. (2009), which clusters people by income instead of by region, because such key parameters as utility and emissions are tied more closely to income than to region. This income-based clustering suggests a promising approach to handling space in climate change mitigation assessment.

The mitigation integrated assessment models contain treatments of utility functions and welfare weights that are noteworthy on several counts. First, the models treat utility functions and welfare weights separately. By treating utility functions and welfare weights separately, these models employ a more sophisticated treatment of the two concepts than is often found in other portions of the literature on these concepts (e.g. Harberger 1978; Drèze 1998). Second, the models commonly use utility functions and welfare weights as components of time discounting. Ramsey equation-based models use the isoelastic utility function (Arrow and Kurz 1970; Atkinson 1970). The isoelastic utility function is ubiquitous in the mitigation models; one exception is Howarth (2006), which uses a utility function that features relative wellbeing. A utilitarian welfare

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[9] Economic assessments such as these are often phrased in terms of "efficiency" instead of "optimality". While there can be some important differences between these two terms (depending on how they are interpreted), these differences are tangential to the present discussion.

weighting scheme is often found (e.g. Stern 2007), as are schemes which place more weight on welfare that occurs earlier (e.g. Nordhaus 2007).

Third, the mitigation models which include spatial disaggregation feature utility functions and welfare weights that can, following the discussion in this dissertation, be interpreted as spatial discounting. For example, Nordhaus and Yang (1996) uses an isoelastic utility function and two welfare weight schemes. The first scheme, Negishi weights (Negishi 1960), sets welfare weights so as to counter the effect of the utility function, rendering a dollar of consumption to hold the same value everywhere. The second scheme, referred to as the non-cooperative or Nash scheme, has each region set welfare weights such that from that region's perspective, the welfare of each other region holds no value. These utility function and welfare weight schemes correspond with the consumption inequality and welfare favoritism reasons for discounting discussed further in Chapter 2; the Chapter 2 discussion develops these reasons in general terms, not in terms of mitigation or other issues.

The literature on the mitigation models also contains some noteworthy discussion of ethical anthropocentrism. Non-human phenomena – in particular climatic phenomena – are valued throughout this literature. Usually, these non-human phenomena hold only extrinsic value, meaning that anthropocentric ethics are being used. Nordhaus (2008:68) is explicit about this, writing that the model used in therein excludes "any 'intrinsic value' of a given climate." One possible exception is McInerney and Keller (2007). This study considers the usual anthropocentric ethics alongside an ethical criterion based on the possibility of climate change causing a collapse in the North Atlantic meridional overturning circulation (MOC). The collapse would have significant consequences for both human and ecological systems. Likewise avoiding the collapse could be justified using either anthropocentric or non-anthropocentric ethics. The non-anthropocentric ethics could be ecocentric ethics, which places intrinsic value on ecosystem flourishing (as in Holbrook 1997). The McInerney and Keller (2007) study does not clarify whether anthropocentric or non-anthropocentric ethics were intended, but the study can be interpreted as having a non-anthropocentric component.

The remainder of this dissertation does not discuss climate change mitigation in significant detail. This is not because mitigation is unimportant as a societal issue or as an application of space-time discounting. To the contrary, mitigation is highly important in both regards. Instead, it is because some focus in this research project has been necessary. I have focused on discounting in adaptation in part because it is relatively uncharted and fruitful intellectual territory and in part due to circumstances in which this research was conducted. As discussed in the Conclusion, mitigation is an especially worthy area for future work. In particular, the conceptualization of space-time discounting developed in this dissertation can be applied to obtain new insights from the extensive existing literature on discounting in mitigation.

In contrast to the rich discussion of discounting found in the mitigation literature, relatively little has been said about discounting in assessments of climate change adaptation. Likewise, there have been relatively few cost-benefit analyses of climate

change adaptation (for reviews, see Adger et al. 2007:724-727; Stage 2010).  This is not because adaptation is unimportant, or because the costs and benefits of adaptation projects are not distributed broadly across space and time.  To the contrary, there are and will be many adaptation projects on a broad range of scales, from the individual household to the global scale, and these projects often feature costs and benefits that are distributed broadly across space and time.  The simple scenario introduced above of the Canadian government's adaptation assistance is just one of many scenarios in which possible adaptation projects need to be assessed in terms of the distributions across space and time of their costs and benefits.  There is thus a strong need for presentations of how to perform such assessments; such presentation can be found in Chapter 4.

## 1.3. A New Treatment of Space-Time Discounting

There has been quite a lot of prior work on time discounting and at least some prior work on discounting across space and other dimensions.  However, to my knowledge, there has not yet been a comprehensive treatment of space-time discounting as a theoretical, empirical, and applied concept.  Given the importance of space to discounting, and the importance of discounting to many important societal issues, the need for such a treatment is strong.  This dissertation presents such a treatment.  The theory is articulated primarily in Chapter 2; the empirics appear mainly in Chapter 3; and the applied work occurs mainly in Chapter 4.  However, each chapter contains some elements of theory, empirics, and application, demonstrating the synergistic nature of this work.

### 1.3.1 Research Questions and Objectives

Although each dissertation chapter focuses on its own set of research questions and objectives, there are some overarching questions and objectives that span the entire dissertation.  Above all, the dissertation asks, *how is space relevant to discounting*?  Related questions include: What does it mean to discount across space?  How do and how should people discount across space and time?  What is the significance of spatial discounting to policy on climate change and other societal issues?  Finally, what are the limits to space-time discounting as a theoretical, empirical, and applied concept?

Likewise, the dissertation has several interrelated objectives.  First and foremost, the dissertation seeks to establish and examine the concept of space-time discounting in a systematic fashion.  This means using a consistent approach to space-time discounting for theoretical, empirical, and applied treatments of this concept.  The aim here is to demonstrate that space-time discounting is at once theoretically sound, empirically observable, and relevant to significant societal issues.  However it is also recognized that the discounting concept has certain fundamental limitations.  Thus an additional objective is to systematically explore the nature of these limitations, i.e. what any discounting paradigm, however broad, can and cannot do.

The theoretical work in Chapter 2 digs deep into the theoretical basis of discounting, asking on the most basic level what it means to discount.  A key question here is why we discount: established reasons for discounting across time assist in the development of the

concept of discounting across space.  Likewise, the objective here is to explore whether one can discount across space for the same reasons that one can discount across time.  Another key question is how discounting can be extended beyond the realm of ethical anthropocentrism.  The objective here is to examine the concept of non-anthropocentric space-time discounting to identify how this concept can and cannot be used.  Finally, having considered space-time discounting for both anthropocentric and non-anthropocentric ethics, a culminating objective of this chapter is to propose a new definition of discounting that can accommodate all these different forms of and reasons for discounting.

The empirical work in Chapter 3 explores both how people discount across space and time and the limits to which we can describe people's values in terms of discounting.  This project is thus narrower than that of Chapter 2, because it looks only at the discounting and other values of humans, as opposed to those of individuals across all species.  However even exploring only human values in their full breadth is too expansive of a project for one chapter.  This chapter thus aims to provide basic, preliminary contours of how people discount across space, time, and other dimensions, and of the extent to which human values can be described in terms of discounting.  Finally, the chapter asks, what is the policy significance of how people do and do not discount?  The objective here is revisit the descriptive approach to discounting in light of the available evidence on how people discount across multiple dimensions and how well human values can be described in terms of discounting.

The applied work in Chapter 4 examines the significance of space-time discounting to three cases in climate change adaptation.  The central question here is, how does the inclusion of space affect the assessment of these adaptation cases, and societal issues more generally?  This project is even more narrow than that of Chapter 3, just as Chapter 3 was more narrow than Chapter 2.  Chapter 4 is more narrow because it expands the usual anthropocentric time discounting only to accommodate discounting across space; non-anthropocentric ethics and the limitations of discounting are not considered.  This narrower focus permits a richer examination of the importance of space to societal issues.  The three adaptation cases considered represent cases of project evaluation, cooperation, and conflict.  Thus the objective here is to examine the importance of space-time discounting to issues of these types.  In short, what do we gain in analytical capacity and insight by including space in discounting?

Collectively, these three chapters aim to provide a detailed understanding of the space-time discounting concept.  They focus on successively more narrow sets of topics mainly because as we move from theory to empirics to application, the level of complexity increases considerably.  The narrow focus relative to the complexity of the subjects suggests an abundance of potential for future work, as is discussed in more detail in the Conclusion.

## 1.3.2 Methods

The narrowing of focus between chapters, along with the different types of questions and objectives for each chapter (i.e. theoretical, empirical, and applied), also suggests a different set of methodologies for each chapter. In rough terms, the methods of Chapter 2 are mainly those of theoretical ethics; for Chapter 3, moral psychology; and for Chapter 4, environmental economics. However some additional detail on each is warranted.

Chapter 2 is primarily an inquiry into the ethical theory underlying the concept of space-time discounting. As such it employs methods oriented towards developing this theory. The basic approach is to identify the logic and reasoning that underlies established conceptualizations of discounting (in particular anthropocentric time discounting) and then illustrate how this same logic and reasoning suggests that the concept of discounting can and should be extended to include space and non-anthropocentric ethics. First, to establish the role of space in discounting, I examine spatial components and spatial analogs to established reasons for time discounting. A *spatial component* is a component of time discounting such that where gains and losses occur affects how we discount across time. A *spatial analog* is a reason for comparing values across space analogous to the corresponding reason for comparing values across time. By analyzing spatial components and analogs, I am able to establish that discounting as it is commonly understood has spatial attributes. Second, to establish the concept of discounting beyond the realm of ethical anthropocentrism, I examine discounting by individuals/groups and discounting for individuals/groups. *Discounting by* individuals/groups refers to the discounting practices that individuals support and exhibit. *Discounting for* individuals/groups refers to discounting practices made on behalf of them. The analysis of discounting by and for nonhuman individuals/groups allows me to establish that non-anthropocentric discounting follows much of the same logic as anthropocentric discounting and thus that discounting should not be restricted to the anthropocentric realm. Finally, the chapter concludes with theoretical design work: a novel conceptualization of discounting is designed and proposed. This new conceptualization is designed to accommodate the new theory of space-time and non-anthropocentric discounting and also to be relatively easy for scholars and analysts to use and understand.

Chapter 3 is primarily an inquiry into the psychology of space-time discounting and the psychology of the broader realm of morality. This inquiry proceeds in four stages. First, Chapter 3 establishes the relevant theory, much of which is covered in more detail in Chapter 2. Second, Chapter 3 surveys the existing literature on the psychology of space-time discounting and its limitations. The literature survey is especially relevant here because it includes several lines of empirical work not traditionally associated with discounting, in particular those relevant to the limitations of discounting as a descriptor of human values. Third, Chapter 3 presents a new survey that explores how people discount across space, time, and other dimensions (including social space) as well as the limits to discounting as a paradigm for describing human values. In order to accommodate a large number of dimensions and limits to discounting and to focus on isolated reasons for discounting, a new survey technique is employed, which I call the *principle agreement approach*. This approach focuses on the ethical principles underlying discounting and its

limitations, so as to quickly assess core ethical reasons people have for discounting or for following other ethics. The survey also includes an established set of environmental values questions (Schwartz 1992, 1994; Stern et al. 1998), results for which are compared to the novel principle agreement questions so as to establish confidence in the new technique and explore relationships between the two approaches to moral psychology. Fourth and finally, Chapter 3 synthesizes the old and new empirical findings in the context of the relevant theory so as to ascertain the implications of the empirics for science and policy, in particular for the descriptive approach to discounting.

Chapter 4 is primarily an inquiry into the relevance of space-time discounting to how people do or can adapt to climate change. The chapter begins by reviewing the relevant space-time discounting theory. The chapter then analyzes three climate change adaptation cases, representing project evaluation, cooperation, and conflict. The project evaluation case employs the methods of welfare economics, using empirical data on crop indemnity payments to estimate welfare impacts of the payments under various space-time discounting schemes. The essence of the approach here is to compare welfare estimates under different schemes so as to illustrate the significance of space to discounting for project evaluation. The cooperation and conflict cases both employ methods oriented towards describing the cases in question in terms of space-time discounting. This approach involves detailed examinations of the particular cooperation and conflict cases as they feature instances of space-time discounting. The examinations then lead to new reflection on both the adaptation cases and the space-time discounting paradigm. All three adaptation cases involve analysis of coupled natural-human systems in the context of space-time discounting theory.

### 1.3.3 Original Contributions

Above all, this dissertation contributes what is to my knowledge the most comprehensive treatment of the importance of space to discounting available. To achieve this, the dissertation synthesizes three bodies of work. First is the existing discounting literature, including the large body of time discounting literature and the much smaller spatial discounting literature. Second is the existing literature on related topics, including utility functions and welfare weights. This literature points to phenomena that can be interpreted as discounting, though the connection between these phenomena and discounting is not always made. Third is work that (again to my knowledge) did not exist prior to this dissertation. This includes new theory, new empirics, and new application. By synthesizing these three bodies of work, the dissertation enables a deeper and more thorough understanding of the importance of space to discounting than was previously available.

Beyond this broad understanding of space in discounting, there are several specific original contributions made throughout the dissertation. Chapters 2 and 4 presents original discussions of already-established reasons for discounting. Chapter 2 also presents original discussion of discounting in non-anthropocentric ethics and an original definition of discounting, referred to as *Discounting as Values Comparison*. Chapters 2 and 3 present original discussion on the limitations of discounting as a theoretical

construct and as a paradigm for describing human values. Chapter 3 also presents a survey featuring an original line of discounting questions, the first data using these questions, and original discussion of the significance of moral psychology to policy analysis – in particular certain existing approaches to discounting for policy analysis. Chapter 4 presents three original case studies illustrating the importance of space-time discounting to three topics in climate change adaptation. These case studies generate original insights including the complex geometries of some spatial discounting and the multiple forms of spatial discounting that can influence conflict.

These contributions are all above and beyond the original synthesis of existing literature found throughout the dissertation. This dissertation draws on many seemingly disparate bodies of literature that are rarely if ever found together. Most of the discounting literature focuses exclusively on time and anthropocentric ethics. This literature is large in its number of publications but small in its intellectual scope, existing almost exclusively within narrow portions of economics, ethics, and psychology. By focusing on time, the literature overlooks the geographer's spatial discounting (Hannon 1994) and the psychologist's social discounting (Jones and Rachlin 2006). By focusing on anthropocentric ethics, the literature overlooks the biologist's discounting by non-human animals (Stevens et al. 2005), and the ecologist's ecocentric ethics (Leopold 1949/1979). And by focusing on discounting itself and not considering the limitations of the discounting concept, the literature overlooks non-consequentialist ethics as discussed by philosophers (Hursthouse 2007) and psychologists (Ginges et al. 2007). None of these and other topics and references are found in the overwhelming majority of discussions of discounting, but as discussed in this dissertation, they are all highly relevant. Part of the project of this dissertation is to show how these seemingly disparate bodies of literature speak to each other and in particular to a much more inclusive and holistic understanding of discounting.

### 1.3.4 Structure of the Dissertation

As has been already explained, the dissertation is written to yield three stand-alone journal articles instead of one continuous manuscript. Because of this, individual chapters each feature enough information to be read without any of the other chapters, including this Introduction and the Conclusion. Each chapter thus includes a detailed literature review, a statement of the relevant space-time discounting theory, and a general discussion of the significance of space-time discounting. There is inevitably some redundancy across chapters. However, the similarities across chapters are also indicative of the synergistic nature of the work. The intent here is that a comprehensive understanding of space-time discounting as a theoretical, empirical, and applied concept will emerge from the three following chapters, especially when they are taken with this Introduction and the Conclusion.

**Chapter 2: Space-Time Discounting Without Ethical Anthropocentrism**

Discounting is traditionally conceptualized as the comparison of the value of gains or losses that occur at different times. The value is traditionally defined using anthropocentric ethics, meaning that the gains and losses are ultimately linked to humans. This traditional discounting figures prominently in many societal issues, especially climate change and other long-term environmental issues. However, the traditional discounting neglects the important roles of space in value comparisons and the possibility of non-anthropocentric valuations. This chapter analyzes discounting across space as well as time in which the value need not be anthropocentric. Prominent reasons for time discounting have spatial components, such that space matters to time discounting, and spatial analogs, which suggest the idea of spatial discounting. Outside the realm of anthropocentrism, there can be discounting by non-humans as well as discounting for non-humans. These findings about space and non-anthropocentric ethics suggest the need for a new conceptualization of discounting. In response to this need, a new conceptualization is introduced that readily handles both space and non-anthropocentric ethics. This space-time discounting without ethical anthropocentrism can broaden and refine our treatments of discounting, with implications for the major societal issues in which discounting plays a role.

**2.1. Introduction**

Discounting typically refers to the process of comparing the value of gains or losses (which might or might not be classified as costs or benefits) that occur at different times. Debate over discounting has lead to extensive attention regarding when gains and losses occur in cost-benefit and other analyses, in particular for climate change, energy, and other long-term environmental and natural resource issues. In contrast, *where* gains and losses occur goes relatively overlooked, despite being quite important as well. Furthermore, these valuations of gains and losses almost always use an anthropocentric form of ethics, meaning that they are gains and losses to humans. This restriction to anthropocentric ethics persists despite strong calls for ethics that do not privilege the human species, in particular ecocentric ethics and non-anthropocentric forms of utilitarianism.

In this chapter I examine the role of space in discounting and the possibility of discounting with non-anthropocentric ethics. To examine the role of space, I consider three major reasons given for time discounting: investment opportunity, consumption inequality, and welfare favoritism. Details of these reasons are presented below. These are perhaps the most commonly cited reasons for time discounting, especially in the prominent debates about discounting in climate change policy (e.g. Arrow et al. 1996; Nordhaus 2007; Stern 2008). Many other reasons have been given for time discounting as well, but these are beyond the scope of the present chapter.

For each of the three reasons for time discounting considered here, there are what I will call a spatial component and a spatial analog. A *spatial component* is a component of time discounting such that where gains and losses occur affects how we discount across

time.  Neglecting these spatial components – which is quite often done – can lead to analytical mistakes.  A *spatial analog* is a reason for comparing values across space analogous to the corresponding reason for comparing values across time.  These spatial analogs suggest the concept of spatial discounting.  The existence of spatial components and spatial analogs for each of the three reasons for time discounting considered here demonstrate the importance of space in discounting.

The dissertation also considers the possibility of discounting with non-anthropocentric ethics.  *Anthropocentric ethics* refers to ethical views that gives "exclusive or arbitrarily preferential consideration to human interests as opposed to the interests of other beings" (Hayward 1997:51).  Ethical anthropocentrism is contrasted with ontological anthropocentrism, which is the idea that humans hold some special place within the universe, or "seeing humans as the centre of the world" (Hayward 1997:50).  Note that the environmental ethics literature sometimes distinguishes between strong ethical anthropocentrism and weak ethical anthropocentrism (see e.g. Eckersley 1998).  Here, *strong ethical anthropocentrism* means that humans are given exclusive consideration; *weak ethical anthropocentrism* means that humans are given preferential consideration relative to non-humans, though non-humans are given some consideration.  In weak ethical anthropocentrism, when there is a trade off between human interests and non-human interests, one almost always decides in favor of the humans.  The discussion in this chapter involves going beyond both strong and weak ethical anthropocentrism, but since most existing discounting literature features strong ethical anthropocentrism, when no qualification between strong and weak ethical anthropocentrism is given, strong ethical anthropocentrism is intended.

To examine the possibility of discounting with non-anthropocentric ethics, I consider discounting by non-humans and discounting for non-humans.  *Discounting by* non-humans means that the non-humans are the ones performing the discounting: they are the ones comparing values across time and space.  It is quite clear that at least some sentient non-human animals discount in ways similar to how humans discount.  Perhaps non-sentient organisms or even ecosystems discount, although this is less clear.  *Discounting for* non-humans means that the values being compared across space and time (by either humans or non-humans) are values for the non-humans.  The value here is specifically intrinsic value, meaning that which is valuable for its own sake.  The non-humans (e.g. ecosystems, non-human animals) are valued for their own sake instead of for what they can do for humans.

Discounting by and discounting for non-humans are not handled by standard anthropocentric conceptualizations of discounting.  While definitions of discounting are often ambiguous on who it is that is performing the discounting, the corresponding research typically only considers discounting by humans.  Research that explicitly considers discounting by non-humans is only a small minority of all existing discounting research, as reviewed below.  Meanwhile, treatments of discounting are also typically discounting for humans.  That is, the values being compared in the treatments of discounting are almost always rooted in an anthropocentric notion of intrinsic value.  Typical values being compared include money, human health, and human utility.  There

are examples (also reviewed below) of discounting for non-humans, but these are the exception.

Given the failure of standard conceptualizations of discounting to handle space and non-anthropocentric ethics and limitations in existing spatial and non-anthropocentric conceptualizations, I introduce a new conceptualization of discounting which succeeds in these areas. This new conceptualization refers to discounting as any process of comparing the value of gains or losses that occur at different locations in space and/or time. This *discounting as values comparison* conceptualization facilitates the treatment of space in temporal discounting. It also permits discounting across space in which there is no temporal component, which can be called spatial discounting. Meanwhile, the valuations need not be restricted to anthropocentric ethics, and instead can use any form of consequentialist ethics, including those that favor ecosystems or the interests of all species. By consequentialist ethics, I mean any ethics that judges us based on what actions we take, and judges our actions based on their consequences. Good consequences are gains; bad consequences are losses. The conceptualization of discounting developed here permits any definition of good and bad consequences, including definitions that are not tied to any aspect of the human condition. It does not, however, permit discounting using non-consequentialist ethics; I believe that no conceptualization of discounting can. The idea that discounting is confined within consequentialism is discussed further in Section 2.5 and in more detail in Chapter 3.

The chapter is organized as follows. I begin by reviewing previous work on discounting, including both standard anthropocentric time discounting and other forms. I then develop the three reasons for time discounting listed above, showing how each has a spatial component and a spatial analog. Next, I develop discounting without anthropocentric ethics, including discounting by and discounting for non-humans. Finally, I develop the new *discounting as values comparison* conceptualization of discounting.

## 2.2. Previous Work

Almost all previous work on discounting has been time discounting using anthropocentric ethics. There has been a small amount of other work on discounting. Both are relevant to this chapter.

### 2.2.1. Anthropocentric Time Discounting

The extensive literature on anthropocentric time discounting is found mainly in economics, as well as philosophy, policy, psychology, and related disciplines, often coming from the portions of these disciplines that focus on environmental issues.[10] This literature vividly illustrates the importance of discounting in environmental policy and other realms of decision making, as well as the durable and often fierce disagreements that exist over how these decisions should be made. But although there are strong

[10] See among many others Ainslie (1974); Lind (1982); Laslett and Fishkin (1992); Loewenstein and Elster (1992); OMB (1992); Peterson (1993); Price (1993); Arrow et al. (1996); Portney and Weyant (1999); Frederick et al. (2002); Frederick (2006); Wissenburg (2010); and the special journal issues introduced in Weisbach and Sunstein (2007); Zeckhauser and Viscusi (2008).

disagreements over the details of discounting, there is more consensus over what discounting is.

Conceptualizations of discounting generally come in one of three closely related forms, all of which involve comparisons over time of either money or human welfare.[11]  The first defines discounting as any comparison of value over time, without specifics on what the value is.  For example, Price (1993:4) defines discounting as "any process of revaluing a future event, condition, service or product to give a present equivalent."  Similarly, Frederick et al. (2002:352) "use the term time discounting broadly to encompass any reason for caring less about a future consequence."  Although in principle these definitions could include a broad range of values, in practice they almost always focus on money, human welfare, or close proxies thereof such as human health.  For example, Chapman (2002:410) defines discounting as "a method of adjusting the value of delayed outcomes so that they can be directly compared to immediate outcomes" and considers discounting of both money and human health.

The second form of discounting conceptualization defines discounting as the comparison of costs and benefits that occur at different times.  Here discounting is explicitly embedded within cost-benefit analysis.  For example, Henderson and Sutherland (1996:527) define discounting as "the process by which we translate the value of expected future costs and benefits into present-day values."  Similarly, Sen (1982:326) holds that "the discount rate specifies the rate at which additional benefits in period $t + 1$ are converted into equivalent amounts of benefits in period t."  In these and other cases, costs and benefits are defined in the usual anthropocentric manner, usually in terms of money but sometimes in terms of social welfare.

The third form defines discounting explicitly in terms of social welfare.  The social welfare definitions are quite technically precise, defining discounting as value comparisons across time that maximize a social welfare function.[12]  For example, Drèze and Stern (1990:29) define the social discount rate as "the rate at which the marginal social value of the numéraire is falling over time."  (For a more detailed treatment, see Drèze and Stern 1987:967-974.)  The essence of this definition is that gains and losses (as measured by the numéraire, or unit of analysis) should be valued according to their contribution to total social welfare, and that discounting should proceed accordingly.  In implementations of this definition, spatial heterogeneity can be accounted for, but the heterogeneity is not explicitly acknowledged in the definition, thereby feeding the general neglect found in common discounting discourse and practice.  Meanwhile, non-anthropocentric ethics cannot be accounted for, because social welfare is an aggregate of the welfare of individual humans and nothing else.

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[11] An exception within the realm of anthropocentric time discounting is Caney (2008), who discusses the time discounting of human rights.

[12] One can imagine defining discounting in terms of social welfare without incorporating the concept of maximization.  However, to my knowledge, non-maximizing social welfare discounting definitions are absent from the existing literature.

## 2.2.2. Spatial and Non-Anthropocentric Discounting

Although discounting almost always involves anthropocentric comparisons of value across time, there are a few exceptions looking at comparisons across space and comparisons with non-anthropocentric values.

The most thorough treatment of spatial discounting is the work by geographer Bruce Hannon (see Hannon 1987; 1994; 2005; Perrings and Hannon 2001). Hannon (1987:229) defines discounting quite generally: "To discount is to devalue. More precisely, to discount an event is to devalue it compared to its value if it were happening now, certain to continue to happen, happening here, affecting me, through all my senses." The essence of this discounting is that individuals favor some phenomena to others. Thus Hannon's spatial discounting is based on the insight that humans and nonhumans alike tend to favor being closer to some things and farther from others. For example, animals (including humans) in general want to be close to food sources but far from predators.

Closely related to spatial discounting is the idea of social discounting developed by psychologists Bryan Jones and Howard Rachlin (Jones and Rachlin 2006; 2009; Rachlin 2006; Rachlin and Jones 2008). Like Hannon, Rachlin (2006:425) also defines discounting quite generally "to mean the reduction of a quantity with the increase of some variable", in which the variable could be time, space, or other variables. Jones and Rachlin's social discounting is based on the insight that people tend to favor other people who are closer to them in social distance, such as family and friends. Social distance can have temporal as well as spatial components. For example, people care about their descendants, who live at different times, and their siblings, who live in different places.

A final discussion of spatial discounting is in the work of Baum and Easterling (2010), who discuss spatial discounting in the context of adaptation to climate change. Baum and Easterling use two of the reasons for discounting developed here: welfare favoritism and consumption inequality. Baum and Easterling cover these topics less thoroughly than the present chapter and do not consider anthropocentrism.

The largest body of work on discounting with non-anthropocentric ethics is the substantial empirical literature on how non-human animals discount gains and losses across time (cf. Richards et al. 1997; Stephens et al. 2002; Evans and Beran 2007; Jimura et al. 2009). This literature tends to define discounting in terms of subjective value. For example, Jimura et al. (2009: 1071) write "One common situation involves choosing between a larger delayed reward and a smaller reward that is available sooner. In such situations, the subjective value of a reward is typically inversely related to the delay until its receipt—a phenomenon termed delay discounting." Here the subjects performing the discounting could be either humans or non-humans: the discounting could be either by humans or by non-humans.

There is a smaller literature on non-anthropocentric spatial discounting lead by Bruce Hannon (see Hannon 1984; 1990; 1994; Amir and Hannon 1992). This literature discusses spatial and temporal discounting in non-human animals and even in plants and

ecosystems. Another study worth noting is Stevens et al. (2005), which examines spatial components of how non-human animals discount across time. Specifically, Stevens et al. examine how New World monkeys compare the value of immediately available rewards and future rewards that require some travel. Stevens et al. describe this as spatial discounting, but under the terminology of this chapter, it would be classified as a spatial component of temporal discounting. At any rate, the existing work on non-human discounting (across both space and time) does not fit within the traditional anthropocentric conceptualizations of discounting.

There has also been at least one psychological study (Böhm and Pfister 2005) examining how humans discount using non-anthropocentric – in this case, ecocentric – ethics. This study clearly distinguishes between the environment as being valuable to humans (which is anthropocentric ethics) and as being valuable for its own sake (which is ecocentric ethics). Other environmental discounting studies (e.g. Hendrickx and Nicolaij 2004; Hardisty and Weber 2009) focus only on anthropocentric forms of environmental value or fail to distinguish between the two forms. Although the anthropocentric environmental (time) discounting can be readily fit within traditional discounting conceptualizations, the ecocentric discounting cannot, because the traditional conceptualizations only permit anthropocentric values.

Finally, there have been some ethical discussions of non-anthropocentric discounting. Barkin (2006) argues that ecocentric considerations imply that traditional anthropocentric discounting is inadequate for long-term environmental problems. Kant (2003) argues that the complexity and functional importance of ecosystems defies the commoditization necessary to apply standard monetary discount rates to ecosystem services. Lastly, Baum (2009) explores non-anthropocentric forms of the "descriptive approach" to discounting. In this approach, the discounting parameters that should be used in policy and other societal decisions are derived from descriptions of how society actually does discount. Traditional implementations of the descriptive approach only include humans in their descriptions; Baum (2009) suggests that non-humans could be included in the descriptions. These various ethical discussions all suggest that we can include non-humans in discounting.

## 2.3. Three Reasons for Space-Time Discounting

Why would we discount gains and losses that occur at different times? Many reasons have been given. Cowen and Parfit (1992) and Frederick (2006) provide excellent overviews. Here I develop three: investment opportunity, consumption inequality, and welfare favoritism. These reasons are among the most important in the discounting literature, particularly the literature in the context of climate change assessment. Readers familiar with this literature may recall that discounting debates are commonly framed in terms of parameters in the Ramsey equation (named after Ramsey 1928; see Dasgupta and Heal 1979:296-297):

$$ r = \rho + \eta * g \tag{2.1} $$

Here, r and ρ are the discount rates on money and utility, respectively. These are used to compare the values of gains and losses of consumption and utility that occur at different times. ρ is sometimes referred to as the pure rate of time preference. In all discussions of discounting, it is important to recognize that the discount rate will in general depend on the numéraire (unit of analysis). η is the elasticity parameter, sometimes referred to as the rate of relative risk aversion. η defines the relationship between utility and monetary consumption, indicating how much more a dollar of consumption is worth to the poor than to the rich. g is the growth rate of per capita consumption, indicating how consumption changes over time. Note that Equation 2.1 neglects the effects of uncertainty.

Debates over how to set the Ramsey equation parameters are generally divided into two camps, known as the "descriptive approach" and the "prescriptive approach" (Arrow et al. 1996; see Baum 2009 for details and a critique). Typically the descriptive approach matches r to market interest rates, citing investment opportunity as the key reason (cf. Nordhaus 2007). The prescriptive approach typically sets ρ to zero or close to zero, citing welfare favoritism (specifically that we should not favor some welfare over others) as the key reason, and sets η to some value (a range of values have been given), citing consumption inequality as the key reason (cf. Cline 1992; Stern 2007; Broome 2008; Dasgupta 2008).[13] The centrality of investment opportunity, consumption inequality, and welfare favoritism here is why I focus on them in this chapter.

There are many other reasons given for time discounting, including in the selection of values for the variables in the Ramsey equation. For example, some supporters of both the descriptive approach (e.g. Weitzman 1998) and the prescriptive approach (e.g. Stern 2007) have cited uncertainty as a factor in Ramsey equation parameters (r and g for the descriptive approach; ρ for the prescriptive approach; see also Ng 2005). Also, at least one prescriptive approach supporter (Dasgupta 2008) has argued for certain parameter values (in this case η) on grounds that other values would demand that some individuals sacrifice excessively on behalf of others. Although these and other reasons for time discounting also have spatial components and spatial analogs, further discussion is beyond the scope of this chapter. To repeat from above, a spatial component is an aspect of where gains and losses occur that affects how we discount across time. A spatial analog is a reason for spatial discounting – comparing values across space – which is an analogous to a reason for comparing values across time.

### 2.3.1. Investment Opportunity

A core argument for discounting future money (and sometimes other gains and losses) is the idea that present money is worth more because it can be invested, yielding more money later. Therefore, per this argument, we should discount the value of future dollars

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[13] Stern (2007) sets ρ=0.01 instead of ρ=0 as a means of handling the possibility that future benefits will not materialize due to the occurrence of a global catastrophe such as a large asteroid impact. As noted in Section 2.3, this handling of possible catastrophe can be interpreted as discounting for the reason of uncertainty. As with most if not all other prescriptive approach implementations, Stern (2007) argues that we should not favor some welfare over others.

using the return rates we can get on investments.  Many analysts treat investment opportunity as the core reason for discounting, including both supporters of this approach to discounting (e.g. Weitzman 1998; Nordhaus 2007) and critics (e.g. Barkin 2006).  If this approach is used, one challenge is deciding which of the several available market interest rates to match discount rates to.  Much attention has gone towards the difference in rates found in equities and in bonds; this challenge is known as the "equity premium puzzle" (Mehra and Prescott 1985; for recent commentary, see Brekke and Johansson-Stenman 2008; Quiggin 2008).

*Spatial component*: Intertemporal investment opportunity varies across space for several reasons.  First, investments in some regions bring different returns, which is why we see such products as "emerging markets" mutual funds (cf. Harvey 1995).  When matching discount rates to investment return rates, we face decisions about not only what type of investment instrument to use (e.g. equities or bonds) but also where the instrument is located.[14]  Second, different people have different capability to invest, due to differences in such things as knowledge and market access.  These differences exist even in this era of globalized finance.  Thus we also face decisions about who is making the investment, which is a spatial component simply because, at any given time, different people exist in different places.  Third, some organizations (companies, municipalities, etc.) may be forbidden from making certain types of investments, such as investments involving risk of significant loss or investments that violate local policies.  Organizations, like people, exist in different places at a given time.  For all of these reasons, space matters to investment opportunity and thus to time discounting.  If we neglect space, we can end up making analytical mistakes such that we use the wrong time discount rates.

*Spatial analog*: Investment as traditionally understood is fundamentally a temporal phenomenon: we forgo something (generally money) at present so as to gain more of that thing in the future.  A monetary investment takes money now and (among other things) converts it into more money later.  This process does have a spatial analog: arbitrage.  Here, one "invests" some amount of money in a first place and simultaneously sells the "investment" in a second place, yielding more money.  One can thus speak of discounting a dollar in the second place relative to the first place, just as one can speak of discounting a future dollar relative to an earlier dollar due to investment opportunity.  Arbitrage opportunities are rare, especially relative to the very ubiquitous temporal investment opportunities, but the rarity is not the issue.  What matters is that arbitrage does exist,[15] and that it serves as a spatial analog to investment.  If we can speak of temporal discounting due to intertemporal investment opportunity, then we should also be able to speak of spatial discounting due to arbitrage opportunity.

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[14] Some regions' markets have yielded higher returns than others' in the past, and presumably some regions will yield higher returns than others in the future.  However, in general we do not know which regions will yield higher returns in the future.  Thus, adjusted for risk, investment opportunities may not significantly vary across regions.  This is an important caveat to the spatial component of investment activity.

[15] See Baker and Savaşoglu (2002) and de Jong and Rosenthal (2009) for stastical analyses indicating the existence of (imperfect) arbitrage opportunities.  See MacKenzie (2003) and Beunza and Stark (2004) for descriptions of actual arbitrage operations.

## 2.3.2. Consumption Inequality

The consumption inequality reason for time discounting is that future dollars are worth less than present dollars because future humans will have higher consumption levels.[16] This argument is based on the idea of diminishing marginal utility of consumption: a dollar is worth more (brings more utility) to the poor than to the rich. Because economies tend to grow over time, it is standard to assume that future humans will consume more. It thus follows that future dollars are worth less and should be discounted relative to present dollars. By this logic, future dollars should be discounted even in the absence of any investment opportunity, although in general, investment opportunities exist within a growing economy.[17] Discounting based on consumption inequality is a function of the rates at which consumption changes over time.

*Spatial component*: Intertemporal rates of consumption change can – and in general do – differ significantly from one place to another. Some regions may have rapidly expanding economies, permitting rapid growth in consumption. Other regions' economies may grow more slowly or even stagnate or contract. This can be seen clearly from Figure 2.1, which maps the real (i.e. inflation-adjusted) growth rates of gross domestic product (GDP). GDP is not equivalent to consumption, but it is a widely used proxy for consumption, including in the climate change analyses of Nordhaus (2007), Stern (2007), and others. The data in Figure 2.1 are from 2009 or the most recently available year, as found in CIA (2010).[18] The fact that 2009 was an unusual year for GDP growth is unimportant here. What is important is that the growth rates vary widely around the world, from -17.8% per year (Latvia) to 13.2% (Macao). There is also significant variation among larger countries, from -8.5% (Russia) to 8.4% (China). It thus follows that when we discount across time due to consumption inequality, we must account for where the consumption is occurring. Neglecting this can lead to analytical mistakes in time discounting.

A second source of analytical mistake in time discounting can be found in the considerable consumption inequality that exists across space. Suppose a future generation is on average wealthier, but some future individuals are poorer than some contemporary individuals. The typical, space-neglecting discounting will value future dollars less than present dollars, even if the comparison is between the poorer future

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[16] It is generally expected that future humans will have higher consumption levels due to ongoing economic growth. However, economies sometimes contract. If future humans have lower consumption levels, then the consumption inequality reason for discounting would suggest negative discount rates.

[17] It is possible to have consumption inequality across time in the absence of investment opportunity. As an example, consider a subsistence farmer who is isolated from financial markets and whose consumption depends on her farm's yield. This yield, and in turn the farmer's consumption, can fluctuate over time due to fluctuations in growing conditions. While it is possible for subsistence farmers to invest in future consumption, such as by saving seeds for future planting, these investment opportunities are the reason for only some of the consumption inequality across time, with the other consumption inequality being due to fluctuations in growing conditions or perhaps other reasons.

[18] An effort is currently underway to provide higher resolution gross product data – see Nordhaus (2006). Higher resolution data would further enhance the point being made here about the importance of space to time discounting for consumption inequality.

individuals and richer present individuals. Regrettably, this mistake is commonplace in much of the discounting literature.
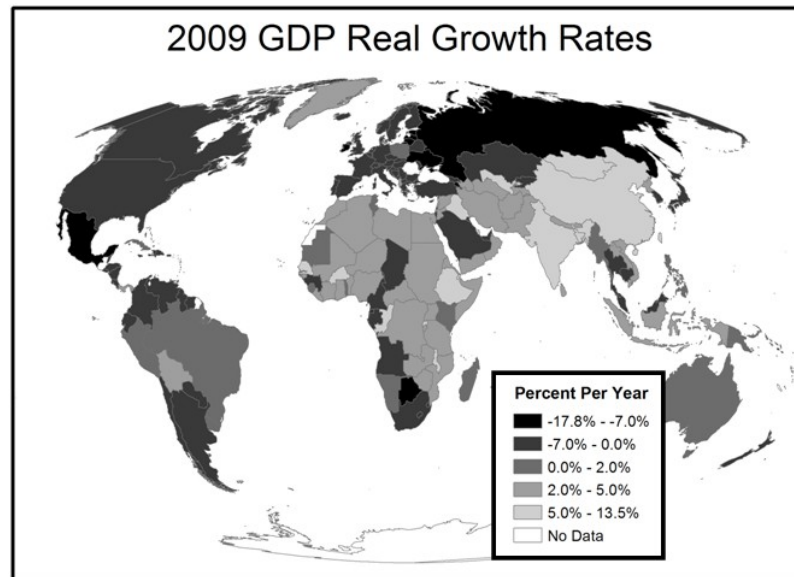


Figure 2.1: Map of gross domestic product (GDP) real growth rates, using data from 2009 or the most recent available data as found in CIA (2010).

The climate change literature has seen several noteworthy treatments of consumption inequality across space. Schelling (2000) argues that if the present and future gains and losses occur in different places, then differences in consumption across space (among other reasons) render traditional approaches to discounting inappropriate. Azar and Sterner (1996) and Stern (2007) find that including consumption inequality across space leads to recommending stronger efforts to reduce greenhouse gas emissions. In contrast, Nordhaus and Yang (1996) employ a weighting system (Negishi weights – see Negishi 1960) to reduce the significance of consumption inequality to emissions reduction recommendations. These varied treatments of consumption inequality demonstrate that it can be an important component of time discounting.

*Spatial analog*: The consumption inequality that exists across space is the spatial analog to consumption inequality across time. Here, a dollar held by a rich person would generally be (spatially) discounted relative to a dollar held by a contemporaneous poor person. The literature on social welfare-based CBA generally refers to this form of spatial discounting as welfare weighting, equity weighting, or distributional weighting (cf. Harberger 1978; Brekke 1997; Johansson-Stenman 2000). These weights are defined so as to account for differences in the marginal utility of consumption across space. As the spatial analog to consumption inequality-based temporal discounting, the weights can be considered a form of spatial discounting.

### 2.3.3. Welfare Favoritism

The welfare favoritism reason for discounting is that a unit of welfare is worth more today than it is worth tomorrow because people favor having welfare today to having

welfare tomorrow (i.e. $\rho > 0$ in Equation 2.1). Intertemporal welfare favoritism is often called the pure rate of time preference because it involves preferring welfare at certain times (i.e. earlier ones) purely because of when the welfare occurs, instead of due to other factors related to consumption or anything else. Debate over temporal welfare favoritism considers questions such as whether it is fair or even rational to favor present welfare over future welfare, or whether the views of future individuals (including future versions of our present selves) should be factored in.

*Spatial component*: How people favor welfare across time will commonly depend on where the welfare is. For example, I might value my future welfare more than I value your future welfare. This is part of Schelling's (2000) argument that conventional time discounting is inappropriate for climate change mitigation: emissions reductions involve (in many cases) present losses to those making the reductions in exchange for future gains to people worldwide. Mitigation thus has an inherent spatial component, trading off losses here (and now) for gains everywhere (and later). But conventional time discounting lacks this spatial component. If we valued all future welfare equally, this spatial component would not matter. However, we tend to value our own future welfare more than that of others around the world. Thus, conventional time discounting is inappropriate. In general, neglecting where (or to whom) present and future welfare occurs can yield analytical mistakes in our temporal discounting.

*Spatial analog*: Similarly, people often favor welfare across space. For example, I might favor my present welfare to your present welfare. People may place more value on the utility of those in their own region, or nation, or even race, gender, religion, socio-economic class, or other categories. We might object to some of these practices, but they occur nonetheless. Similarly, the Jones and Rachlin (2006; 2009) social discounting is based on the idea that people care more about others who are closer to them in social distance. Finally, social welfare functions that weight some welfare more than other contemporaneous welfare (e.g. Negishi weights – see again Negishi 1960) show spatial welfare favoritism. These instances of spatial welfare favoritism are all directly analogous to intertemporal welfare favoritism and qualifies as a form of spatial discounting.

## 2.4. Non-Anthropocentric Discounting

As we move from the human to the non-human realm, it is worth distinguishing between discounting *by* individuals/groups and discounting *for* individuals/groups. Discounting by individuals/groups refers to the discounting practices that individuals support and exhibit. For example, the numerous psychological studies of how humans discount all describe discounting by the humans who participate in the studies. In contrast, discounting for individuals/groups refers to discounting practices made on behalf of them. These practices might be made by other groups or individuals. For example, in discussions by academics of what discount rates governments should use in policy analyses, the discounting is for governments and the societies they aim to assist.

The distinction between discounting by and discounting for is especially important in the non-human realm because of the considerable debate on the capabilities and moral standing of non-humans. When we ask whether or which non-humans are capable of discounting, we refer to discounting by non-humans. Likewise, when we consider discounting using ethics that ultimately aims to assist non-humans, we refer to discounting for non-humans. Both forms of discounting are relevant to non-humans, and both will be considered here.

Discounting by and discounting for can be interrelated in at least two ways. First, if individuals are selfish, then discounting by them will also be discounting for them. Indeed, the claim that discounting by and discounting for can be different from each other depends on the possibility of altruism. Second, under at least some interpretations of the "descriptive approach to discounting" (Arrow et al. 1996; Baum 2009), discounting recommendations are based on descriptions of how society discounts. Here, discounting recommendations made by descriptive approach supporters are discounting recommendations for society based on discounting by society.

In each of the following two subsections, I argue that our conceptualizations of discounting should be expanded to include non-anthropocentric ethics. The argument here is, at is with including space, an argument from semantics: while we can define the word "discounting" however we would like, the word is most clear and useful when it is defined to include non-anthropocentric ethics. It is important to understand that the argument being made here is not an argument for non-anthropocentric ethics itself. While I do have views on non-anthropocentric ethics, these are not relevant to the present discussion. Instead, all I am arguing is that our discounting conceptualization should include non-anthropocentric ethics. A broader, more inclusive conceptualization permits users of the conceptualization to decide for themselves which specific ethical views to use.

### 2.4.1 Discounting by Non-Humans

Within the non-human realm, it is most straightforward to speak of discounting by sentient non-human animals. This is because of the close parallels that likely exist between the cognitive processes involved in discounting by humans and those involved in discounting by other sentient animals. The neural foundations of discounting by humans are already beginning to be identified (see McClure et al. 2004). There is no a priori reason to assume that humans are the only sentient animals capable of the cognitive processes of discounting. After all, human neural anatomy resembles that of other animals, especially those that are phylogenetically similar, and intelligence has evolved throughout at least the vertebrate portion of the animal kingdom (Roth and Dicke 2005).

It does appear as though at least some non-human animals do indeed discount in ways similar to how humans discount. This discounting by non-human animals has been explored in a modest literature, as cited in Section 2.2.2. This is mostly behavioral research, in the sense that the studies observe how non-human animals behave in response to choices between gains or losses at different times (and in different places, in

the case of Stevens et al. 2005).  There is also some neuroscience research examining the neural foundations of discounting in non-human animals (e.g. Churchwell et al. 2009).  This research provides insights about discounting by non-human animals and humans alike: contemporary research ethics standards permit certain procedures to be performed on non-human animals (for example, invasive brain surgery) but not on humans.  Some of these procedures can help us learn about discounting by humans, because at least some non-human brains can serve as at least rough proxies for human brains.

Non-human animals appear to discount for at least some of the same reasons as humans.  The most straightforward comparison is in welfare favoritism.  As with humans, non-human animals may value gains and losses here, now instead of later and/or elsewhere because they are impatient and because they favor their own welfare to that of others.  Additionally, some non-human animals appear to discount due to consumption inequality.  The clearest example is of animals such as squirrels who store seeds and other foods for future consumption, because otherwise they would have very unequal consumption between different periods.  Finally, it is even plausible that some non-human animals could discount for a reason analogous to investment opportunity.  This would occur if the animals restrained themselves from eating too much food at present so that the food could multiply into more food in the future.  A herbivore might eat fewer seeds so that more plants could grow into even more seeds later; a carnivore might eat fewer of its prey so the prey could breed more.  These similarities between discounting by humans and by sentient non-human animals further strengthen the case for including discounting by non-humans.

If discounting is not a cognitive processes, then there can also be discounting by entities other than sentient non-human animals.  In other words, non-sentient entities could perform the process of discounting.  These non-sentient entities could be non-sentient animals (such as sponges, which have no nervous system), living organisms other than animals, or even ecosystems.  The idea of discounting non-sentient entities has been developed by Bruce Hannon (see Hannon 1984; 1990; Amir and Hannon 1992).  In this work, discounting is not a cognitive process but instead is an appearance of discounting that must be interpreted by sentient observes – in particular by humans.  Hannon observes that non-sentient entities can appear to be maximizing some value function that is used to compare values (discount) space and time.  For example, a tree with a high discount rate grows quickly but is not durable, such as the locust or silver maple; a tree with a low discount rate grows slowly but is durable, such as the oak, hickory, or sugar maple (Hannon 1990:120).  The lower the tree's discount rate, the more it appears to sacrifice short-term growth for the sake of long-term growth.

I am uncomfortable with the idea of discounting by ecosystems or by other non-sentient entities.  As far as I can tell, the ecosystems are not actually performing any valuations of gains and losses: such valuations require cognition, which ecosystems do not have.  These phenomena are not discounting per se but instead are the appearance of discounting.  There is no actual discounting by ecosystems.  Although it may be accurate to say that ecosystems appear to discount, this appearance may not match reality.

How is discounting by non-humans significant? First and foremost, we must acknowledge that discounting is not a strictly human phenomenon. To be sure, one can define the word "discounting" in any way, including in ways that exclude what is here referred to as "discounting by non-humans". But such exclusion would be arbitrary and unhelpful. Regardless of what words are used to describe it, the process referred to as "discounting by non-humans" exists. I can think of no alternative terminology that describes this process as well as "discounting" does, and so I for one favor using the word "discounting" here. Likewise, any conceptualizations that define discounting strictly in human terms will be neglecting (what is referred to here as) discounting by non-humans. A more complete, more helpful conceptualization would include discounting by both humans and non-humans. One such conceptualization is presented in Section 2.5.

A second significance of discounting by non-humans is in its implications for the "descriptive approach to discounting." The approach aims (at least sometimes) to base discount rates on descriptions of how society discounts. Society here is almost always defined exclusively in terms of human populations (but see Baum 2009). Given that at least some sentient non-human animals discount, and other non-humans might too, an ethical argument must be made for why they should be excluded from the descriptions. Such an argument would have to stand up to accusations of speciesism, which could be similar to accusations of speciesism in anthropocentric utilitarianism (such as in Singer 1975; see also Horta 2010). Alternatively, new descriptions could be made which include non-humans. The new descriptions could draw on the existing research on discounting by non-humans. However, new methods would be needed to merge human and non-human discounting into a combined description. The merge would be particularly challenging if human discounting is described using market interest rates, as is commonly the case, because non-humans do not participate in financial markets or any close analog thereof. Thus, the existence of discounting by non-humans poses either ethical or methodological challenges to the descriptive approach to discounting.

### 2.4.2. Discounting for Non-Humans

In contrast with discounting by non-humans, it is about as straightforward to speak of discounting for sentient non-human animals as it is to speak of discounting for non-sentient animals, other organisms, ecosystems, or other non-sentient entities. This is because the entities that are being discounted for need not be the entities doing the discounting. Instead, the discounting can be done by humans, or by other sentient animals, or by anything else that turns out to be capable of discounting. All that is needed is for intrinsic value to be defined in terms of whatever is being discounted for.

As noted in the introduction, intrinsic value is that which is valuable for its own sake. (For a detailed discussion, see Rønnow-Rasmussen and Zimmerman 2005.) If an ethical framework is (strongly) anthropocentric, then it will place intrinsic value exclusively on some property of humans, such as their lives, health, or welfare. For example, the social welfare function ubiquitous in welfare economics represents total intrinsic value; individuals' welfare holds component intrinsic value. Other ethical frameworks place

intrinsic value on other phenomena.  In particular, many utilitarians place intrinsic value on the utility of all species, not just humans (e.g. Singer 1975; Ng 1995); consequentialist forms of ecocentric ethics claim that ecosystem fitness holds intrinsic value (Holbrook 1997).

This chapter's discussion of discounting for sentient non-human animals and ecosystems depends on the possibility of placing intrinsic value on non-human phenomena.  This is because, in the context of discounting, intrinsic value is defined in terms of whatever is being discounted for.  If we are discounting for sentient non-human animals, then intrinsic value is defined in terms of some property of sentient non-human animals, such as their lives or their welfare.  Likewise, if we are discounting for ecosystems, then intrinsic value is defined in terms of some property of ecosystems, such as the flourishing of the ecosystems.

Discounting for sentient non-human animals can parallel discounting for humans.  We can exhibit welfare favoritism by valuing the welfare of some animals more than that of others.  We might favor the welfare of our pets, or of animals alive today, or of animals in our region.  We might favor the welfare of members of some species – indeed, the anthropocentric practice of not valuing non-human animal welfare can be expressed as discounting non-human animal welfare at an infinite discount rate.  All this can be interpreted as an extension of the Jones and Rachlin (2006; 2009) social discounting to the interspecific domain.  As with anthropocentric social discounting, interspecific welfare discounting can be mapped to some form of space-time welfare discounting, because two sentient animals cannot exist at the same place at the same time.

One can imagine discounting for sentient non-human animals for other reasons as well.  Perhaps managers of an animal shelter must compare the value of food for the animals across space and time, for reasons of consumption inequality between the animals or within animals over time.  Alternatively, perhaps the managers must factor in the opportunity to invest in financial markets when making decisions about how best to utilize their resources for the welfare of the animals.  Both of these scenarios could qualify as discounting for the animals.  One could readily come up with other scenarios beyond these.

An interesting and important parallel to discounting for sentient non-human animals is discounting for members of an extraterrestrial civilization.  Humanity has never encountered extraterrestrials (conspiracy theories aside), but an encounter could happen, and might even be likely if humanity colonizes space.  In the event of an encounter, how the civilizations discount each others' welfare could determine whether there is cooperation or conflict between them.  Even if an encounter is unlikely, the possibility is noteworthy for its profound implications for ethical anthropocentrism.  Many reasons for discounting the welfare of sentient non-human animals could work in reverse with extraterrestrials: just as humans are smarter, more civilized and more sophisticated than non-human animals, extraterrestrials may be smarter, more civilized and more sophisticated than humans.  If we do not discount our own welfare relative to the extraterrestrials', then can we be justified in discounting the welfare of non-human

animals relative to ourselves?  In the extreme case, if we justify sacrificing non-human animals for food, should we then be willing to sacrifice ourselves for food for extraterrestrials?  (For discussion of these issues, see Baum 2010.)  How we answer these difficult questions speaks strongly to what our ethics are, in particular how we discount across species.

Discounting for ecosystems or for non-sentient individuals is somewhat different than discounting for sentient individuals, because non-sentients lack welfare.[19]  However, as long as we can still find reason to place intrinsic value on the non-sentients, then we can discount for them.  The idea that ecosystems have intrinsic value has a long history, dating to at least Leopold (1949/1979, pp. 224-225), who wrote "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community.  It is wrong when it tends otherwise."  The idea has caught on among environmental ethicists, as discussed in Holbrook (1997), Devall (2001) and elsewhere.  It also is used in the many ecosystem management efforts in which the ecosystems are managed for their own integrity instead of for humans.  These efforts have lead to extensive discussion of how to measure ecosystem integrity, as reviewed by Niemi and McDonald (2004).  Thus the idea that ecosystems can have intrinsic value has strong tradition in both ethical theory and in ecosystem management practice.

A vivid example of discounting for ecosystems is the case of Canada's Experimental Lakes Area (ELA; Stokstad 2008).  The ELA supports large-scale experimental ecology research in which lakes are intentionally polluted to help researchers better understand the relationships between pollutants and ecosystems.  When the research is successful (and it often is), this understanding then informs policy efforts that might lead to the protection of other lakes elsewhere.  The ELA receives support because (among other reasons) the environmental protections generated by the research are considered to be good enough to outweigh the bads of the environmental destructions of the research itself.  Thus, at its core, the ELA project features a trade-off of short-term, localized ecological destruction against long-term, international ecological protection.  This tradeoff involves a comparison of ecocentric value over space-time which can be considered space-time discounting for ecosystems.

Another example of discounting for ecosystems can be found in biodiversity preservation practices.  Hunter and Hutchinson (1994) discuss the phenomenon in which humans invest more heavily in spatially proximate preservation projects.  One reason for this could be biodiversity favoritism, in the sense that people favor (place higher intrinsic value on) spatially proximate biodiversity.  This can be described as spatial discounting for biodiversity.  One can readily imagine other examples of ecosystem favoritism across space and time.

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[19] The set of individuals with welfare is a subset of the set of individuals with sentience.  As Ng (2005:258) puts it, the sentients are "usually defined as beings that are capable of subjectively perceiving or feeling by means of the senses. This includes not only beings capable of the feeling of being happy and/or unhappy, but also includes beings just capable of perceiving things without having any affective feeling."  Here, happy/unhappy can be interpreted at least roughly as having/not having welfare.

How is discounting for non-humans significant?  As with discounting by non-humans, we must acknowledge that discounting is not a strictly human phenomenon, and that our conceptualizations of discounting should be able to handle discounting for non-humans. Again, one can define the word "discounting" in any way, including in ways that exclude what is here referred to as "discounting for non-humans".  And again, such exclusion would be arbitrary and unhelpful.  A more theoretically sound and helpful conceptualization of discounting would include discounting for both humans and non-humans, as well as discounting by both humans and non-humans.  A simple way of achieving this is to extend existing conceptualizations of discounting to allow for intrinsic value to be defined in any way.  This extension is central to the discounting as values comparison conceptualization presented here.

## 2.5. Discounting as Values Comparison

As discussed throughout this chapter, discounting traditionally refers to comparisons of the values of gains or losses that occur at different times in which the valuations use anthropocentric ethics.  This section develops a new conceptualization of discounting that readily handles both space and non-anthropocentric ethics.  I refer to this conceptualization simply as *discounting as values comparison* (DaVC).

### 2.5.1. Defining DaVC

To define DaVC, two concepts are needed: total intrinsic value and location.  These concepts, which as used here both come from the ethics literature, offer a solid foundation for discounting.  Note that the ethics here is strictly consequentialist, i.e. ethics which claims that the consequences of our actions are the only things that are ethically important.  As discussed later in this section, it appears that discounting can only function within consequentialist ethics.

As noted above, intrinsic value is that which is valuable for its own sake (Rønnow-Rasmussen and Zimmerman 2005).  All other forms of value are called extrinsic value (Bradley 1998).  Total intrinsic value is the total amount of intrinsic value held by a system.  For example, if we place intrinsic value on human life, then total intrinsic value would be some function of the intrinsic value of all human lives.  Similarly, throughout welfare economics, it is common practice to define intrinsic value in terms of human welfare, and to define total intrinsic value through a social welfare function.  Due to the principle of organic unities (Moore 1903), this function need not be linear.  In other words, although we can define the total intrinsic value of a system as the sum of the intrinsic values of all of the components of the system, there is no requirement that we do this.

Locations are defined here as the points in space-time in which values of any type occur. This definition of location is adapted from Broome (1995).  The term "location" in the present context includes differences across social distance.  No two people (or non-people) can exist at the same place at the same time, and so it follows that people at different social distance are inevitably also at different space-time locations.  Because of

this, any set of points at different social distances from any given individual can be mapped to some (potentially complex) set of points in space-time. Following the same logic, other social dimensions such as race and class can also be mapped to space-time. Thus the use of space-time locations permits the handling of discounting across other dimensions of interest.

In heuristic terms, DaVC simply defines discounting as the comparison of different values across different locations. The values being compared can be of any type. The comparison is to be made in terms of total intrinsic value, which can be set in any way – anthropocentric or otherwise. The locations can vary in either space or time or both. This allows each of temporal discounting, spatial discounting, and spatiotemporal discounting.

In more precise terms, DaVC defines discounting via the ratio of change in total intrinsic value found from two values in two locations:

$$D(v_a, v_b, L_a, L_B) = \frac{\Delta V(v_a, L_a)}{\Delta V(v_b, L_b)} \tag{2}$$

Here, the values being compared are $v_a$ and $v_b$; they are located at locations $L_a$ and $L_b$. Values $v_a$ and $v_b$ can be of any type. $\Delta V$ is the change in total intrinsic value coming from the values at their respective locations, i.e. the increase or decrease in total intrinsic value resulting from the existence of the values $v_a$ and $v_b$. $D$ is the discount factor, which is the numerical embodiment of the values comparison. $D$ is defined as a ratio of values (instead of, for example, a difference) for consistency with the existing discounting literature.

Defined in this way, DaVC permits full treatment of space. This is because locations can vary across space as well as time. For spatial components of time discounting, we handle space by allowing locations to vary across space-time and then use whatever values happen to exist there/then. For spatial analogs of time discounting, we allow locations to vary across space only. For both cases, as long as we accurately value gains and losses in terms of total intrinsic value, then we will make correct value comparisons: we will discount correctly, i.e. without analytical mistake.

DaVC also permits non-anthropocentric ethics. This is done through the definition of total intrinsic value. For example, if one wishes to discount for the welfare of sentient non-human animals, then one defines total intrinsic value thusly. Ditto for discounting for ecosystems, or for biodiversity, or for anything else one might wish to discount for. Meanwhile, the "one" doing the discounting need not be a human. Anyone capable of comparing values across space and time under some definition of total intrinsic value can discount. Thus there can be discounting by sentient non-human animals, or perhaps even by ecosystems or non-sentient individuals.

As far as I can tell, DaVC cannot handle all forms of ethics. Specifically, it can only handle consequentialist ethics. The values we compare are consequences of actions that could be taken: actions about saving, or about government policy, or about anything else. For example, when evaluating climate change policy, we discount the values of gains and losses that are consequences of the policy. In contrast, we cannot discount within deontological ethics, in which some actions are fundamentally right or wrong, regardless of the consequences. We also cannot discount within virtue ethics, in which what ultimately matters is who we are, not what we do. For deontological and virtue ethics, morality does not involve value comparisons across space or time and thus does not involve discounting as defined here. I cannot image any way of defining discounting so as to accommodate non-consequentialist ethics.[20] Further discussion of the limitations of discounting to consequentialism is found in Chapter 3.

### 2.5.2. DaVC Compared to Existing Discounting Definitions

DaVC features full backwards compatibility with existing definitions of spatial and temporal discounting, as well as with existing definitions of discounting across other dimensions that can be mapped to space-time, such as social distance. The backwards compatibility exists because the existing definitions all use some form of consequentialist ethics that can be expressed in terms of total intrinsic value. To be sure, many existing definitions are ambiguous on exactly how they would define total intrinsic value. This ambiguity is discussed further below.

The two existing discounting definitions that are most similar to DaVC are of Hannon (1987) and Rachlin (2006). Per Hannon (1987:229), "To discount is to devalue. More precisely, to discount an event is to devalue it compared to its value if it were happening now, certain to continue to happen, happening here, affecting me, through all my senses." Here, $v_a$ and $v_b$ are the event in its original and devalued forms; $L_a$ and $L_b$ are the space-time locations of the events. Per Rachlin (2006:425) discounting is "the reduction of a quantity with the increase of some variable" such as time or space. Here, $v_a$ and $v_b$ are the quantity in its original and reduced forms; $L_a$ and $L_b$ are the space-time locations of the quantities. Both of these definitions share the space-time orientation of DaVC. Both definitions also lack the inclusion of total intrinsic value, the importance of which is discussed below. Finally, both the Hannon (1987) and Rachlin (2006) definitions also permit discounting across the "dimension" of probability; DaVC does not. DaVC excludes discounting across probability because values do not exist at points in probability as they do at points in space-time. Detailed discussion of the idea of discounting across probability is beyond the scope of this dissertation.

For existing time discounting definitions, the simplest to express in terms of DaVC are those that define time discounting in terms of social welfare. Indeed, these definitions are perhaps unique among existing (time or space) definitions in that they include a clear

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[20] As a caveat, I cannot strictly rule out the possibility of discounting with non-consequentialist ethics. While such discounting appears impossible, following the simple logic sketched here, perhaps an alternative approach to non-consequentialist discounting exists nonetheless. Such non-consequentialist discounting, if possible, would depend on nuances of non-consequentialist ethics that are beyond the scope of the dissertation.

definition of total intrinsic value via the social welfare function. For example, the definitions of Drèze and Stern (1987, 1990) definitions are obtained from setting $V$ to social welfare and neglecting space in $L$. More specifically, Drèze and Stern (1987, 1990) define the shadow discount factor as the increase in social welfare (which here is total intrinsic value) coming from one unit of a numéraire commodity at one time relative to the increase in social welfare coming from one unit of a numéraire commodity at another time. Thus $v_a$ and $v_b$ here are both one unit of the numéraire commodity; $L_a$ and $L_b$ are two points in time.

Apart from those based on social welfare, other definitions of time discounting tend to be ambiguous on how total intrinsic value is defined. This ambiguity does not preclude the expression of these definitions in terms of DaVC. As an example, consider the discounting definition of Price (1993:4), defining discounting as "any process of revaluing a future event, condition, service or product to give a present equivalent." The key feature of this definition is that $L_a$ is the present time. $L_b$ can be any future time. $v_b$ is an event, condition, service or product at $L_b$; $v_a$ is the same event, condition, service or product as it would appear at $L_b$. A similar example is that of Frederick et al. (2002:352), defining discounting "any reason for caring less about a future consequence". Here, $v_a$ and $v_b$ are consequences, $L_b$ is some time in the future, and $L_a$ is presumably the present time.

The ambiguity in existing time discounting definitions includes ambiguity with respect to anthropocentrism. For example, Chapman (2002:410) defines discounting as "a method of adjusting the value of delayed outcomes so that they can be directly compared to immediate outcomes." In principle, this value can be non-anthropocentric. However, Chapman (2002) goes on to consider discounting of money and human health, two values that are anthropocentric in that they are both tied to the interests of humans. Interestingly, non-anthropocentric discounting research also includes ambiguous definitions. For example, Jimura et al. (2009: 1071) write "One common situation involves choosing between a larger delayed reward and a smaller reward that is available sooner. In such situations, the subjective value of a reward is typically inversely related to the delay until its receipt—a phenomenon termed delay discounting." This definition is typical of the non-anthropocentric discounting literature in phrasing discounting in terms of subjective value. Here the subjects performing the discounting could be either humans or non-humans: the discounting could be either by humans or by non-humans.

An interesting case of time discounting is that of Caney (2008:540). Here, the discounting is of human rights; a positive discount rate is defined to mean that "the rights (or interests) of people should be ascribed less value the further they are into the future". What is interesting here is the use of rights. While rights are commonly used within deontological ethics, in this case they are used within consequentialist ethics (for discussions, see Nozick 1974; Sen 2000). That is, when we discount rights (as in Caney 2008), we are treating rights (or, more specifically, the satisfaction or violation of rights) as the consequences of our actions, and comparing the value of these consequences as they occur at different times. Thus here $v_a$ and $v_b$ are satisfactions or violations of rights at times $L_a$ and $L_b$; total intrinsic value is an function of the satisfactions of rights and

possibly other consequences.  As with many other treatments of discounting, Caney (2008) is ambiguous on exactly how total intrinsic value is to be defined.

The ambiguity with respect to total intrinsic value found in many previous time discounting definitions is in some ways a problem for the definitions.  Where discounting is used as a paradigm for describing human moral psychology, as in Frederick et al. (2002), the ambiguity leaves some uncertainty in exactly why humans are discounting in certain ways.  For example, suppose we observe that someone discounts such that she values present money more than future money.  If the individual defines total intrinsic value such that welfare at all times holds equal intrinsic value, then the discounting must be due to a reason other than welfare favoritism, such as investment opportunity or consumption inequality.  Similar uncertainty exists where discounting is used for describing how non-humans discount, as in Jimura et al. (2009).  To be sure, for both humans and non-humans, the uncertainty can at least in principle be resolved by measuring how the individuals define total intrinsic value.  The key point here is that one way or another, attention to total intrinsic value, such as in DaVC, improves our understanding of how individuals discount.

When time discounting is used as a paradigm for making or helping make decisions, then the lack of a total intrinsic value definition can be even more of a problem.  The problem here is that without a definition of total intrinsic value, we cannot know how to "correctly" discount.  That is, we cannot know what discount rates, discount factors, or other discounting terms we should use in our decision analysis.  (See Baum in press for a similar and more detailed discussion in the context of cost-benefit analysis).  Since such analysis is often highly sensitive to how we discount, the ambiguity with respect to total intrinsic value is of considerable significance.  By placing the definition of total intrinsic value front and center, DaVC improves on previous definitions.

Existing space discounting definitions can also be expressed in terms of DaVC.  Consider Hannon's spatial discounting, which is defined loosely as a "distance-based preference" (Hannon 1994:157).  Here, "to discount an event [across space] is to devalue it compared to its value if it were… happening here (Hannon 1987:229).  Thus $v_a$ and $v_b$ are events occurring at places $L_a$ and $L_b$.  This discounting is used, like Frederick et al. (2002), as a paradigm for describing human moral psychology (and in Hannon's case, also the morals of non-humans).  Thus total intrinsic value can be obtained from those humans or non-humans who are doing the valuing.  With this information, Hannon's spatial discounting could be expressed in terms of DaVC.

Jones and Rachlin's social discounting refers generally to the observed phenomenon of humans placing less value on gains accruing to other humans who are further in social distance (see e.g. Jones and Rachlin 2006; 2009).  That is, we tend to care more about gains to those socially close to us than similar gains to those socially far from us.  Here, $v_a$ and $v_b$ are gains occurring at social distances $L_a$ and $L_b$.  Since no two people can exist at the same point in space-time, it follows that $L_a$ and $L_b$ must also be distinct points in space-time.  Finally, since this discounting is used as a paradigm for describing human

moral psychology, total intrinsic value can be obtained from those humans who are doing the valuing so as to express this discounting in terms of DaVC.

As this section has shown, a broad range of existing discounting definitions can be expressed in terms of DaVC. With the exception of time discounting definitions based on social welfare, existing definitions lack clear statements of total intrinsic value and thus face certain conceptual problems. The selection of definitions presented here is by no means exhaustive. Indeed, an exhaustive treatment would be tedious and excessive. Instead, the selection here covers most of the diversity found in existing definitions. In doing so, this discussion indicates how to express other definitions in terms of DaVC.

## 2.6. Conclusion

Discounting is traditionally conceptualized as the comparison of value across time, where the value is defined using anthropocentric ethics. These conceptualizations neglect space and non-anthropocentric ethics. In response to this neglect, in this chapter I have analyzed space-time discounting and discounting without anthropocentric ethics. I find that there are strong reasons to include space in discounting and to permit discounting using non-anthropocentric ethics.

Reasons for including space in discounting follow from the reasons given for time discounting. Many reasons have been given for time discounting. Investment opportunity, consumption inequality, and welfare favoritism are particularly prominent reasons, especially in climate change discounting debates. Each of these three reasons has a spatial component such that space matters to time discounting, and a spatial analog suggesting the idea of spatial discounting. Thus, within anthropocentric discounting, space plays an important but inappropriately neglected role.

Reasons for permitting discounting using non-anthropocentric ethics follow from the several ways in which this discounting can be done. There can be discounting by non-humans as well as discounting for non-humans. Though excluded from traditional definitions, this non-human discounting clearly exists and can factor prominently in decision making for non-human animal treatment, environmental management, and other significant matters.

Given the shortcomings of traditional anthropocentric temporal discounting conceptualizations and limitations of existing non-anthropocentric and spatial discounting conceptualizations, I have developed a new conceptualization of discounting, which I call discounting as values comparison. DaVC permits discounting across space and time and discounting using non-anthropocentric ethics. However, DaVC cannot handle discounting using non-consequentialist ethics. I believe that no conceptualization of discounting can.

Though simple in form, the DaVC conceptualization represents a significant shift in how we can think about and implement discounting. It has the potential to expand the ways in which we use the discounting concept, opening up new lines of research and new forms

of analysis.  It also has the potential to enhance the clarity of existing discussions of discounting.  It cannot resolve the ongoing discounting debates – these debates can only be resolved through further empirical study and ethical argument.  But it can help clarify the terms of the debates, facilitating progress towards resolution.  Given the importance of discounting to so many major environmental and other issues, this would be a considerable achievement.

**Chapter 3: Multidimensional Descriptive Discounting And Limitations Thereof**

Descriptions of how people discount across time are prominent in both scientific and policy debates. However, almost all treatments of discounting neglect both how people discount across other dimensions and limitations in the extent to which human values can be described in terms of discounting. This chapter develops multidimensional descriptive discounting and limitations thereof as both theoretical and empirical concepts. We review the literature and present an empirical study exploring these concepts.[21] We find, among other things, that people discount similarly across several dimensions and that how people discount appears uncorrelated with the extent to which people's views can be described in terms of discounting. Above all, we find that the traditional time-only discounting is inadequate as a descriptor of human values. This result suggests major transformations to both the science and policy of discounting.

**3.1. Introduction**

Intertemporal discounting remains at the center of major scientific and policy debates. The stakes are quite high: how we discount plays a crucial role in how we make many important decisions. These include both personal decisions, such as how much money we save for our future, and societal decisions, such as how hard we try to address climate change. Likewise, researchers in economics, psychology, and other fields have produced studies of discounting at prolific rates (for example, in the recent special journal issues introduced in Weisbach and Sunstein 2007 and Zeckhauser and Viscusi 2008).

A prominent topic in the study of discounting is the question of how to describe how people discount. This question is of strong scientific interest, but it is also of direct relevance to policy.[22] The policy connection is due to the so-called descriptive approach to discounting (Arrow et al. 1996). The descriptive approach strives to base discount rates for policy purposes on descriptions of how society discounts. A core motivation here is to avoid having analysts, politicians, or anyone else impose their own discounting views on the analysis – instead of imposing their own views, they use a description of society's views in aggregate. Here, the descriptions are generally made via observations of rates of return found in financial markets, under the assumption that these markets provide an aggregate of how individuals in society discount future gains and losses relative to present gains and losses. Other approaches for descriptions of discounting are also available, including several survey techniques and, recently, brain imaging. Given the multiple ways of describing and aggregating how society discounts, analysts and others cannot avoid imposing their own views on how to form aggregate societal descriptions (Baum 2009). However, this fact does not negate the policy significance of discounting descriptions, and it says nothing to the scientific significance.

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[21] Throughout Chapter 3, the term "we" should be interpreted as "Seth Baum and Peter Howe," because the chapter is based on a paper co-authored by Howe and myself.

[22] By distinguishing science from policy here we mean to reference a Humean fact-value (or description-prescription) distinction, although we fully acknowledge that in practice science and policy are commonly intertwined.

Underlying almost all previous work on descriptive discounting is an assumption that it is adequate to only describe how people discount across time. This work neglects how people discount across other dimensions such as social distance (Jones and Rachlin 2006). It also neglects the limitations of discounting as a paradigm for describing human values – that is, it neglects those portions of human values that cannot be described via discounting. The importance of non-discounting values is clear in, for example, research on the moral psychology of the ongoing Israel-Palestine conflict (Ginges et al. 2007) or Iran's nuclear program (Dehghani et al. 2009). These two areas of neglect – multidimensional discounting and the limitations thereof – leave open major lines of scientific inquiry. The neglect also implies that policy analysts using the time-only descriptive approach to discounting are either imposing their view that only time discounting matters, which is a strong view in need of strong justification, or they are making a major analytical mistake by neglecting aspects of human values that they consider important.[23] Either way, the questions remain: how, and how well, are human values described in terms of discounting? In other words, how do humans discount, and to what extent can human values be expressed in terms of some form of discounting?

In this chapter, we develop the concepts of multidimensional descriptive discounting and its limitations as theoretical ideas and present new survey evidence exploring these concepts. Although prior discounting theory has focused almost exclusively on time discounting, there have been some treatments of discounting across other dimensions. We synthesize this work and extend it to novel dimensions. To our knowledge, this chapter also marks the first effort to systematically explore the limitations of discounting – whether across time or across any other dimension – as a descriptor of human values and the only effort to consider the limitations of discounting in terms of consequentialist ethics (discussed below). Meanwhile, the survey work presented here makes both empirical and methodological contributions to the small literature on multidimensional descriptive discounting. Our core methodological contribution is a technique which we call the *principle agreement approach*. This technique, as discussed below, is both grounded in fundamental ethical principles and effective at rapidly obtaining discounting descriptions across a large number of dimensions. We also introduce a line of questioning for assessing discounting limitations with the principle agreement approach. Finally, to probe further into the nature of our discounting results, we compare results from the multidimensional discounting and limitations questions both to each other and to results from a well-established psychological literature on the study of human values (Schwartz 1992, 1994; Stern et al. 1998). To our knowledge this is the first effort to compare discounting descriptions to descriptions from the values questions.

The chapter is organized as follows. Section 3.2 provides an overview of multidimensional discounting theory, which describes comparisons of values across a wide range of dimensions but cannot be used to describe all forms of values that individuals might hold. Section 3.3 reviews previous research on multidimensional descriptive discounting. Although there is little descriptive discounting research for

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[23] A similar point is developed by Schelling (2000), who argues that traditional time-only discounting approaches are inappropriate for evaluating policies to reduce greenhouse gas emissions because the benefits of such reductions go largely to people in countries different from those countries making the reductions.

dimensions other than time, the existing research does suggest some initial insights. Sections 3.4-3.5 present the design of and results from a survey exploring how humans discount across several dimensions. The survey also explores the extent to which humans' values can be described via any discounting paradigm. We find that humans discount across other dimensions similarly to how they discount across time, and that humans have significant support for values that cannot be described in terms of discounting. Section 3.6 discusses the significance of the theoretical and empirical findings of the chapter. A core point is that descriptive discounting work in both science and policy contexts should be expanded to include multidimensional discounting and other forms of values. Section 3.7 concludes.

## 3.2. Multidimensional Discounting Theory

Discounting is usually defined as the comparison of the values of gains and losses (which might or might not qualify as costs and benefits) that occur at different times.[24] With rare exception, future gains and losses are assumed to be of less value than current gains and losses.[25] Sometimes the comparison is across physical/geographic space, or social space (defined below), or some other dimension. Handling value comparisons across dimensions other than time requires a theoretical expansion of the discounting paradigm. The discounting paradigm can be expanded quite broadly to include any value comparison across any dimension. However, the paradigm always requires that some sort of consequentialist ethics (ethics that bases right and wrong on the consequences of our actions) be in effect. This requirement implies that there are fundamental limitations to discounting as a paradigm for describing human values.

### 3.2.1 Time Discounting

Almost all conceptualizations of discounting define discounting as some sort of value comparison across time.[26] These time-only conceptualizations vary somewhat in the specifics, mainly regarding which values are to be compared and how the comparison is to be made. Most often, the comparisons are of either money or human welfare. Here, related phenomena such as consumption (related to money; see Estle et al. 2007; Takahashi et al. 2008) or health (related to welfare; cf. Chapman 2002) are sometimes used. Occasionally, entirely different phenomena are compared. One such other phenomenon is human rights (cf. Caney 2008).

The general conceptualizations of time discounting define it as any comparison of value over time, without specifics on what the value is. For example, at the beginning of one of the most thorough treatments of discounting available, Price (1993:4) defines discounting as "any process of revaluing a future event, condition, service or product to give a present equivalent." Similarly, in another prominent study, Frederick et al. (2002:352) "use the

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[24] On the relationship between costs/benefits and gains/losses, see Baum (in press).

[25] One exception is research on how people value sequences of outcomes. See Loewenstein and Prelec (1993).

[26] In addition to the special journal issues cited above, major works in the time-only discounting tradition include Arrow et al. (1996); Frederick et al. (2002); Lind (1982); Loewenstein and Elster (1992); Portney and Weyant (1999); and Price (1993). Exceptions to the time-only tradition are discussed in Section 3.2.2.

term time discounting broadly to encompass any reason for caring less about a future consequence." Although both studies go on to focus on comparisons of money and welfare, their definitions in principle could support other comparisons.

Others have conceptualized discounting more narrowly. Often, discounting is explicitly embedded within cost-benefit analysis. Here, it is assumed that the gains and losses being discounted are costs and benefits. (In other studies, this assumption is not always made.) For example, Sen (1982:326) holds that "the discount rate specifies the rate at which additional benefits in period t + 1 are converted into equivalent amounts of benefits in period t." This definition does not specify how costs and benefits are to be defined. Most often, costs and benefits are defined in monetary terms, via market prices or willingness to pay estimates. However, this is not always the case (Baum in press). For example, in two detailed analyses, Drèze and Stern (1987, 1990) develop a form of cost-benefit analysis in which costs and benefits are defined in terms of a social welfare function. Here costs and benefits can – but need not be – measured in monetary units. Whichever units are used, costs and benefits must be weighted so that when they are aggregated, increases in net benefits always correspond with increases in social welfare. Likewise, Drèze and Stern define discounting as value comparisons across time that maximize a social welfare function. They define the social discount rate as "the rate at which the marginal social value of the numéraire is falling over time" (Drèze and Stern 1990:29). Here, discounting is still of costs and benefits, but the costs and benefits are defined in a very specific way.

It is important to note that all standard conceptualizations of time discounting consider gains and losses in strictly anthropocentric terms. The gains and losses are ultimately gains and losses to humans. This holds regardless of how the gains and losses are measured. If they are measured in monetary consumption, then it is consumption made by humans. If they are measured in terms of social welfare, then it is the welfare of humans. In more precise terms, these discounting definitions assume that the utility, or lives, or any other property of any nonhuman holds *intrinsic value*. Intrinsic value is that which is valuable for its own sake.[27] If only humans hold intrinsic value, then nonhumans might still hold value, but this value would be defined in relation to humans. For example, a livestock animal would be valuable because humans will eventually kill it and eat it. An ecosystem would be valuable because it provides resources and other amenities for humans.

The restriction that only humans hold intrinsic value is a widespread assumption throughout normative economics with very few exceptions in this broad literature. One exception is work by Solow and Polasky (1994), Weitzman (1992), and others attempting to develop metrics for biological and other forms of diversity that would help operationalize ethics which place intrinsic value on diversity. Another exception is the

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[27] Our use of the term "intrinsic value" is as found in the philosophy literature (e.g. Rønnow-Rasmussen and Zimmerman 2005). The economics literature often uses the term in two subtly different ways: (1) that which humans place intrinsic value on (c.f. Soma 2006); (2) that which is valuable for its own sake *other than* the preferences, welfare, or utility of humans (c.f. Crowards 1997). For a detailed discussion of the concept of intrinsic value (and other types of value) as found in philosophy and economics and as related to cost-benefit analysis, see Baum (in press).

work of Ng (in particular Ng 1995), which has called for nonhuman animal welfare to be brought into the fold of welfare economics. Another exception is a line of work developing economics-inspired mathematical models for optimizing some measure of ecosystem flourishing such as energy consumption or offspring success (Eichner and Pethig 2006; Tschirhart 2000). Finally, Johansson-Stenman (2006) examined intellectual history, finding it curious that normative economics has expressed little concern for nonhuman animal welfare. But none of these studies focus on discounting. The possibility that nonhumans hold intrinsic value will be examined further below in the context of multidimensional discounting.

Throughout this chapter, we will define time discounting broadly to refer to any comparison of the value of any gain or loss across time. We intend no critique of more narrow definitions. Instead, we intend simply to keep our options open with respect to what time discounting can refer to. This openness becomes particularly relevant as we explore the limitations of discounting.

Given a definition of time discounting, it is helpful to understand the theoretical reasons that justify the time discounting. Many reasons exist. Some of the most important reasons can be found by examining the Ramsey equation (named after Ramsey 1928; see Dasgupta and Heal 1979:296-297):

$$r = \rho + \eta * g \qquad (3.1)$$

This equation is particularly prominent in discussions of time discounting in the policy realm (Arrow et al. 1996; Dasgupta 2008; Nordhaus 2007; Stern 2008). In the equation, r and $\rho$ are the discount rates on money and utility, respectively. They represent the rate at which money and utility lose value over time. For purposes of this chapter, utility and welfare can be treated as equivalent concepts. $\eta$ is the elasticity parameter, which defines the relationship between utility and monetary consumption. $\eta$ indicates how much more a dollar of consumption is worth to the poor than to the rich. Finally, g is the growth rate of per capita consumption, which represents how consumption changes over time. Note that Equation 3.1 neglects the effects of uncertainty.

The Ramsey equation contains several important reasons for discounting across time. When $\eta$ and g are both positive, then future consumption is discounted relative to present consumption for the reason that a dollar of consumption is worth less to future individuals because they will be wealthier. Sometimes r is matched to market interest rates for the reason that markets offer investment opportunities, and that we should only choose those projects whose future benefits exceed what we could get via investment (see e.g. Nordhaus 2007). Sometimes r is matched to market interest rates for the reason that market rates are an aggregate description of how society discounts (again see e.g. Nordhaus 2007). This is the central reason behind the term "descriptive approach" to discounting: using market rates as descriptions of how society discounts prevents anyone from imposing their own personal discounting views on the analysis. Though it is less common in the literature, one can match $\rho$ to descriptions of how people compare the

value of utility across time as well. Other reasons for time discounting exist as well, but these are beyond the scope of the present chapter (many are discussed in Cowen and Parfit 1992; Frederick 2006).

### 3.2.2 Multidimensional Discounting

Time is not the only dimension that we compare values across. Some other dimensions have received prior theoretical attention, in particular physical space and social space (defined below). Other dimensions receive original theoretical treatment here, in particular discounting across species and discounting within ecocentric ethics (defined below). Value comparisons across these non-temporal dimensions can be just as important as value comparisons across time to both science and policy. These other comparisons can be labeled discounting, which suggests that we need a conceptualization and definition of discounting that can handle value comparisons across many dimensions.

Consider physical or geographic space, as measured in meters, miles, or similar units. Just as there can be inequality in consumption across time (as represented by the $\eta*g$ term in Equation 3.1), there can also be inequality in consumption across physical space. We see this at many scales: there are wealthy neighborhoods within cities, wealthy regions within countries, and wealthy countries within the world. Likewise, just as descriptions suggest that we might prefer a dollar of consumption or a unit of utility at some times relative to others, descriptions might also suggest that we prefer dollar of consumption or a unit of utility at some places relative to others. Presumably, people tend to prefer consumption and utility closer to themselves; we consider evidence about this below. Thus, for at least some of the reasons for discounting across time – including the reasons based on description – there also exists value comparison across physical space.

Another important dimension is social space. Social space refers to how "close" another person is to you in social terms. Our good friends and family are generally the closest to us in social space. Mere acquaintances who we do not know well are generally further from us in social space. One might hypothesize that we value the utility of people closer to us in social space more than the utility of people farther from us in social space. Assuming no differences in wealth, then consumption would be valued in the same way. Evidence suggesting that this does in fact occur is presented below. As with physical space, these value comparisons across social space directly parallel at least some of the reasons for discounting across time.

Both physical and social space have been considered theoretically. The most extensive existing work on discounting across physical space is that of geographer Bruce Hannon (see e.g. Hannon 1994; Perrings and Hannon 2001). Hannon's spatial discounting is grounded in other reasons for discounting not covered in this chapter. In a recent paper, Baum and Easterling (2010) explore discounting across physical space in the context of adaptation to climate change. Meanwhile, the most extensive existing work on discounting across social space is that of psychologists Bryan Jones and Howard Rachlin (Jones and Rachlin 2006; 2009; Rachlin 2006; Rachlin and Jones 2008). Their work

explores how people compare the value of monetary consumption across social space, neglecting any role that inequalities in wealth might play. Finally, Baron (2000) briefly discusses discounting of utility across both physical and social space (analogous to ρ in Equation 3.1) but does not pursue the concept in detail.

There are other dimensions that one can discount across that, to our knowledge, have not received prior consideration. For example, if we permit consideration of nonhuman values, then we can also consider discounting across the dimension of species. Discounting across species can be thought of as an extension of discounting across social space, if we extend the social realm to include nonhumans. Or, discounting across species can be thought of as an extension of discounting across familial or genetic distance, if we accept the basic claim that different species evolved from common ancestors. Either way, people certainly can compare the value of the utility of an individual in one species to that of another species. Some (such as philosopher Peter Singer – see Singer 1975) value all utility equally, regardless of species. Others do not (for a variety of perspectives, see Dol et al. 1999; Sunstein and Nussbaum 2005). This value comparison again parallels value comparison across time. Value comparison across species has large significance for issues such as the treatment of the billions and billions of livestock animals alive worldwide, the use of non-human animals in research, and the management of ecological systems.

We noted above that traditional definitions of time discounting define value in strictly anthropocentric terms. In other words, the definitions placed no intrinsic value on anything other than humans. This anthropocentrism is equivalent to discounting across species at an infinite rate. Clearly some people (e.g. Peter Singer) reject this discounting. In this chapter, we will remain open to the possibility of discounting across species such that at least some nonhumans hold intrinsic value.

There is at least one other important sense in which intrinsic value can be placed on nonhuman phenomena. This is in ecocentric ethics, in which ecosystems hold intrinsic value, regardless of whether the ecosystems contain any utility. Because utility is often defined as a property of sentience – in simplest terms, pleasure and pain – it is possible for an ecosystem to flourish without containing any utility. Such an ecosystem would simply not contain any sentient beings. Or, we can consider ecosystem flourishing independent of any utility it contains. Some philosophers have argued for such ecocentric ethics (Devall 2001; Holbrook 1997; Leopold 1949/1979); it also appears with some regularity in environmental policy, for example among wildlife managers (as reviewed by Niemi and McDonald 2004). Thus for reasons of both theoretical philosophy and practical policy, ecocentric ethics is worth considering.

It is less straightforward to theorize discounting with respect to ecocentric ethics. Whereas discounting across species permits the same comparisons of the value of utility as are found within anthropocentric ethics, for ecocentric ethics, such comparisons do not hold because ecocentric ethics does not place intrinsic value on utility. This result suggests one limitation of the discounting paradigm. However, as discussed below, there are other, much stronger limitations.

Though it has not received prior theoretical consideration, there is at least one sense in which we can discount within ecocentric ethics: we can compare the values of ecosystem properties across time and space. This sort of comparison directly parallels the discounting of utility across time and space. Just as we might place more (intrinsic) value on the utility of humans – or nonhumans – here and now, we might also place more value on the flourishing of ecosystems here and now. For example, in the context of biodiversity conservation, Hunter and Hutchinson (1994) discuss the phenomenon in which people appear to place greater intrinsic value on the conservation of spatially proximate species than on the conservation of spatially distant species. Though Hunter and Hutchinson do not describe it as such, this phenomenon is essentially discounting across space and time within ecocentric ethics. Such discounting could factor prominently in, among other things, certain ecosystem management decisions.

These various non-temporal dimensions and ethical foundations for discounting suggest the need for a broader conceptualization of discounting than the traditional anthropocentric time discounting. For the purposes of this chapter, we will adopt the broadest conceptualization that we can come up with. This conceptualization defines discounting as any comparison of value across any dimension, in which value is defined in any way. The standard anthropocentric time discounting is included here, simply by defining value in anthropocentric terms and defining the dimension in temporal terms. However, the other forms of discounting discussed here are also included, as are many others.

### 3.2.3 Limitations of Discounting

Even the broad definition of discounting used here – any value comparison across any dimension – has limitations. Above, we saw one limitation: that comparisons of utility cannot be made for ecocentric ethics. But this limitation exists only because ecocentric ethics does not place intrinsic value on utility. We can still discount across time and space (and perhaps other dimensions) within ecocentric ethics. There are other, much stronger limitations to discounting. The existence of these limitations has profound implications for the study and use of discounting descriptions. However, to our knowledge, these limitations have not been previously developed in the discounting literature. We introduce them here.

The stronger limitations to discounting derive from its concept of value. When we compare values, however defined, we are comparing consequences of possible actions we can take. For example, should we spend money on consumption now or save it for future consumption? The values of the consumption at different times are consequences of our actions to spend or save. Should we keep money to help ourselves, or should we donate it to charities to help people in other places around the world? Should we protect a forest near our city or should we protect a forest elsewhere in the world? The values of the help and the forests are again consequences of our actions. Likewise, as far as we are able to understand it, discounting inevitably operates within consequentialist ethics. In other words, questions of how we should discount require that some sort of consequentialist

ethics be in effect – otherwise, discounting would be irrelevant, since the phenomena being discounted would not be valued. But not all ethics are consequentialist.

The two most prominent competitors to consequentialism are deontology and virtue ethics. Indeed, consequentialism, deontology, and virtue ethics are commonly cited as being the three most important forms of ethics. For example, Ord (2009:abstract) writes "It is often said that there are three great traditions of normative ethics: consequentialism, deontology, and virtue ethics." There do exist other forms of ethics, such as discourse ethics (on which, in the context of environmental issues, see Krebs 1997; Mason 1997). These other forms of ethics are not covered in this dissertation.

Deontological ethics, in basic terms, bases right and wrong on the actions themselves, instead of the consequences (Alexander and Moore 2007). For example, a deontologist might argue that it is fundamentally wrong to torture an innocent person, or to let another species go extinct, regardless of the consequences. If torture is always wrong, then there is no sense in comparing the value of torture, or the value of the consequences of torture, across time, space, or any other dimension. The same holds for any other action that might be fundamentally right or wrong. Thus, where deontological ethics are in effect, discounting does not apply. By "in effect," we mean that these ethics are either actually correct or believed to be correct such that they serve as a guide for the actions or the lives of one or more (human or nonhuman) agents.

Virtue ethics, in basic terms, emphasizes who we are instead of what we do (Hursthouse 2007). For example, virtue ethics might argue that we should be someone who loves nature or respects others. Although these dispositions will often suggest specific actions, such as preserving ecosystems or being polite, the emphasis is on the disposition, not on the action. Given this, there is no sense in comparing values across some dimension. Under virtue ethics, one strives to be what one should be; here there are no values to be compared in any way that could qualify as discounting. Thus, as with deontological ethics, where virtue ethics are in effect, discounting does not apply.

There are other, more complex ways of describing the differences between consequentialism and deontology and between consequentialism and virtue ethics. Pettit (1991) classifies deontology as asking individuals to honor values and consequentialism as asking individuals to promote values. In rough terms, an individual honors values if she exhibits them within her own life and promotes values if she endeavors for these values to be realized in the world in general. McNaughton and Rawling (1992) classify deontology as being agent-relative and consequentialism as being agent-neutral. In rough terms, an ethical framework is agent-relative if it defines right or wrong or good or bad behavior in terms of the individual doing the behavior; it is agent-neutral if it evaluates behavior with no reference to the individual doing the behavior.

Regarding the distinction between consequentialism and virtue ethics, Driver (2001) discusses virtues as holding instrumental value within consequentialist ethical frameworks. This instrumental view of virtues amounts to (1) a rejection of virtue ethics and an endorsement of consequentialism, at least as these ethical theories are used in this

dissertation, and (2) an observation that virtues exist and can affect the values of the consequences of our actions. Similarly, Russell (2007) discusses virtues as holding either instrumental value within consequentialist ethics or intrinsic value. This view amounts to a hybrid consequentialist-virtue ethical framework, again at least as these terms are used in the dissertation.

These more complex distinctions between consequentialism, deontology, and virtue ethics raise some interesting questions about discounting. May certain discounting schemes be agent-relative? May some forms of discounting be promoted by certain virtues? But detailed discussion of these complex distinctions and the questions they raise is beyond the scope of the dissertation. Indeed, a simplistic understanding of these ethical theories is essential for compressing and expressing them as short survey questions to be given to people without prior expertise on these theories. Such simplicity is adequate for the core goal of this part of the dissertation, which is to bring deontology and virtue ethics into the conversation about descriptions of discounting, given that discounting does not fit within either deontology or virtue ethics.

One complication in the relationships between consequentialism, deontology, and virtue ethics that is worth discussing in some detail is the possibility of hybrid ethical frameworks that combine elements of two or three of these types of ethics. Such hybrids permit an ethical framework to include both discounting and non-consequentialist ethics. These hybrids are significant because they permit discounting to occur while non-consequentialist ethics are in effect. However, the hybrids do not permit discounting to occur within non-consequentialist ethics, because the discounting here is exclusively within the consequentialist portion of the ethical framework. Thus it remains the case that if one rejects any use of consequentialism, then one will also have no need for the concept of discounting.

The nature of hybrid ethical frameworks and their use of discounting can be illustrated by a few examples. One form of hybrid consequentialist-deontological framework would consider some actions to be fundamentally right or wrong regardless of the consequences while judging other actions in terms of their consequences. For example, a framework might consider it fundamentally wrong to let a non-human species go extinct but otherwise recommend acting so as to maximize the total value of human wellbeing, in which the value of the wellbeing is discounted across space and time. Another form of consequentialist-deontological hybrid would consider it fundamentally right or wrong to act in a way that achieves certain consequences. For example, a framework might maintain that some individuals (e.g. corporate executives) have a fiduciary duty to maximize the discounted value of expected shareholder profits, perhaps adjusted in some way for uncertainty. (On this use of fiduciary duty, see Kay 2011; Martin 2009.)

Meanwhile, one form a hybrid consequentialist-virtue ethics framework would consider it virtuous to work towards certain consequences. For example, a framework might consider it virtuous to be thrifty, seeking to maximize (or at least to increase) the discounted value of money saved via thrifty behaviors. (On this use of thrift as a virtue, see Steigerwald 2008.) Note that for the framework to be a consequentialist-virtue ethics

hybrid, the virtue of thriftiness must be intrinsically valued. In contrast, one might value thriftiness extrinsically. For example, one might place instrumental value on thriftiness, finding that thriftiness improves certain consequences. Indeed, some research has found that thriftiness often brings people more happiness (Chancellor and Lyubomirsky 2011) – a finding that runs in contrast to the common assumption that happiness increases as consumption increases. This assumption is central to, among other lines of research, integrated assessment models for climate change mitigation (Nordhaus 2007; Stern 2007).

The limitation of discounting to consequentialism is profound for several reasons. First, it implies that any descriptions of how people discount inevitably only cover one portion of human values. Research focused on describing how people discount fails to even identify whether these other values are held; it thus also fails to offer any description of the forms of these values. Second, it implies that policy using the descriptive approach to discounting imposes the consequentialist structure of discounting on its descriptions. This is a powerful result, because the descriptive approach often strives to avoid imposing personal views on the analysis. By choosing to describe discounting instead of describing human values more broadly, analysts (or whoever is requesting that the descriptive approach to discounting be used) are imposing the view that only consequentialist ethics matter. In practice, of course, the imposition is even more severe, because standard implementations of the descriptive approach to discounting only consider anthropocentric ethics and value comparisons across the temporal dimension. It is possible that this imposition is unintentional – that is, that the analysts (or others) do not realize that other values are being excluded and would not wish to make such an exclusion. In this case, the exclusion signifies a strong analytical mistake. Given the potential importance of both multidimensional discounting and the limitations thereof, it is worth considering the ways in which human values are described via multidimensional discounting or non-consequentialist ethics.

## 3.3. Descriptive Discounting: Prior Results

Descriptive discounting research is scientific research that strives to describe how individuals and groups discount. Almost all of the research aims to describe how humans discount, although there is a line of descriptive research on how nonhumans discount (cf. Evans and Beran 2007; Jimura et al. 2009; Richards et al. 1997; Stephens et al. 2002). The research on nonhumans is insightful and potentially quite important – should nonhumans be included in the descriptions of how society discounts used in the descriptive approach to discounting? (See Baum 2009 for discussion.) However, here we focus exclusively on how humans discount.

As with theoretical research on discounting, descriptive research on how humans discount has focused mainly on discounting across time (for a review, see Frederick et al. 2002). This research generally involves either survey methods or observations of financial markets. There are even descriptions using brain imaging, indicating which parts of the brain might be involved in time discounting (Hariri et al. 2006; McClure et al. 2004). Much has been learned from this research. One key insight is that many time

discount rates can be observed, depending on such factors as the wording of survey questions or the choice of financial instrument to use for interest rates (Baum 2009; Frederick et al. 2002).  Thus, it appears that there is no one single rate that describes how humans discount across time or one single method that can be used to obtain such a rate.

Descriptive research on time discounting can be divided into intra- and inter-individual studies.  Intra-individual studies explore how people compare the value of a personal gain or loss (i.e. a gain or loss to themselves) now to a personal gain or loss that comes at a later time.  Intra-individual time discounting thus corresponds with cognitive phenomena such as impatience and impulsivity, as well as the idea that individuals strive to maximize their own discounted utility.  In contrast, inter-individual studies explore how people compare the value of gains and losses to other people at different times.  The other people could be specific individuals or members of society at large.  Although most of the descriptive time discounting research has been on intra-individual time discounting (see Frederick et al. 2002 for a review), several studies have explored inter-individual time discounting.  Of particular relevance to the new empirical work presented below are the studies of time discounting of lives (e.g. Cropper et al. 1991, 1994; Horowitz and Carson 1990; Johannesson and Johansson 1996; Poulos and Whittington 2000; see Asenso-Boadi et al. 2008 for a review).  These studies explore how individuals compare the value of the loss of one or more lives (not the individual's own life) at different times, finding generally that individuals tend to prefer saving lives earlier to saving lives later.

Although these studies all consider that lives might hold different value at different times, none of them consider that lives hold different value at different places.  To our knowledge there is no survey research on the question of spatial variation in the value of lives.  The only empirical work on spatial variation in the value of lives that we are aware of involves willingness to pay studies which find that poorer people (or, people in poorer regions) tend to be willing to pay less to avoid risks to their lives than wealthier people (or, people in wealthier regions).  This finding is highly controversial because it suggests that we should not try as hard to save the lives of the poor.  For a heated debate on this issue in the context of climate change policy, see Azar (1999).

Much of the existing descriptive time discounting research fails to isolate distinct reasons for discounting.  For example, someone might value her own future consumption less than her present consumption because she values her future utility less than her present utility (as in $\rho$ in Equation 3.1).  Or, she could do so because she expects to be wealthier in the future, and places less value on the consumption of the wealthy (as in the term $\eta*g$ in Equation 3.1).  When descriptive research only compares consumption across time without identifying *why* consumption might be valued differently across time, this research fails to learn why people might be discounting.  Without understanding why people discount in one circumstance, we cannot readily generalize what we have learned to other circumstances.  For example, how would a person discount future consumption if she did not expect to be any wealthier in the future?  This is a major shortcoming of many descriptive time discounting studies, including studies using survey questions or observations of investment decisions.  One implication of this is that Ramsey equation-

based implementations of the descriptive approach are often ambiguous on how to define $\rho$ and $\eta$ (cf. Nordhaus 2007).

The same shortcoming can be found in the main line of descriptive research exploring discounting across other dimensions. This is the social discounting studies of Jones and Rachlin (Jones and Rachlin 2006, 2009; Rachlin 2006; Rachlin and Jones 2008). In a series of studies, they explored how people discount across social distance. These studies asked participants to imagine a list of 100 acquaintances, ordered from their closest friend or relative (closer social distance) to someone who they had barely met (further social distance). Participants then made tradeoffs between money for themselves and money for people at several places on the list. As is to be expected, the results showed that participants were more generous towards people closer in social distance. Interestingly, the decay across social distance resembles the hyperbolic function that often accurately describes time discounting. However, the studies did not explore why people discount monetary consumption across social space.

Descriptive research on discounting across dimensions other than time or social space is very sparse. Hannon (1994) presents some data suggesting that people discount across space in the sense that they prefer being near certain phenomena and far from other phenomena. However, these data do not follow standard descriptive discounting approaches and thus are difficult to compare to other discounting research. Baum and Easterling (2010) present some data indicative of the spatial discounting of welfare (analogous to $\rho$ in Equation 3.1) and spatial discounting due to consumption inequality (analogous to $\eta*g$ in Equation 3.1). However, both the Hannon (1994) and Baum and Easterling (2010) data involve specific case studies. We are unaware of any more general descriptive studies of spatial discounting analogous to the survey research found in temporal and social discounting.

Gattig (2002, chapter 7) presents assorted evidence that people discount similarly across time, physical space, and social space. This study compares monetary gains and losses across time on scales from four to 48 weeks. Across physical space, the study compares the gains and losses of having a shop built or removed within distances of two to 32 streets away. Across social space, the study compares monetary gains and losses to fictional people with attributes varying across five dimensions: age, social-economic status, hobbies, nationality, and political orientation. The assumption here is that similarities in these dimensions correspond with proximity in social space. Unfortunately, the scenario of the Gattig physical space question set is qualitatively different (a shop instead of money), rendering comparison difficult with the time and social space question sets. Also, by using monetary gains and losses for time and social space, the study fails to control for multiple possible reasons why one might discount money (e.g. consumption inequality, welfare discounting). However, the Gattig study remains informative, and the similarities it finds in discounting across dimensions resemble the across-dimension similarities found in the new survey we present below.

We are also not aware of any research explicitly exploring how humans discount across species. There is, however, one study that effectively studies this topic (Johansson-

Stenman 2006).  This study presents a survey exploring the extent to which Swedish adults place intrinsic value on nonhuman animal welfare, finding substantial intrinsic valuation of nonhuman animal welfare.  This survey has strong parallels to part of the survey presented below.  Other than this one study, the only data we have are the vigorous debates on what is essentially species discounting among philosophers and others (Dol et al. 1999; Singer 1975; Sunstein and Nussbaum 2005).  However, the debaters are highly trained and highly motivated scholars, activists, and others and thus unlikely to be representative of any broader human population.  We are thus still in rudimentary stages of describing how the broader human population discounts across species.

Research that explores the limitations of discounting is similarly sparse.  The one line of research in this area that we are aware of is that of Scholten and Read (2010).  This research finds that traditional conceptualizations of time discounting cannot handle how people sometimes make intertemporal tradeoffs.  Specifically, they find that decisions between smaller-sooner and larger-later options can be affected by the set of options.  The decisions appear illogical and even intransitive, suggesting limitations to the descriptive accuracy of traditional time discounting paradigms.  This intriguing result is similar in spirit but conceptually orthogonal to the discounting limitations explored in this chapter.

To our knowledge, there exist no dedicated studies on discounting limitations as pursued here.  There has been one prior study on the related question of the limitations of consequentialism (Johansson-Stenman 2006).  In addition to studying nonhuman animal welfare, Johansson-Stenman also explored whether people supported consequentialist ethics.  This study found little support for non-consequentialist ethics among the general population of Swedish adults.  However, the study's survey item on consequentialism did not assess the extent to which people supported consequentialism and instead assumed that people either supported consequentialism or supported some other ethics.  Furthermore, the survey question's response option for deontological ethics was "The extent to which the action infringes upon someone else's rights" (p.26).  This response option could potentially fall within consequentialism, if the infringement of rights is treated as a consequence whose value can be weighed against other consequences (on this, see Sen 2000:936-937).  Thus this study, which is only indirectly related to discounting, fails to provide a satisfying description of the extent to which people support consequentialism.

However, there are significant lines of research exploring the psychology of non-consequentialist ethics.  One line is on the importance of deontological ethics.  In the psychology literature, deontological ethics is often expressed in terms of protected values (values that people wish to protect at any cost; see Baron and Spranca 1997), sacred values (values that people consider sacred and thus inappropriate for tradeoffs; see Tetlock 2003), and omission bias (greater concern for outcomes caused by action than for outcomes caused by the omission of action; see Ritov and Baron 1999).  Deontological ethics can factor significantly in major societal issues.  For example, Ginges et al. (2007) present evidence suggesting that sacred values play important roles in the motivations

and behaviors of key players in the ongoing Israel-Palestine conflict. Similarly, Dehghani et al. (2009) find sacred values involved in Iran's nuclear program. Of particular concern is the finding that attempts to treat sacred values in consequentialist terms often provokes hostile responses. This finding highlights a major potential pitfall in using descriptive discounting as a basis for policy analysis and decision making.

Another important line of research on the psychology of non-consequentialist ethics focuses on virtue ethics. In the psychology literature, virtue ethics is often studied to assess the extent to which people have situation-independent virtues or character traits. For example, Milgram's (1963) classic study on electric shocks shows that many people will inflict considerable amounts of pain on others when in the context of a research study even though people would not otherwise do so. Studies such as this find that people commonly do not display much in the way of situation-independent virtues. However, Arjoon (2008), Kamtekar (2004) and others note that this finding does not disprove the existence of virtues but instead depends on a narrow reading of virtue ethics theory and also suggests that many people are simply not virtuous. Perhaps these people have no consistent or coherent ethics at all. Or perhaps they support other ethics, such as consequentialist or deontological ethics. Another issue is that these studies focus on the connection between virtue and behavior (see also Richardson 2003). A problem here is that virtue ultimately concerns *who we are*, not *what we do*. In our view, behavioral studies are not well suited to examining the extent to which people's ethics can be described in terms of virtues as opposed to other forms of ethics, such as the consequentialist ethics that can be expressed though discounting.

In summary, although there have been many studies describing time discounting, there have been relatively few describing discounting across multiple dimensions or testing the limits of how well individuals' ethics can be described via discounting. Furthermore, there have not been any systematic attempts to assess both how individuals discount across a broad range of dimensions and the limitations of discounting in one study with a consistent population and methodology. Such a study is presented in the following section.

## 3.4. A New Survey

How humans discount across multiple dimensions and how well humans' ethics can be described via discounting are both highly complex questions that cannot be fully resolved in any one study. Just as there are many nuances and subtleties observed in how humans discount across time (Frederick et al. 2002), it is to be expected that similar complexities are to be observed across other dimensions and in the limitations of discounting. The existing inquiries into time discounting have been quite extensive but still paint an incomplete picture. Existing inquiries into multidimensional discounting and its limitations are quite scarce; we are thus still painting the most superficial features of these pictures. In other words, there is a strong need for insights into the basic contours of multidimensional discounting and its limitations.

The present survey aims to provide fundamental descriptions of both how humans discount across multiple dimensions and how well humans' ethics can be described via discounting. As explained below, the survey provides a description of only a small portion of humanity. Our aim is to paint with broad strokes: we explore discounting across many dimensions and also many ways in which discounting can be limited. We are not capturing significant detail on any dimension or limitation. Such detail would require a much lengthier study than the present work permits and must be saved for future work. Instead, we aim to produce descriptions of multidimensional discounting and its limitations in general terms and in one clear and consistent fashion.

Because multidimensional discounting and its limitations are such uncharted territory, our survey also includes a more established set of items on environmental values. The environmental values items, adapted from Schwartz (1992, 1994) and Stern et al. (1998), are designed to capture certain features of human values – specifically whether a given human has a general value orientation toward relative self-enhancement (including power and achievement) or relative self-transcendence (including universalism and altruism). Comparing responses to our discounting items with responses to these values items helps us understand how multidimensional discounting and its limitations relates to more familiar values metrics. Although the items are relevant to human values broadly considered, they have some emphasis on environmental matters. The survey was conducted in association with the Penn State Focus the Nation event. Focus the Nation was a collection of events around the United States taking place on our near 31 January 2008 with the aim of raising awareness and understanding of climate change. The survey's environmental emphasis derives from the orientation of the Focus the Nation event and also from the prominence of discounting in environmental issues such as climate change (Arrow et al. 1996; Dasgupta 2008; Nordhaus 2007; Stern 2008).

### 3.4.1 Participants

We use a convenience sample of participants recruited via the Penn State Focus the Nation event. Recruitment consisted of an e-mail solicitation, and survey responses were collected from January 25 to January 30, 2008. Our sample population consists of 184 people, including 37 freshmen, 44 sophomores, 35 juniors, 27 seniors, 14 graduate students, and 14 who were not a college student. Most of our survey participants were connected to the Penn State event through Penn State classes or student groups. Some participants were connected in similar ways to Focus the Nation events at other institutions including the University of Pittsburgh and the University of Wisconsin–Madison. Participants were compensated with an entry into a prize raffle.

Participant ages ranged from 18 to 78; the median age was 20. Females made up 58 percent of the sample. Eighty-four percent of participants were white, 5 percent Asian, 3 percent Hispanic, and 3 percent Black or African American (5 percent reported "Other" or did not specify). In keeping with the survey's association with Focus the Nation, 45 percent of participants indicated that they were planning on attending the event. Forty percent indicated that they had previously been involved with environmental extracurricular activities.

### 3.4.2 Procedure

Data collection for this study was conducted via an online survey platform. Participants first completed a series of demographic items, followed by a series of environmental values items, followed by a series of discounting items, followed by additional survey items.

*Environmental values.* Items were adapted from a set originally introduced by Stern et al. (1998:995; see also Dietz et al. 2005:351) based on the Schwartz model of human values (Schwartz 1992, 1994). Fourteen items were drawn from the original set of 56 value items. These items are representative of the four broad value categories identified by Schwartz, which can be drawn on a two-dimensional space with the value categories of *openness to change* and *conservatism* forming one axis and *self-transcendence* and *self-enhancement* forming a second axis. As in Stern et al. (1998), we utilize a six-item scale within the self-transcendence value category to distinguish between *biospheric* (items 1-3) and *altruistic* (items 4-6) values, which have been shown to have significant and distinct relationships with pro-environmental attitudes. Three-item scales measured conservatism (items 7-9) and self-enhancement (items 10-12) values, and a two-item scale measured openness to change (items 13-14) values. The biospheric value cluster has been shown to reliably predict environmental beliefs and intentions across multiple cultures and modes of administration (Stern et al. 1998; Schultz et al. 2005; de Groot and Steg 2007). The full set of environmental values items appear in Table 3.1.

*Multidimensional discounting items.* Just as there are many reasons to discount across various dimensions, and also many ways in which discounting can be limited, there are many questions one could ask on these topics. As discussed above, many popular discounting survey questions fail to isolate specific reasons people have for discounting. Our items are designed to avoid this problem, i.e. to focus specifically on one reason for discounting: variations across a given dimension in how people value utility, which is related to $\rho$ in Equation 3.1. To simplify the question wordings for the non-expert survey population, we have replaced "utility" with "lives" in most questions, under the assumption that all human lives hold approximately the same amount of utility. In one question comparing the utility of humans to the utility of non-humans, we have used replaced "utility" with the comparable but more familiar term "wellbeing"; the term "lives" is inappropriate here because the lives of members of different species hold significantly different amounts of utility. By focusing on how we value utility, the discounting survey items identify an ethical aspect of how people discount, as opposed to empirical aspects such as people's estimations for wealth inequality (which is related to the term $\eta*g$ in Equation 3.1). By focusing on ethics, survey insights hold (or are more likely to hold) under any social or environmental circumstances, such as variations in wealth inequality, social condition, or ecological flourishing. Furthermore, because the core limitations of discounting are also grounded in ethics, focusing on ethical principles permits more direct comparisons between questions about multidimensional discounting and questions about the limitations of discounting.

| Item | | Centered Mean Score | SD |
|---|---|---|---|
| | **Self-transcendence values** | 0.34 | 1.19 |
| | *Biospheric values* | 0.26 | 1.71 |
| 1 | Protecting the environment, preserving nature. | | |
| 2 | Unity with nature, fitting into nature. | | |
| 3 | Respecting the earth, harmony with other species. | | |
| | *Altruistic values* | .42 | 1.28 |
| 4 | A world at peace, free of war and conflict. | | |
| 5 | Social justice, correcting injustice, care for the weak. | | |
| 6 | Equality, equal justice for all. | | |
| | **Conservatism values** | 0.94 | 1.45 |
| 7 | Honoring parents and elders, showing respect. | | |
| 8 | Family, security, safety for loved ones. | | |
| 9 | Self-discipline, self-restraint, resistance to temptation. | | |
| | **Self-enhancement values** | -1.53 | 1.54 |
| 10 | Authority, the right to lead or command. | | |
| 11 | Influential, having an impact on people and events. | | |
| 12 | Wealth, material possessions, money. | | |
| | **Openness to change values** | 0.26 | 1.63 |
| 13 | A varied life, filled with challenge, novelty, and change. | | |
| 14 | An exciting life, stimulating experiences. | | |

Table 3.1: Environmental values scale items.

Seven Likert-type items asked participants to rate their level of agreement with discounting principles on a five-point scale (strongly disagree; disagree; somewhat agree/somewhat disagree; agree; strongly agree) across five categories: intertemporal discounting (one item), spatial/geographic discounting (one item), social discounting (two items), geopolitical discounting (two items), and interspecies discounting (one item; see Table 3.2). These categories capture the various dimensions that we and other authors have suggested humans may discount across. Geopolitical discounting, which refers to the tendency to discount across national identity, may be considered a subcategory of social discounting, which refers to the tendency for people discount across social distance.

*Discounting limitations items*. We have also developed and included a simple set of items on the limitations of discounting as a paradigm for describing human values. These items focus on the extent to which humans support deontological (one item) and virtue ethics frameworks (one item; see Table 3.2) as opposed to the consequentialist frameworks of discounting. The discounting limitations items use a similar Likert-type principle agreement approach as the multidimensional discounting items with the same five-point scale (strongly disagree; disagree; somewhat agree/somewhat disagree; agree; strongly agree).

For both lines of questioning – multidimensional discounting and discounting limitations – we ask participants how strongly they agree with specific ethical principles, i.e. with fundamental assumptions underlying specific ethical views. This approach, which we call the *principle agreement approach*, directly elicits responses on specific reasons for

discounting and holding non-discounting views.  It also enables rapid assessment of many discounting dimensions and non-discounting views, a feature which is quite important for survey environments in which participant time is at a premium.  It is thus well-suited for survey research involving large sample sizes and for surveys exploring broad ranges of discounting views.

| Item | | Dimension | Mean | SD |
|---|---|---|---|---|
| | **Multidimensional discounting** | *Dimension* | | |
| 1 | The further into the future someone's life occurs, the less her/his life is worth. | Time | 1.48 | 0.75 |
| 2 | The further away around the world someone lives, the less her/his life is worth. | Space | 1 | 0.88 |
| 3 | The lives of the members of my family are worth as much as my own life.* | | 4.48 | 0.75 |
| 4 | The lives of my friends are worth as much as my own life.* | Social | 4.29 | 0.8 |
| 5 | The lives of other citizens of my country are worth as much as my own life.* | | 4 | 0.94 |
| 6 | The lives of citizens of other countries are worth as much as my own life.* | Geopolitical | 3.94 | 0.99 |
| 7 | The wellbeing of other animals is worth as much as the wellbeing of humans.* | Inter-species | 3.51 | 1.16 |
| | **Limits of discounting** | *Ethical framework* | | |
| 8 | Whether an action is right or wrong depends on what the action itself is, not the action's outcomes. | Deontological | 3.15 | 1.05 |
| 9 | What makes a person good or bad is the quality of a person's character, regardless of what his/her actions are. | Virtue | 2.55 | 0.98 |

*Question:* How strongly do you agree or disagree with the following statements?
(1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree
*Reverse coded

Table 3.2: Survey items on the limits of discounting and multidimensional discounting.

One key limitation of the principle agreement approach as we have implemented it is that it does not yield discount rates in any traditional sense.  It could be modified for this purpose, using multiple items per dimension, along the lines of the discounting items used in Chesson et al. (2006).  However, some caution is warranted here.  Discount rates are rates in which values decline across some dimension.  This dimension thus must have a cardinal (i.e. interval) metric defined for it.  Time has such a metric, but for other dimensions the situation is more complicated.  Furthermore, in order for there to be a single discount rate parameter, value must decline monotonically.  Such a decline is commonly found across time and has been found across social space (Jones and Rachlin 2006), but may not exist across other dimensions.  Indeed, drawing on the case of the Commonwealth of Nations, Baum and Easterling (2010) find that monotonic declines often do not exist for the discounting of intrinsic value across geographic space.  For these reasons, researchers should be cautious when attempting to detect rates of

discounting across dimensions other than time. Likewise, for our present purposes, our principle agreement approach is adequate and appropriate.

## 3.5. Results

This section presents several quantitative analyses that provide 1) a description of discounting across multiple dimensions, 2) an exploration of the relationship between questions on the limits of discounting and multidimensional discounting, and 3) a description of the relationship between empirically derived human value categories and multidimensional discounting.

### 3.5.1 Multidimensional Discounting

Although the principle agreement approach to measuring individual discounting used in this study is unable to describe discount rates across various dimensions, it does provide a general picture of the magnitude and direction of discounting for each dimension.

A comparison of responses across the five discounting categories indicates that people do indeed discount across a broad range of dimensions. If people did not discount across a given dimension, then they would answer the discounting items so as to indicate that they place the same intrinsic value on a given phenomenon across all points in that dimension. For example, they would strongly agree with the principle that "the life of a citizen of another country is worth the same as my own life." Some people did respond in this fashion, indicating that they did not discount across some or all dimensions. However, many people did not respond in this fashion, indicating that they do discount across the several dimensions considered in our study. This result offers initial support for the principle that multidimensional discounting is a valid empirical concept.

Our results further suggest that people discount similarly across multiple dimensions in the sense that they give similar responses to survey items for discounting across multiple dimensions. We tested the null hypothesis that there is no relationship between each individual's responses to the discounting items by calculating Spearman rank correlation coefficients between each discounting item. The Spearman coefficient is a nonparametric statistic used to test for the presence of a monotonic relationship between two variables. It converts values into ranks, and is thus frequently used for ordinal discrete data, such as survey responses. Indeed, this procedure assumes ordinal level data; our data are ordinal. The Spearman rank correlation coefficients between each discounting item were significant at either the $p < .01$ or $p < .001$ levels (Table 3.3). The weakest relationships, though still significant, were between the inter-species discounting item (7) and the rest of the items. The strongest correlations were within the cluster of social and geopolitical discounting items (3–6). Significance was calculated using the equation

$$t = S\sqrt{\frac{n-2}{1-S^2}}$$

(3.2)

and comparing to a table of Student's t-distribution values.  In this equation, n is the number of degrees of freedom, i.e. the number of pairs of observations, and S is the Spearman coefficient.[28]  We have 157 survey participants, so n=156.

| Item | 1 | 2 | 3 | 4 | 5 | 6 |
|------|-----|-----|-----|-----|-----|-----|
| 1 | | | | | | |
| 2 | .729# | | | | | |
| 3 | -.361# | -.388# | | | | |
| 4 | -.410# | -.374# | .667# | | | |
| 5 | -.403# | -.364# | .561# | .771# | | |
| 6 | -.433# | -.403# | .546# | .712# | .934# | |
| 7 | -.210* | -.218* | .263# | .302# | .384# | .429# |

Table 3.3: Spearman rank correlations between multidimensional discounting items. Item numbers correspond to those shown in Table 3.2.  Asterisks (*) denote p < .01; number signs (#) denote p < .001.

The strong inter-item correlations between each of the discounting items indicate that the various discounting items across multiple dimensions have a high internal consistency (Cronbach's alpha = .835), suggesting that the items about discounting may be describing the same underlying discounting construct. An exploratory principal components analysis supported this conclusion, with the first component explaining over 55 percent of the variance in the discounting items. Given these findings, we aggregated the items into a single scale to provide a method of efficiently measuring each individual's tendency to discount across multiple dimensions.  The multidimensional discounting scale is an aggregate measurement of agreement with discounting principles across the dimensions of time (item 1, space (item 2), social distance (mean of items 3 and 4), geopolitical distance (mean of items 5 and 6) and inter-species distance (item 7).  (Responses for items 3–7 were inverted to account for reverse wording.)  Values were rescaled to the range of 0 – 1 (Mean = .25, SD = .18, Min = .00, Max = .72).  Higher values represent greater agreement with discounting principles across multiple dimensions; lower values represent less agreement with discounting principles.  We use this scale in the following analyses comparing discounting to other constructs.  The distribution of the multidimensional discounting scale did not differ significantly from the normal distribution according to a Kolmogorov-Smirnov test ($p > .1$).

### 3.5.2 Discounting Limitations

Our simple set of two discounting limitations items uses the principle agreement approach to test whether people support principles that cannot be described via discounting, specifically deontological and virtue ethics principles.  If people's values could be described fully via discounting, then they would answer "strongly disagree" both to "Whether an action is right or wrong depends on what the action itself is, not the action's outcomes" and to "What makes a person good or bad is the quality of a person's character, regardless of what his/her actions are."  Some people did answer "strongly

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[28] Traditionally, r or ρ is used for the Spearman coefficient, but these two variables are already in use in this chapter in the Ramsey equation (3.1).

disagree" here. However, many did not. This gives us strong evidence that discounting is limited in the sense that it cannot fully describe human values.

Agreement was considerably stronger for the deontological ethics framework item than for virtue ethics. Seventy-two participants agreed or strongly agreed with the deontological ethics principle, whereas only 35 participants agreed or strongly agreed with the virtue ethics framework. There is some evidence that agreement with these frameworks may not be mutually exclusive: 18 participants agreed or strongly agreed with both the deontological ethics and virtue ethics principles. This result suggests that many people hold hybrid deontological-virtue ethics frameworks, perhaps with some support for consequentialist ethics, or for other ethical frameworks (such as discourse ethics) not covered in this study.

Finally, agreement with the two non-consequentialist frameworks did not have any statistically significant correlation with discounting. There was no statistically significant correlation between the multidimensional discounting scale and the deontological ethics item (Spearman $\rho =$ .00, *ns*) or the multidimensional discounting scale and the virtue ethics item (Spearman $\rho =$ .04, *ns*). This result suggests that how people discount is independent of how well their values can be described via discounting.

### 3.5.3 Discounting And Human Values

The human values items are generally understood to form a broad two-dimensional structure as developed by Schwartz (1992, 1994). One dimension is formed by the self-transcendence and self-enhancement value categories. The other dimension is formed by the conservatism and openness to change value categories. Nine of the 14 items in the values scale used in this study were part of the self-transcendence versus self-enhancement dimension. This dimension has previously been found to relate most strongly with environmental values and attitudes (de Groot and Steg 2007; Schultz et al. 2005; Stern et al. 1998).

The self-transcendence/self-enhancement dimension exhibited a relationship with the aggregated multidimensional discounting scale. The self-transcendence value category had a statistically significant negative correlation with multidimensional discounting (Pearson r = -.39, *p* < .001). The self-enhancement value category had a statistically significant positive correlation with multidimensional discounting (Pearson r = .48, *p* < .001). Within the self-transcendence value category, the multidimensional discounting scale had a negative relationship with both biospheric values (Pearson r = -.33, *p* < .001) and altruistic values (Pearson r = -.29, *p* < .001). These results imply that individuals who tend to agree in principle with discounting across multiple dimensions tend to put more value on self-enhancement and less value on self-transcendence.

The remaining value dimension, conservatism versus openness to change, exhibited only a weak relationship with multidimensional discounting. Because of the small number of survey items addressing this dimension, results reported are not as robust as those reported for the first dimension. However, there was a weak but significant positive relationship between multidimensional discounting and the conservatism value category

(Pearson r = .22, *p* < .01).  There was no relationship between discounting and the openness to change value category (Pearson r = -.09, *ns*).

These results suggest that the construct measured by the multidimensional discounting items may be a component of the self-transcendence versus self-enhancement dimension of human values.  Those who have a greater tendency to discount across multiple dimensions also placed less value on altruism, universalism, and the environment, while placing greater value on power, conformity, and security.

## 3.6. Discussion

The results of the new survey presented above, combined with the results of the prior work on discounting, hold major implications for discounting as both a scientific and a policy construct.

### 3.6.1 Broadening Human Values Descriptions

First and foremost, we conclude that the standard anthropocentric time discounting paradigm is fundamentally inadequate as a descriptor of human values.  This is because humans discount across non-temporal dimensions and hold non-anthropocentric and non-consequentialist values.  Furthermore, these portions of human values that are not anthropocentric time discounting cover a significant portion of the totality of human values.  Prior work detected assorted evidence of these phenomena; our survey observes the phenomena with a consistent sample and methodology.  It thus follows that the extensive existing descriptive research on anthropocentric time discounting only describes one portion of human values.

The inadequacy of anthropocentric time discounting suggests the need for strong revisions to the descriptive approach to discounting as used in policy analysis.  As explained above (see also Baum 2009), the descriptive approach is often justified by using a description of how society discounts instead of analysts or others imposing their own views on society.  However, by restricting descriptions to anthropocentric time discounting, analysts (or whoever makes the restriction) impose the view that only anthropocentric time discounting matters.  This imposition, if consciously made, constitutes a strong value judgment that would need strong justification.  Such justification is, to our knowledge, absent from the literature.  Alternatively, if this imposition is not consciously made, then it constitutes a major analytical mistake (as suggested by Schelling 2000) in that analysts would realize that they should include descriptions of other portions of human values if only they were aware of these other portions.

Expanding the descriptions to cover more – ideally all – of human values would radically change the descriptive approach to policy analysis.  Including non-anthropocentric values would alter (and in most cases increase) the importance of such phenomena as nonhuman animal welfare and ecosystem flourishing.  Including discounting across dimensions such as geographic, social, or geopolitical distance forces analysts to consider issues of intra-

temporal justice and also introduces issues of conflict and cooperation into the analysis (Baum and Easterling 2010; Hannon 1987). Including deontological and virtue ethics could require broad paradigm shifts in the types of policies recommended. These would be policies that forbid or require certain types of actions, or that nurture certain types of virtues. All of this is well beyond the scope of what is found from policies based on the traditional descriptive approach to discounting.

### 3.6.2 Discounting vs. Consequentialism

Among the more interesting results of the new survey presented in this chapter is the finding that how people discount does not correlate with how strongly they support non-consequentialist ethical principles (in our case, deontology and virtue ethics). Given that discounting inevitably operates within consequentialist ethics, how strongly people support consequentialism vs. other ethics corresponds with how well their ethics can be described in terms of discounting. Thus, our study finds that how people discount does not correlate with how much of their values can be described via discounting. This result makes sense in terms of the underlying ethical theory. In principle, how much of a consequentialist someone is should be independent of what type of consequentialist she is for that portion of her that is consequentialist. That is, the form of one's consequentialist views should be independent of the strength of these views: there is *form-strength independence*.

To see this form-strength independence, imagine that someone supports a hybrid ethical framework containing some consequentialist elements and some deontological elements. (The logic here applies equally well to other non-consequentialist ethics besides deontology, such as virtue ethics.) This individual will have some strength of support for consequentialism relative to deontology. She might be mainly consequentialist, for example by wishing to maximize total utility except in isolated cases that involve the torture of innocent people. Or, she might be mainly deontological, for example by wishing to follow strict deontological rules except in isolated cases that involve the prevention of global catastrophes.

Regardless of whether this individual is mainly consequentialist or mainly deontological, she will have some consequentialist views and some deontological views. The form of these views need not depend on whether she is mainly consequentialist or mainly deontological. For example, she could prefer utilitarianism to other forms of consequentialism just as easily as if her views are mainly consequentialist or if her views are mainly deontological. This is the essence of the form-strength independence described here.

### 3.6.3 Discounting vs. Human Values

To our knowledge the study presented here is the first to compare descriptions of discounting to the Schwartz (1992, 1994) human values scale. Our initial inquiry finds that how much people discount correlates with how much people favor self-enhancement values in the Schwartz values classification scheme. As with the finding on discounting

vs. consequentialism, this makes philosophical sense: both discounting and self-enhancement represent some form of selfishness. Similarly, non-discounting and self-transcendence represent some form of altruism. That is, the more we discount, the more we favor ourselves and those closer to us in space, time, or any other metric of closeness. Such favoritism is selfish in the sense that it favors one's self. Likewise, the less we discount, the more we value everyone equally, regardless of who they are or how close they are to us. Such egalitarianism is generally altruistic (though pure altruism could involve placing less or even no value on one's self, which is inegalitarian). Given the conceptual parallel between discounting/non-discounting and selfishness/altruism, we are not surprised to see this particular correlation in the data presented in this chapter.

While the correlation found may not be conceptually surprising, it is nonetheless significant for several reasons. First, it provides us with some confidence that the principle agreement approach to descriptive discounting is giving us meaningful results. This is an important result because it suggests that the approach can be successfully used more broadly. The approach is very concise and well-suited to measuring discounting across a wide range of dimensions, making it a powerful tool for many survey settings. Although it is possible that further research could find fundamental defects in the principle agreement approach, the correlation between principle-agreement discounting and the Schwartz values suggests that the principle agreement approach is at least moderately capable of measuring discounting.

### 3.6.4 Caveats and Future Work

Despite the considerable significance of the work presented here, it does have some important limitations. Some limitations are due to our survey methodology. First, our new survey featured only a limited sample consisting predominantly of university undergraduates. We cannot readily generalize our findings to broader populations, including to both human and nonhuman populations. (As noted above, there does exist empirical research on how nonhuman animals discount.) Although our proof-of-principle result – that anthropocentric time discounting is inadequate as a descriptor of human values – still holds, we cannot readily estimate how strongly it holds across broader populations. Second, our survey used only one survey technique, the principle agreement approach. Given the preponderance of framing effects found throughout the descriptive time discounting literature, we expect to observe similar effects for multidimensional discounting and its limitations. Thus, the descriptions of multidimensional discounting and its limitations presented here are necessarily tentative and limited though nonetheless powerful. Future work would be required to establish precisely what sample and framing effects might exist.

Another limitation of the present study is in its critique of the descriptive approach to discounting in policy analysis. The essence of this critique is that the approach as it is commonly implemented (using market interest rates) makes analytical mistakes by only describing anthropocentric time discounting.[29] This critique calls into question the

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[29] The critique also applies to the small number of studies that use description-based arguments for the selection of spatial welfare weights, such as the discussion of Negishi weights found in Nordhaus and Yang

justification of the approach that is based on a desire to avoid imposing analysts' views on the analysis. However, the approach has other justifications, in particular those based on the efficiency of market investments. The critique presented here says nothing about those other justifications.

A further limitation of the present study is in its treatment of deontology and virtue ethics. As noted in Section 3.2.3, there exist more complex definitions of deontology and virtue ethics than those used in this study. By using simplistic treatments of deontology and virtue ethics, the study was able to present these ethical views within a concise survey given to survey participants who are not expert in ethics. However, the same simplicity may also limit the extent to which the survey accurately assesses participants' support for deontology and virtue ethics. While this study succeeds in bringing deontology and virtue ethics into the conversation about descriptive discounting, it does not provide the final word. Further research using more complex treatments of deontology and virtue ethics would further improve our understanding of the role of these ethical views within human moral psychology, including as moral psychology is relevant to discounting.

One additional promising direction for future research is in the relationship between temporal discounting and discounting across other dimensions. This study found strong correlation between discounting across different dimensions. This result suggests a common cognitive process underlying discounting across different dimensions. The existence of such a process could be tested, for example, by comparing the multidimensional discounting scale developed here with specific rates of temporal discounting. Another approach to exploring cognitive processes could involve brain imaging techniques to study what parts of the brain are active in time vs. other discounting. This would help establish how the magnitude of agreement to discounting principles along various dimensions may be related to discount rates.

## 3.7. Conclusion

In this chapter we have systematically explored the concepts of multidimensional discounting and its limitations, both as descriptors of human values. On these closely related topics, we have developed theory, reviewed prior work, and presented a new survey. Insights from this exercise all point in the same direction: despite its broad use in science and policy, the traditional anthropocentric time-only discounting is inadequate for describing human values. Instead, humans support non-anthropocentric ethics, discount across space and other non-temporal dimensions, and support non-consequentialist ethics that cannot be expressed in terms of discounting.

Given the prominence of the traditional anthropocentric time-only discounting in both science and policy, this conclusion is of profound significance. For science, major lines of inquiry emerge from the possibility of multidimensional discounting as well as from

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(1996:746), except that these studies consider anthropocentric discounting across space as well as time. See Section 1.2 for further discussion of Negishi weights and other forms of welfare weights and their relationship to discounting.

the limitations of discounting. Many of the quirks and nuances found throughout the rich scientific literature on time discounting could be tested and explored for discounting across other dimensions, and new dimension-specific quirks and nuances may await discovery. Correlations and other relationships between dimensions of discounting also merit further inquiry, as do the general contours of the limits of discounting.

Meanwhile, policy using the descriptive approach to discounting faces a new challenge. The traditional approach as justified by the desire to avoid imposing value judgments on society cannot suffice. In previous research, I argued that the descriptive approach necessarily involves value judgments in deciding which individuals to describe, how to form the descriptions, and how to aggregate these descriptions into a single description of how society discounts across time (Baum 2009). This chapter shows that the descriptive approach must also make value judgments in its decision to only describe discounting across time, instead of including discounting across non-temporal dimensions and non-discounting values. Proponents of the traditional time-only descriptive approach to discounting could make arguments for why only time discounting should be included in the description. Or, the descriptive approach could change to incorporate discounting across non-temporal dimensions and non-discounting values, under the principle that all of human values should be included in the descriptions. Or, proponents of the descriptive approach could cease justifying it via the desire to avoid imposing value judgments on society. Any of these options suggests significant revision to this approach to policy analysis.

Several other generalizations can be made from the empirical portion of this study. First, people appear to discount similarly across multiple dimensions, which suggests the possibility of a common cognitive process underlying multiple discounting dimensions. Second, how people discount appears to be independent of (uncorrelated with) how well people's values can be described via discounting. Third, how people discount appears to be correlated with self-enhancement vs. self-transcendence in the Schwartz (1992, 1994) line of human values research. Although these generalizations can be strengthened by future research using broader samples and survey methodologies, these initial results represent important steps towards a stronger understanding of discounting and its relation to the broader realm of human values.

We conclude that multidimensional discounting and the limitations thereof constitute important and interesting features of human values and components of policy analysis. Researchers and policy analysis alike should incorporate these phenomena into their work.

**Chapter 4: Space-Time Discounting in Climate Change Adaptation**

Discounting is traditionally interpreted as the technique for comparing the values of costs and benefits which occur at different points in time. It endeavors to incorporate how humans trade off values to be received in the future versus value received immediately into economic analysis. Interpreted as such, discounting neglects important spatial influences on how values are compared, thereby hindering cost-benefit analyses of climate change adaptation. In this chapter, we present new theory on space-time discounting and use it to analyze aspects of how humans adapt to climate change.[30] Three climate change adaptation cases are considered. First, analysis of crop indemnity payments to farmers shows that failure to discount across space and time yields inaccurate evaluations of adaptation projects. Second, adaptation efforts of the Commonwealth of Nations show irregular patterns of international cooperation that suggest spatial discounting of adaptation that are not found in temporal discounting. Third, the nexus between climate change, migration, and conflict shows how various forms of space-time discounting can influence whether climate change and migration will lead to conflict. Collectively, these cases demonstrate the analytical power of the space-time discounting theory and also show how the complexity of climate change adaptation can challenge and strengthen this theory. Finally, this chapter's analysis demonstrates that including space as well as time can make our treatments of discounting more complete.

**4.1. Introduction**

Discounting traditionally refers to a process used to compare the values of costs and benefits that occur at different times within a cost-benefit analysis (CBA). It measures, among other things, willingness to put off a benefit today in return for one in the future. For example, a $1000 benefit that comes in ten years is worth $905 in present dollars if discounted at a 1 percent annual rate or $368 at a 10 percent annual rate.[31] The effect of discounting increases as the costs and benefits fall further into the future. Indeed, at even modest discount rates, virtually all distant-future costs and benefits appear negligible, prompting vigorous discussion of inter-temporal and inter-generational distributive justice (Lind 1982; Laslett and Fishkin 1992; Portney and Weyant 1999; Weisbach and Sunstein 2007; Zeckhauser and Viscusi 2008).

Discounting has figured prominently in CBAs of long-term societal issues. Many of these issues have been related to the environment, with climate change getting much of the attention. Indeed, the role of discounting in climate change CBAs made international headlines in recent years in the aftermath of the *Stern Review* (Stern 2007). The *Review*, produced by a UK-sponsored team led by former World Bank Chief Economist Nicholas Stern, was heavily criticized by other economists and researchers, primarily for how it handled discounting. Though the *Review* itself was much broader, the critiques focused on the *Review's* approach to greenhouse gas mitigation (Neumayer 2007; Nordhaus 2007;

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[30] Throughout Chapter 4, the term "we" should be interpreted as "Seth Baum and William Easterling," because the chapter is based on a paper co-authored by Easterling and myself.

[31] $1000 * \exp(-0.01\text{yr}^{-1} *10\text{yr}) \approx $905; $1000 * \exp(-0.1\text{yr}^{-1} *10\text{yr}) \approx $368.

Spash 2007; Weitzman 2007; Barker 2008; Hasselmann and Barker 2008; Dasgupta 2008; Jaeger et al. 2008; Mendelsohn 2008; Quiggin 2008; Sterner and Persson 2008; Weyant 2008; Yohe and Tol 2008; an exception is Pielke 2007, who focuses on impacts and adaptation). The *Review* derived discount rates from ethical principles roughly corresponding with classical utilitarianism. For example, criticizing this discounting, Nordhaus (2007) argues that the *Review* should have matched discount rates to market interest rates so that the resulting mitigation policy would be more efficient and better matched with how society discounts. Meanwhile, Dasgupta (2008) argues that the *Review*'s discounting leads to mitigation policy that places insufficient emphasis on the interests of the poor. But while this discounting debate is diverse, it focuses on discounting across time, neglecting important spatial aspects of discounting.

In this chapter, we deviate from the customary discourse on discounting in climate change in two key regards. First, we focus not on mitigation of emissions but on adaptation to climatic changes. Though the existing discounting debates have generally avoided adaptation, we argue that discounting is central to adaptation decisions and deserves more robust treatment. Climate change adaptation refers to efforts to minimize damage or seize opportunity from the impacts of climate change. The Intergovernmental Panel on Climate Change (IPCC) defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Watson et al. 2001:365). Note that this definition is based on costs (harms) and benefits that are not necessarily monetary or even human. Money is undoubtedly important to climate change adaptation, but other factors matter too. Innovation and technical change, knowledge, human capital, and governance structures, among other things, have been identified as influential to successful adaptation (Adger et al. 2007). Efforts to convert these factors into a common monetary numéraire (unit of analysis) mask the full complexity of the adaptation process. For this reason, the possibility of performing CBAs with non-monetary numéraires is central to the analyses in this chapter.

There have been relatively few CBAs of climate change adaptation. See Adger et al. (2007:724-727) or Stage (2010) for reviews. The lack of adaptation CBAs derives largely from the complexity of adaptation scenarios. Of the CBAs that have been conducted, most use a monetary numéraire. This includes the agriculture sector analyses of Adams et al. (2003) and Butt et al. (2005) as well as the Yohe and Schlesinger (1998) and Ng and Mendelsohn (2005) analyses of adaptation to sea level rise. An exception is Easterling et al. (2003), who measure benefits to adaptation in the agriculture sector in units of crop yield.

Adaptation, like mitigation, involves investments that will play out over a long period. Thus, several of the adaptation CBAs incorporate some treatment of temporal discounting. For example, Yohe and Schlesinger (1998) use a 3 percent annual monetary discount rate; Ng and Mendelsohn (2005) use a 4 percent rate. However, these treatments of discounting have not provoked anything near the strong discounting debates found within the mitigation literature. Though the reasons for why discounting debates have been more muted in the adaptation literature are not well established, several

possibilities come to mind.  First, adaptation projects generally involve shorter (though nonetheless long) time horizons.  Second, adaptation projects are often smaller, especially when mitigation is treated as a global project.  Indeed, the prospect of reorienting the global industrial economy for mitigation is so large that it could affect the trajectories of market interest rates.  This effect makes discounting important to mitigation studies in a way that generally does not exist for adaptation studies.

The second way in which we deviate from the customary discourse on discounting in climate change is by considering discounting across space as well as time.  The traditional time-only conception of discounting neglects important spatial attributes of how people make (and how people should make) discounting decisions.  The need for the handling of space in discounting is particularly acute in many aspects of climate change adaptation, such as the complex spatial heterogeneity of climate change impacts, in the evaluation of adaptation projects, and of cooperation and conflict in adaptation efforts.  Indeed, one reason we focus on adaptation is because the complexities of adaptation demand more complex discounting treatments than are commonly offered (see in particular Sections 4.4 and 4.5).  Thus the analysis of integrated spatial and temporal discounting in climate change adaptation offers advances in our understandings of both adaptation and discounting, advances that may facilitate further CBAs of adaptation and other complex nature-society phenomena.

Although several of the previous adaptation CBAs consider spatial heterogeneity in costs and benefits (such as in agricultural land productivity), none explicitly include treatments of spatial discounting.  Instead, the studies generally treat a unit of money (or other numéraire) as equally valuable regardless of where they occur.  We illustrate the role of discounting in adaptation through discussion of three cases.  The first case is an example of the evaluation of an adaptation-oriented government program focusing on the use of crop indemnity payments.  This case illustrates how failure to discount across space and time can yield inaccurate evaluations.  The second case is of cooperation among nations with regard to adaptation projects sponsored by the Commonwealth of Nations.  The Commonwealth sponsors a variety of adaptation projects focusing primarily on building adaptive capacity among its membership and advocating climate change action globally (e.g., CCGE 2007).  The Commonwealth's irregular border geometry, institutional capacity, and emphasis on national-scale assistance yield interesting discounting insights.  The third case is of conflict, specifically in the hypothesized connection between climate change, forced migration, and violent conflict.  Though much uncertainty exists, many believe that this causal chain could lead to significant conflict over upcoming decades and beyond (e.g., Reuveny 2007).  Migration's climatic driver, the attitudes of migrant and host communities towards each other, and the functional relationship between the respective communities all yield interesting discounting insights.  Collectively, these three cases show the power of the space-time discounting paradigm for analyzing climate change adaptation.  The three cases are analyzed in detail below.  First, however, we introduce some background on discounting.

The overarching objective of this chapter is to demonstrate the importance of taking into account the propensity to discount across time *and* space in climate change adaptation.

Our cases were chosen to represent a broad range of adaptation scenarios thereby indicating the broad importance of space-time discounting to adaptation. These cases, and the theory that drives them, can be readily adapted for many other adaptation cases.

## 4.2. Theory of Space-Time Discounting

Our theory of space-time discounting is an extension of the traditional time-only discounting, which is in turn embedded within the broader domain of CBA. Some background on all three topics is necessary for our discussion of discounting in climate change adaptation.

Two approaches to CBA and discounting predominate. The "descriptive" approach aims to describe how people value and discount costs and benefits, often by observing market behavior. This description is essentially an exercise in moral psychology with no inherent normative significance. In other words, the descriptions are of how people *do* make valuations, not of how people *should* make valuations. However, many analysts argue that costs and benefits should be valued and discounted based on these descriptions (Nordhaus 2007). Meanwhile, the "prescriptive" approach aims to identify how costs and benefits should be valued and discounted based on fundamental ethical principles as embodied in a *social welfare function*, i.e. a function of the welfare of the (human) members of society (Stern 2007).[32] These prescriptions need not match how people actually value and discount costs and benefits. Much debate exists over whether the prescriptions should be based on descriptions or ethical principles (Arrow et al. 1996; Baum 2009). The emphasis of this chapter is on descriptions of discounting. We make no claims here that these descriptions hold any prescriptive significance.

CBA, despite common perception, is not just about money.[33] It is true that most CBAs do count costs and benefits in monetary units, with many even placing monetary values on such non-market phenomena as ecosystem services and human lives (Costanza et al. 1997; Viscusi and Aldy 2003). However, classic CBA theory defines costs and benefits in terms of social welfare (Meade 1955; Drèze and Stern 1987). Here CBA can be conducted in any unit, monetary or otherwise; the unit of analysis in CBA is known as the *numéraire*. Note that different people may define social welfare differently, setting the stage for conflict, as we discuss below. Although the classic theory can be extended beyond an anthropocentric notion of social welfare, in this chapter, the conventional social welfare approach suffices.

In this chapter, it is also important to distinguish between the types of value held by costs and benefits. Most CBAs neglect this, leading to analytical mistakes. Here, two types of value are relevant. Intrinsic value is that which is valuable for its own sake (Rønnow-Rasmussen and Zimmerman 2005). Throughout this chapter human welfare holds

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[32] A person's welfare simply means how well her life fares, which may or may not relate to how much money she has. The term welfare is often used synonymously with utility and preference. This usage is problematic: we often prefer outcomes beyond just what makes our own lives fare well. In this chapter, we assume that utility and welfare are equivalent and leave open the relationship between these concepts and the concept of preference.

[33] Adler and Posner (2006) offer an excellent introduction to and extension of traditional CBA theory.

intrinsic value via various social welfare functions. Instrumental value is that which is valuable because it causes intrinsic value (or, more generally, causes other value; Bradley 1998). In this chapter several phenomena hold instrumental value, including climate, human labor, and social institutions. The distinction between intrinsic and instrumental value is central to understanding spatiotemporal discounting in climate change adaptation. For example, we might want to help someone adapt to climate change both because we place intrinsic value on her welfare (i.e. we care about her welfare for its own sake) and because we think she holds instrumental value (for example if she can help others adapt). Our examples illustrate these concepts in greater detail.

Traditional temporal discounting compares costs and benefits that occur at different times. This comparison usually uses a monetary numéraire but sometimes uses a welfare numéraire. Descriptions of monetary discounting generally involve observations of market interest rates. Descriptions of welfare discounting often use survey research (Frederick et al. 2002). Both market and survey descriptions emphasize functions in which the value of future costs and benefits decays exponentially as a function of the time delay until the cost or benefit occurs (solid curve, Figure 4.1). Some survey research identifies a more gradual decay, often represented by a hyperbolic function (dashed curve, Figure 4.1). But regardless of the specifics, all descriptions of temporal discounting use some sort of smooth decay function. Our example of the Commonwealth of Nations will demonstrate that such functions are inadequate for spatial discounting.
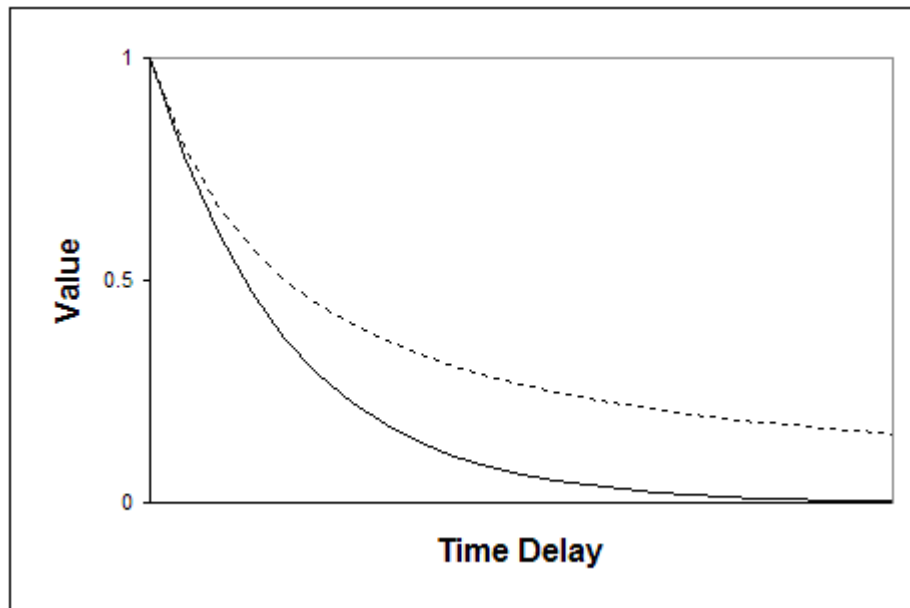


Figure 4.1: Exponential (solid curve: v = exp(-t) ) and hyperbolic (dashed curve: v = 1/ (1+t) ) temporal discounting, showing the relationship between value (v) and time delay (t).

Many reasons have been given for time discounting (Cowen and Parfit 1992; Frederick 2006). Here we focus on three which are central to climate change adaptation:

1. *Welfare favoritism*.  Here, future costs and benefits are considered to be worth less because individuals favor welfare that occurs sooner to welfare that occurs later.  Because welfare is assumed to hold intrinsic value, to favor some welfare over others is to place more intrinsic value on some welfare than on others.  The future welfare can be the individual's own welfare or it can be the welfare of one or more other individuals.  Welfare favoritism across time is often labeled pure time preference (e.g. Arrow et al. 1996) because welfare at certain times is being favored purely because of when it occurs, not because of other factors.

2. *Consumption inequality*.  Here, future costs and benefits are considered to be worth less because future individuals are wealthier, i.e. they consume at higher rates.  Consumption is an instrumental value bringing more welfare to those who consume.  The underlying idea here is that a unit (e.g. a dollar) of consumption is worth more (brings more welfare) to the poor than it is to the rich.  Assuming a growing economy which brings future generations greater wealth, future units of consumption will be worth less than present units of consumption.  The relationship between consumption and welfare is commonly expressed in terms of the isoelastic utility function (Arrow and Kurz 1970; Atkinson 1970):

$$u = \frac{(c+1)^{1-\eta} - 1}{1 - \eta}$$
(4.1)

Here u is utility (or welfare), c is consumption (measured in dollars or other monetary units), and $\eta$ is the elasticity parameter.  If $\eta=1$ then Equation 4.1 reduces to $u=\ln(c+1)$.  Equation 4.1 is often written in the simpler form $u=(c^{1-\eta})/(1-\eta)$, but this form fails to cross the origin at c=0 for all $\eta$.  $\eta$ specifies how much more a dollar of consumption is worth to the poor than to the rich.  Higher $\eta$ values correspond with larger differences in the value of a dollar between the poor and rich.  If $\eta=0$, then a dollar holds the same value for everyone.  Empirical evidence on $\eta$ is mixed: in various contexts $\eta$ could be as low as 0.5 or higher than 1 (Quiggin 2008).

3. *Stimulus magnitude*.  Here, future costs and benefits are considered to be worth less (or more) if they are of lower (or higher) magnitude as a stimulus of welfare.  In other words, the value of some stimulus is discounted because it does not stimulate the same amount of welfare.  The stimulus holds instrumental value, causing welfare for those exposed to the stimulus.  For example, "a bottle of wine may taste better or worse when consumed later because of chemical reactions occurring within it, and atomic decay may reduce the radioactivity of a barrel of nuclear waste, such that a future spill would be less deadly" (Frederick 2006:670).  In these examples, the wine and the radioactivity are the stimuli, affecting the welfare of whoever is exposed to them.

These and other reasons for discounting are almost always only considered across the temporal dimension.  However, space matters for each of these reasons for discounting.  People often favor the welfare of others in different places just as they favor welfare across time.  For example, we might discount the welfare of people who are far away, or

are part of a different family, religion, or nation.  Consumption inequality exists across space as well as time.  And the magnitude of a stimulus can vary across space as well as time – for example, the magnitude of the effect of radioactivity on welfare decreases as a function of distance from the radioactivity.  Despite often going overlooked, this variation across space as well as time is of considerable importance to climate change adaptation and many other issues.

While temporal discounting has gotten almost all of the attention, there is some prior work on spatial discounting.  One main line of work is that of geographer Bruce Hannon (see Hannon 1987, 1994, 2005; Perrings and Hannon 2001).  Hannon's spatial discounting is based on the idea that individuals (human or otherwise) prefer being closer to some things (e.g., public parks or food sources) and further from other things (e.g., polluting factories or predators).  Note that these costs and benefits are all instrumental values.  This is spatial discounting based on stimulus magnitude.  It parallels the temporal discounting in which individuals (often, but not always) prefer that instrumental benefits/costs occur sooner/later.  In summary, this discounting refers to the idea that individuals have preferences for when and where instrumental values occur.

The other significant line of work on spatial discounting is in the similar concept of social discounting recently developed by psychologists Bryan Jones and Howard Rachlin (Jones and Rachlin 2006, 2009; Rachlin 2006; Rachlin and Jones 2008).  Social distance here captures our sense of personal connectedness to others: family and friends are socially close to us, whereas mere acquaintances are socially distant.  Assuming that these "others" exist at the same time as ourselves (i.e. we are not considering past or future friends, family, acquaintances, etc.), then this social discounting is a form of spatial discounting.  In a series of studies, Jones and Rachlin find that people generally sacrifice more consumption for the benefit of socially close others than for socially-distant others.  Because the studies did not control for wealth, we cannot know whether the social discounting observed is due to welfare favoritism or consumption inequality, although it is likely that welfare favoritism played a dominant role unless consumption inequality happened to be strongly correlated with social distance within the studies' sample populations.  The observed sacrifice trend directly parallels the trends found in the temporal discounting literature studying current sacrifice for future benefit (see in particular Rachlin and Jones 2008).  Many circumstances could be described with either spatial discounting or social discounting; throughout this chapter, we use the term spatial discounting.

This theory of space-time discounting has broad applicability.  One main application is in the evaluation of projects that may be undertaken by governments or other entities seeking to advance the public interest.  Project evaluation is a main application of traditional CBA and time discounting theory (Dasgupta et al. 1972).  The evaluation commonly involves quantifying the costs and benefits of possible projects in terms of a social welfare function, which is presumed to hold intrinsic value.  The costs and benefits can be in any space-time location and can be measured with any numéraire, as long as they are aggregated so as to maximize the social welfare function.  When costs and benefits are distributed across different points in space and time, then they must be

discounted so that they can be aggregated per the social welfare function. This process is demonstrated in an example relevant to climate change adaptation involving crop indemnity payments.

A second application of the theory of space-time discounting is that of cooperation. Two parties tend to cooperate when they believe that cooperation will lead to mutually better outcomes than absent cooperation. However, a problem often arises when two or more parties have different views of what qualifies as a better outcome. Cooperation can thus occur under several scenarios. One scenario occurs when the cooperating parties value each others' welfare enough that they both value mutual success. This scenario involves welfare favoritism between the respective parties. Another scenario occurs when cooperation permits the enhancement of certain instrumental values, such that each party considers itself better off even if they don't place significant intrinsic value on each others' welfare. This scenario involves the stimulus magnitude of whatever instrumental values are involved. Both of these scenarios are demonstrated in an example relevant to climate change adaptation involving the Commonwealth of Nations.

A third application of the theory of space-time discounting is that of conflict. Conflict generally occurs when the parties to the conflict disagree with each other on some issue. This issue is often (though not always) an issue of space-time discounting, in the sense that the parties discount each others' welfare enough that they would rather fight than allow the other party to have its way. This scenario is typical of environmental conflicts, in which parties compete over scarce resources. Here, if the parties placed equal intrinsic value on each others' welfare, then they would agree on how to distribute the resources. Because each party would rather keep the resources for itself, conflict can arise. But other factors can also be relevant to whether conflict occurs, including how much instrumental value the parties hold for each other. These various factors are illustrated in an example relevant to climate change adaptation involving the nexus between climate change, migration, and conflict.

## 4.3. Crop Indemnity

As an example of project evaluation in climate change adaptation, we analyze indemnity payments in the agricultural sector, specifically for crops. Indemnities are payments made to a party due to a loss suffered by that party. Crop indemnities are payments made to farmers, generally due to losses suffered as a result of unfavorable growing conditions. The favorability of growing conditions are strongly dependent on climatic conditions which are expected to change significantly due to climate change (Easterling et al. 2007). Changes in the payments of indemnities are thus one expected adaptation to climate change in the agricultural sector.

In contrast with the Commonwealth of Nations and climate change-migration-conflict cases, crop indemnity is relatively conducive to quantitative CBA. This is because indemnity payment data are readily available for many jurisdictions. These data are not perfect. In particular, they are generally aggregated across broad space-time regions, instead of showing the details of each specific indemnity payment. For example, we use

a data set that is aggregated across United States counties and one-year periods. This aggregation makes the analysis more tractable but introduces important inaccuracies, as discussed below. Even with these inaccuracies, our analysis still demonstrates the importance of space-time discounting to adaptation project evaluation. Furthermore, the fact that these inaccuracies derive from the data being aggregated across space and time only makes the case for space-time discounting that much stronger.

We evaluate an indemnity payment program by estimating the increase in welfare it brings. We make no claim here that programs bringing the highest welfare increase should be chosen. While such a claim can be defensible, it would require ethical argument – namely, that all welfare holds equal intrinsic value – that is beyond the scope of this chapter. Instead of making this sort of ethical argument, our interest here is in presenting and discussing the sort of analysis needed to describe welfare changes caused by indemnity payments so as to show the importance of space-time discounting to them.

Indemnity payments have distinct distributions across space and time, which imply the need for space-time discounting. The reason for this discounting is consumption inequality: payment amounts vary across space and time, as do the initial incomes of those who receive the payments. The increase in welfare due to the payments will thus depend not only on the total amount of payment but also on the distributions of initial incomes and payment amounts across space and time. By discounting the payments, the consumption inequality is factored into the analysis, bringing accurate results.

We illustrate this point using a simple example based on indemnity payments in the U.S. state of Delaware in 2007 and 2008. Delaware is chosen because it is a small state, divided into only three counties, thus making it a simple case for illustrating the importance of space-time discounting. The insights found in this simple case readily extend to more complex cases, such as for larger states or for the entire country. In general, these insights apply to any evaluation of welfare in which consumption inequality – from either initial incomes or the project under evaluation – exists across space and time.

By focusing on Delaware in 2007 and 2008, our analysis asks: What was the increase in welfare due to indemnity payments in Delaware in 2007 and 2008? Because climate change has presumably at least marginally affected agricultural conditions in Delaware in 2007 and 2008, some of these payments qualify as a climate change adaptation. They are also representative of the sorts of payments we can expect as a climate change adaptation in regions worldwide over the upcoming years. For the Delaware payments, we cannot know exactly which portion qualify as adaptation, but this uncertainty does not detract from the importance of space-time discounting to the evaluation of the overall indemnity project.

To calculate the welfare increase from indemnity payments, we approximate the welfare of a household during a period as the natural logarithm of its monetary consumption during that period, adjusted such that zero consumption brings zero welfare (utility):

$$u(r,t) = \ln(c(r,t) + 1) \qquad\qquad (4.2)$$

Here, u is utility or welfare; c is consumption measured in dollars; r and t are coordinates within space and time respectively.  In our calculations, we will be using household income as an approximation for consumption.  This approximation assumes that approximately all income received within the space-time region is used for consumption within this region.  The approximation thus neglects the portions of income that are invested for future consumption and the portions that are donated or taxed for consumption in other places or for any non-consumption purposes.  However, for the present purposes, we expect that this approximation does not introduce any significant inaccuracies.  r can be conceptualized as an index number for households.  t is always either 2007 or 2008.

Equation 4.2 corresponds with η=1 in Equation 4.1.  As discussed above, some empirical evidence suggests that this may be an accurate approximation of the relationship between consumption and utility.  While other functional relationships between consumption and welfare are plausible, the core result of our analysis persists as long as the relationship is such that a dollar of consumption brings more welfare to the poor than to the rich.

Given Equation 4.2, the increase in welfare for a household during a period from indemnity payments is:

$$\Delta u(r,t) = \ln(c(r,t) + \Delta c(r,t) + 1) - \ln(c(r,t) + 1) \qquad\qquad (4.3)$$

Here, Δu and Δc are the increases in utility and consumption due to indemnity payments; the other variables are the same as in Equation 4.2.

The total welfare increase due to indemnity payments is then calculated by summing the welfare increases for each household at each time across the space-time region of interest, in this case Delaware during 2007 and 2008.  This corresponds with a social welfare function in which all welfare holds equal intrinsic value.  A fully accurate total welfare calculation would sum the income (c) and indemnity payment (Δc) for each household at each moment in time.  However, such accuracy would require having and handling a very large, high-resolution data set.  When data at this high resolution are unavailable, or would be too burdensome to analyze, a lower-resolution data set must be used instead.  The lower-resolution data aggregate household-moments into broader clusters across space and time.  This aggregation process can introduce inaccuracies if there is any consumption inequality within the clusters.  In general, limitations in data and in our ability to analyze necessitate at least some clustering, as is the case here.  Care must be taken to handle any inaccuracies introduced.

The data available to us are aggregated at the county scale across space and the year scale across time.  This includes indemnity payment data from the Risk Management Agency of the United States Department of Agriculture (RMA 2008; 2009) and number of households and median household income data from the United States Census Bureau

(2009a; 2009b; median income is used as a reasonable approximation of average income).  There exists consumption inequality within counties and within years, thereby introducing some inaccuracy into our analysis.  This inaccuracy further highlights the importance of space-time discounting: the less we account for consumption inequality by discounting consumption across space and time, the more inaccuracies we introduce to our analysis.

We demonstrate the importance of space-time discounting by calculating welfare increases for Delaware in 2007 and 2008 at four disaggregation configurations: no disaggregation; disaggregation across time only; disaggregation across space only; and disaggregation across space and time.  The no disaggregation configuration uses values for income and indemnity payment averaged across the entire three-county, two-year period.  The time-only disaggregation uses two sets of values, averaged across space within 2007 and 2008.  The space-only disaggregation uses three sets of values, averaged across time within Kent, New Castle, and Sussex counties.  The space-time disaggregation uses six sets of values for each of the six county-year pairs.  For simplicity, we represent these aggregations and pairs using a coordinate system presented in Table 4.1.

| Coordinate System | | | |
|---|---|---|---|
| | 2007 | 2008 | Aggregate |
| Kent | (1,1) | (1,2) | (1,Agr) |
| New Castle | (2,1) | (2,2) | (2,Agr) |
| Sussex | (3,1) | (3,2) | (3,Agr) |
| Aggregate | (Agr,1) | (Agr,2) | (Agr,Agr) |

Table 4.1: Coordinate system used in the agriculture indemnity calculations.

Using this coordinate system, the total welfare increase under each disaggregation configuration can be written as follows:

No disaggregation:
$$\Delta u_{tot} = N(Agr, Agr)\Delta u_{avg}(Agr, Agr) \tag{4.4}$$

Time disaggregation:
$$\Delta u_{tot} = \sum_{t=1}^{2} N(Agr,t)\Delta u_{avg}(Agr,t) \tag{4.5}$$

Space disaggregation:
$$\Delta u_{tot} = \sum_{r=1}^{3} N(r,Agr)\Delta u_{avg}(r,Agr) \tag{4.6}$$

Space-time disaggregation:

$$\Delta u_{tot} = \sum_{t=1}^{2} \sum_{r=1}^{3} N(r,t)\Delta u_{avg}(r,t)$$

(4.7)

In Equations 4.4-4.7, $\Delta u_{tot}$ is the total utility or welfare increase due to indemnity payments for across the entire Delaware 2007-2008 space-time region; $N(r,t)$ and $\Delta u_{avg}(r,t)$ are the number of households and the average utility increase within the space-time region $(r,t)$, which could be either one county-year or an aggregate across counties and/or years. $\Delta u_{avg}(r,t)$ is calculated using Equation 4.3 using income and indemnity payment data averaged across the region $(r,t)$.

The number of households, income, and indemnity payment data for Equations 4.3-4.7 appear in Tables 4.2-4.4. For the number of households, aggregate values are the sum of the values within the region of aggregation; for income and indemnity payment, aggregate values are the average of the values within the region of aggregation.

| Number of Households | | | |
|---|---|---|---|
| | 2007 | 2008 | Sum |
| Kent | 61,641 | 62,889 | 124,530 |
| New Castle | 212,419 | 213,489 | 425,908 |
| Sussex | 114,553 | 116,587 | 231,140 |
| Sum | 388,613 | 392,965 | 781,578 |

Table 4.2: Number of households in Delaware counties in 2007 and 2008, from U.S. Census Bureau (2009a).

| Median Income Per Household | | | |
|---|---|---|---|
| | 2007 | 2008 | Average |
| Kent | $47,407 | $55,179 | $51,293 |
| New Castle | $59,871 | $63,301 | $61,586 |
| Sussex | $50,132 | $47,727 | $48,930 |
| Average | $52,470 | $55,402 | $53,936 |

Table 4.3: Median household income in Delaware counties in 2007 and 2008, from U.S. Census Bureau (2009b).

| Average Indemnity Per Household | | | |
|---|---|---|---|
| | 2007 | 2008 | Average |
| Kent | $117.63 | $106.56 | $112.10 |
| New Castle | $2.33 | $11.80 | $7.07 |
| Sussex | $82.09 | $49.02 | $65.55 |
| Average | $67.35 | $55.79 | $61.57 |

Table 4.4: Average indemnity payout in Delaware counties in 2007 and 2008, calculated using indemnity payout data from the United States Department of Agriculture Risk Management Agency (RMA 2008; 2009) and the household data in Table 4.2.

Table 4.5 shows total welfare increase within each space-time region at each aggregation scheme calculated using data from Tables 4.2-4.4. These data correspond with the terms

N(r,t)*$\Delta$u$_{avg}$(r,t) in Equations 4.4-4.7.  The data at each coordinate in Table 4.5 are acquired by plugging data from the corresponding coordinates in Tables 4.2-4.4 into Equation 4.3.  Thus the aggregate data in Table 4.5 are not a function of the disaggregated county-year data in Table 4.5.  Likewise, different portions of the Table 4.5 data are used for different aggregation schemes.  The six county-year values [(1,1) through (3,2)] are used for the space-time disaggregation scheme.  The three aggregate county values [(1,Agr) through (3,Agr)] are used for the space-only disaggregation scheme.  The two aggregate year values [(Agr,1) and (Agr,2)] are used for the time-only disaggregation scheme.  Finally, the one aggregate value (Agr,Agr) is used for the space-only disaggregation scheme.

| Total Welfare Increase | | | |
|---|---|---|---|
| | 2007 | 2008 | Aggregate |
| Kent | 152.76 | 121.33 | 271.85 |
| New Castle | 8.28 | 39.81 | 48.88 |
| Sussex | 187.42 | 119.68 | 309.46 |
| Aggregate | 498.51 | 395.54 | 891.71 |

Table 4.5: Welfare increases from indemnity payouts in each county-year and in statewide and multiyear aggregates, calculated using data from Tables 4.2-4.4.

Following Equations 4.4-4.7, we can now use the data in Table 4.5 to produce estimates of the total welfare increase ($\Delta$u$_{tot}$) for the entire Delaware 2007-2008 space-time region using each of the four disaggregation schemes.  The $\Delta$u$_{tot}$ estimates are found by summing the values in Table 4.5 according to Equations 4.4-4.7.  These estimates are found in Table 4.6.

| Disaggregation Scheme | Welfare Increase |
|---|---|
| None | 891.71 |
| Time Only | 894.04 |
| Space Only | 630.19 |
| Time & Space | 629.27 |

Table 4.6: Total welfare increases using four different disaggregation schemes, calculated using Equations 4.4-4.7 and data from Table 4.5.

The total welfare increase estimates in Table 4.6 clearly illustrate the importance of disaggregating and discounting across space and time.  Simply put, we find different results for the same parameter ($\Delta$u$_{tot}$) using the same data (Tables 4.2-4.4), depending on how the disaggregation is conducted.  This is because the study region has consumption inequality across space and time.

It is of note that estimates of $\Delta$u$_{tot}$ are more sensitive to disaggregation across space than to disaggregation across time.  In other words, the differences between (1) no disaggregation and space disaggregation and between (2) time disaggregation and time and space disaggregation are larger than the differences between (3) no disaggregation and time disaggregation and between (4) space disaggregation and time and space disaggregation.  This means that for this example, disaggregation across space is more

important than disaggregation across time. This is because the consumption inequality across space affects $\Delta u_{tot}$ more than the consumption inequality across time. Thus, for this example, and for similar other cases, the practice of discounting consumption across time but not across space is an ineffective approach to achieving more accurate results.

Finally, it is important to recall that the $\Delta u_{tot}$ estimates in Table 4.6 are inaccurate because they are calculated using data averaged across all households and moments within a county-year. This averaging was performed due to limitations in the available data and because finer detail in the data was not necessary to make the core point that space-time discounting is necessary to make accurate $\Delta u_{tot}$ estimates. Where further accuracy is required, further disaggregation across space and time should be conducted.

## 4.4. Commonwealth of Nations Adaptation Efforts

As an example of cooperation in adaptation, we analyze the Commonwealth of Nations. The Commonwealth is an international organization composed of nations with ties to the former British Empire. The Commonwealth includes 53 countries (Figure 4.2) and two billion people, cutting across geographic, socio-economic, and religious lines (Commonwealth Secretariat 2009). The Commonwealth also has a longstanding interest in climate change adaptation and mitigation, dating to its 1989 Langkawi Declaration on the Environment. The Commonwealth's ongoing climate change response activities consist primarily in meetings amongst government officials of member countries aimed at building capacity and advocating broader climate change action, often coupled with discussions of other topics as well. In 2007 alone, such meetings occurred in Belize, Guyana, Uganda, and Kenya (cf. CCGE 2007). The Commonwealth's efforts are thus a major instance of people cooperating towards improved adaptation.
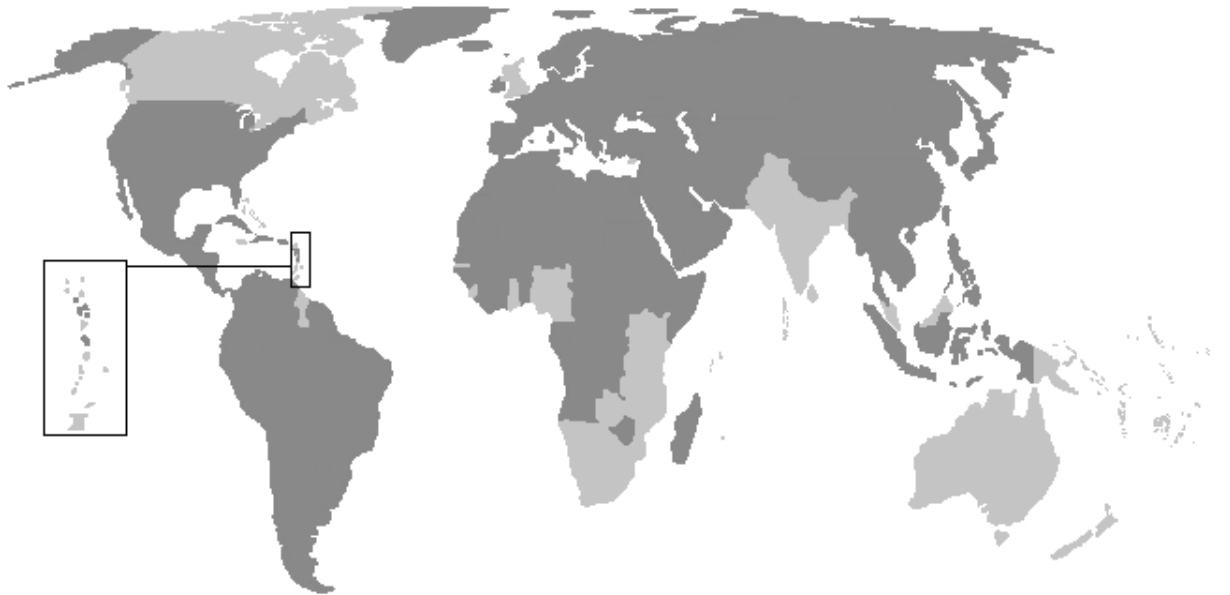


Figure 4.2: Commonwealth of Nations membership (light grey). Image adapted from Commonwealth Secretariat (2009:2). Copyright of the Commonwealth Secretariat, reproduced with permission June 2009.

Like other adaptation efforts, those of the Commonwealth can be analyzed in a cost-benefit framework. Here, the cost is the cost of organizing and hosting meetings and producing informational and advocacy materials. The benefits are the improved adaptations of people both in the Commonwealth and beyond. The Commonwealth clearly does not strive to maximize money here, because its efforts consistently emphasize helping its poorest and most vulnerable members. Money-maximizing CBAs would instead emphasize higher-dollar adaptation projects such as protecting high-end ski resorts. This is because the money-maximizing CBA has no diminishing marginal utility of consumption, so all dollars are counted equally. However, the Commonwealth's adaptation efforts can reasonably be described as maximizing some social welfare function, because the efforts aim to improve human welfare. The specifics of this social welfare function reveal important spatial discounting insights.

We do not attempt here to conduct a quantitative analysis of how the Commonwealth discounts costs and benefits across space and time. Such an analysis would be extremely difficult given the very subtle and complex nature of the Commonwealth's efforts. Activities like advocacy and capacity building do bring benefits in terms of climate change adaptation, but these benefits are very difficult to quantify because they are spread across many stakeholders and tightly coupled with many other activities. An attempt to quantify these benefits would be so complex and fraught with uncertainty that it would distract from the simpler and more robust insights to be found from a more qualitative and heuristic analysis of how the Commonwealth discounts in its adaptation practices.

Although the Commonwealth does appear, through its adaptation practices, to place intrinsic value on the welfare of all humans, it appears to place more on Commonwealth members. This is seen, for example, in its "advocacy work related to the concerns of vulnerable [to climate change impacts] member states" (CCGE 2007:45). In other words, the Commonwealth discounts the welfare of non-members relative to members. This discounting occurs because the Commonwealth supports global adaptation efforts but emphasizes adaptation within the Commonwealth. Such discounting is unremarkable: groups of all types tend to favor their own membership.

What is remarkable about this discounting is its irregular spatial geometry. Assume that the Commonwealth values the welfare of all people in the Commonwealth at one level and that of everyone else at another, lower level. (We will question this assumption shortly.) Then a map of the Commonwealth's welfare discounting is that of Figure 4.2. Notice that this map completely lacks the smooth decay of the typical temporal discounting shown in Figure 4.1. It is as if we favor welfare that occurs in 2010, 2012, and 2013 relative to welfare occurring in 2011, 2014, and 2015: no simple pattern exists. But while such meandering temporal discounting is unexpected and inexplicable, the corresponding spatial discounting pattern is anything but that. As noted above, the fact that the Commonwealth exhibits this pattern is unremarkable. The geometry of the Commonwealth is somewhat more interesting but its irregularity is hardly unique. We could have just as easily mapped la Francophonie, or the Christian or Muslim worlds, or many diasporas, though not all of these groups are as active on climate change as the

Commonwealth. Clearly, the smooth decay functions common to temporal welfare discounting are inadequate for spatial welfare discounting.

But the fact that the Commonwealth favors its own membership in its adaptation efforts reveals more than just how it discounts welfare across space. There is another reason for this favoritism: the Commonwealth's institutional capacity. The Commonwealth's shared protocols, professional networks, and language enable it to provide more adaptation assistance to its own membership per unit cost (measured in money, effort, etc.) than to non-members. On this, it writes:

> Because member states share similar legislative and legal systems, the Commonwealth Secretariat is also well placed to facilitate networking and the review of national legislative frameworks to help ensure that these are up to date and comprehensive in their approach to sustainable development. The Commonwealth Secretariat is currently working with member states to examine legislative frameworks on environmental protection. As we have seen, this is a fundamental prerequisite to adaptation to climate change. It will also explore, through its work on human settlements, the potential for a similar programme examining legislative frameworks to support disaster risk reduction and adaptation to climate change (CCGE 2007:45).

In other words, the Commonwealth holds instrumental value. Thus even if the Commonwealth did not discount non-members' welfare (i.e. if it placed the same intrinsic value on everyone's welfare), it would still favor its own membership in its adaptation efforts. This fact highlights the importance of recognizing the different value types held by costs and benefits: if the Commonwealth's instrumental value was ignored, then we would overestimate how much more intrinsic value it places on the welfare of members than on the welfare of non-members.

A final point of note regarding the Commonwealth's adaptation efforts is that these efforts focus on helping its member *nations*. This is unsurprising given the Commonwealth *of Nations'* structure but is important nonetheless. This nation-favoritism means that the Commonwealth provides more adaptation assistance to small nations than to equally vulnerable small regions of large nations. For example, the Commonwealth heavily emphasizes adaptation in small island nations, which are unquestionably very vulnerable to climate change (CAG 1997). However, this emphasis comes at the expense of adaptation in regions of larger countries such as India, Pakistan, Bangladesh, and Malaysia, all of which feature regions every bit as vulnerable to climate change as the small island nations. Thus the map in Figure 4.2 does not accurately describe how the Commonwealth discounts welfare across space. A more accurate description would, due to the quirks of national borders, resemble a smooth decay function even less. In summary, although the Commonwealth does successfully facilitate cooperation towards adaptation, it does so in a very specific and complex way.

## 4.5. Climate Change, Migration and Conflict

As an example of conflict in climate change adaptation, we analyze conflict caused by migration that is itself a climate change adaptation. This causal chain is quite simple. Climate change will have profound effects on regions worldwide, but will have different effects on different regions. Some regions may deteriorate so much that residents adapt by migrating to other regions. Deterioration causes include sea level rise, agricultural productivity declines, disrupted water resources, and extreme weather events. The total number of expected climate refugees is highly uncertain, but some estimates have been as high as several hundred million (Nordås and Gleditsch 2007). The nub of the issue is that such migration may create or exacerbate tensions between migrant and host communities, resulting in conflict.

Several aspects of the climate change-migration-conflict nexus can be described via space-time discounting. This includes the climatic driver of mitigation, the intrinsic value that the migrant and host communities place on each others' welfare, and the instrumental value that each community offers to the other. As with the Commonwealth of Nations case, the costs and benefits involved in the climate change-migration-conflict nexus are quite difficult to quantify. Simply put, it is difficult to know the extent to which climate change causes migration, and the extent to which migration causes conflict. Any quantitative CBA of this nexus must put this uncertainty front and center or else risk arriving at very inaccurate results. However, again as with the Commonwealth of Nations case, much insight can be gained from a qualitative, heuristic analysis of the climate change-migration-conflict nexus.

The climatic driver of migration is a form of space-time discounting. Specifically, climate change causes changes over time in the instrumental value of different spatial regions. The result is that people in one region come to prefer being in a different region. In other words, they discount the instrumental value of the departure region relative to that of the arrival region. This spatial discounting is essentially variation in stimulus magnitude, comparable to Hannon's spatial discounting in that it compares spatial locations in which people can be relative to geographically-fixed instrumental values. Given this comparison, people will generally migrate when the benefit of migration (the improvement offered by the arrival region) exceeds the cost (such as transportation, psychological, and transaction costs; see Reuveny 2007:658). This migration then leads to conflict whenever it brings together two communities sufficiently prone to conflict with each other.

Whether or not migration induced by climate change leads to conflict is the subject of much debate. Analyses suggesting that conflict is likely generally have Malthusian tendencies (Homer-Dixon 1999; Reuveny 2007). Other analyses emphasize several competing factors which make conflict less likely (Suhrke 1997). These competing factors can be succinctly described in terms of spatial discounting of intrinsic and instrumental value.

The intrinsic value here concerns the migrant and host communities' attitudes towards each other. A key finding of the migration-conflict literature is that conflict is more likely when there are pre-existing tensions between the two communities (Reuveny 2007). Here climate change is only one of multiple conflict causes. For example, intra-national migration may cause less conflict than international conflict so long as compatriots tend to like each other more. In other words, the more the two communities favor, or discount each others' welfare, the more likely it is that conflict will result. If the communities happen to place the same intrinsic value on each others' welfare (or, more generally, if the communities happen to support the same social welfare function), then conflict will in general not occur. This connection between spatial discounting and conflict was first described by Hannon (1987). It is of clear relevance to conflict in the climate change context, whether due to migration or other factors such as induced resource scarcity.

But the spatial discounting of welfare alone is insufficient to cause conflict. Communities could discount each others' welfare but avoid conflict if the communities hold instrumental value for each other. For example, migrants often provide (instrumentally) valued labor for the host community, which then provides money, civic infrastructure, and other services in return (Suhrke 1997). If this instrumental value is high enough, it may outweigh other factors, thereby preventing conflict. This instrumental value adds an additional form of spatial discounting: people prefer being near other people who can help them. As with the spatial discounting of regions discussed above, this spatial discounting of people is grounded in changes in instrumental value across space. Thus Hannon's instrumental value-based spatial discounting is broadly applicable to the climate change-migration-conflict nexus.

## 4.6. Conclusion

As the cases of crop indemnity payments, the Commonwealth of Nations, and the climate change-migration-conflict nexus illustrate, climate change adaptation, like many nature-society phenomena, features rich complexity that poses significant analytical challenges. This complexity has hindered past climate change adaptation CBA research, contributing to the dearth of adaptation-focused CBA studies. In this chapter, we apply a new approach to space-time discounting to climate change adaptation which better handles the complexity, thereby facilitating climate change adaptation CBAs.

The crop indemnity payments case illustrates the importance of space-time discounting in the evaluation of adaptation projects. The uneven distribution of household incomes and indemnity payments across space and time necessitates space-time discounting: if payments are not discounted across space and time, then inaccurate results are obtained. This point is seen clearly in the simple case of payments in the three counties of Delaware, United States during 2007 and 2008. The core insights from this case, as well as the methods used to produce these insights, readily extend to more complex cases, including other climate change adaptation projects involving costs and benefits that are distributed across space and time.

The Commonwealth of Nations illustrates the importance of space-time discounting in cooperative adaptation efforts. The Commonwealth's irregular border geometry shows that the smooth decay functions common in temporal discounting are inadequate for spatial discounting. The Commonwealth's institutional capacity shows that an organization's instrumental value must be recognized to avoid misinterpreting the relationship between its actions and what it places intrinsic value on. Lastly, the Commonwealth's national scale of operation shows how geopolitical circumstance can further distort descriptions of spatial discounting.

The climate change-migration-conflict nexus illustrates the importance of space-time discounting in conflictive adaptation efforts. The climatic driver of the migration shows that changes in how people spatially discount the instrumental value of different locations can cause the people to migrate across these locations. The attitudes of migrant and host communities towards each other show how conflict can occur when the communities discount each others' welfare. Lastly, the functional relationship between the respective communities show that even when the communities discount each others' welfare, conflict might not occur if the communities provide instrumentally valuable assistance to each other.

In closing, we emphasize that our analysis in this chapter is purely descriptive and without any attention to prescription. However, the analysis can readily be extended for prescriptive purposes. Doing so requires some choice of intrinsic value which would serve as the basis for evaluating the prescription. The choice in turn requires taking certain ethical positions. Thus the spatiotemporal discounting theory presented here is applicable to both descriptive and prescriptive analysis, for climate change adaptation as well as other topics. Moreover, our analysis strongly indicates that the analytical methods of CBA must include space in addition to time in the calculus of discounting.

**Chapter 5: Conclusion**

**5.1. Dissertation Summary**

This dissertation makes a case for discounting in both time and space as a vital element in any disciplined assessment of the costs and benefits of confronting a societal problem such as climate change. The preceding chapters have laid out a broad case for space-time discounting as a theoretical, empirical, and applied concept. Chapter 1 introduced the concept of space-time discounting and outlined how the concept would be approached in subsequent chapters. Chapter 2 developed the theory of space-time discounting, establishing strong reasons for adding the spatial dimension to the usual time-only discounting concept. Based on a survey of mainly Penn State students, Chapter 3 presented an empirical inquiry into how humans discount across space and time and the limits to which human values can be described in terms of discounting. Finally, Chapter 4 applied the space-time discounting concept to several cases in climate change adaptation, illustrating how the concept can be useful to complex and important societal issues.

This concluding chapter synthesizes insights from across the dissertation, discusses what has been learned, and considers opportunities for future research in space-time discounting.

**5.2. Review of Research Objectives and Findings**

This dissertation asks an interrelated set of questions all revolving around one key, central question: How is space relevant to discounting? Because discounting in any of its formulations is at once a theoretical, empirical, and applied concept, the dissertation asks questions about how space is relevant to each of these aspects of discounting: What does it mean to discount across space? How do and how should people discount across space and time? What is the significance of spatial discounting to policy on climate change and other societal issues? And what are the limits to space-time discounting as a theoretical, empirical, and applied concept?

From the work presented throughout this dissertation, several general findings emerge. These findings concern space-time discounting as a theoretical, empirical, and applied concept. But despite the dissertation being organized into separate theoretical, empirical, and applied chapters, the findings are strongest when the chapters are all considered together. Thus the chapters, despite their different foci, are strongly synergistic in the treatment of space-time discounting they develop.

**5.2.1. Chapter Summaries and Caveats**

Chapter 2's objective was the establishment of a strong theoretical foundation for the concept of space-time discounting. The chapter argued for including space in conceptualizations of discounting by showing that major reasons given for time discounting have (1) spatial analogs, meaning that we can discount across space for

reasons analogous to why we can discount across time, and (2) spatial components, meaning that how we discount across time will also depend on the spatial locations of whatever is being discounted. The chapter also argued for including non-anthropocentric ethics (that is, ethics that do not depend on any connection to humans) in conceptualizations of discounting by analyzing (1) discounting by non-humans, in which non-human individuals are performing the discounting process, and (2) discounting for non-humans, in which the intrinsic values (i.e. the values that are valuable for their own sake) being compared in discounting are tied to non-humans. Finally, the chapter had the objective of designing and proposing a new definition of discounting derived from the insights gained in the chapter's inquiry. This definition, called *discounting as values comparison* (DaVC), permits discounting across space and time and with either anthropocentric or non-anthropocentric ethics. DaVC improves on previous definitions by readily handling space and non-anthropocentric ethics while maintaining a clear and broad treatment of intrinsic value.

A key caveat with Chapter 2 is that not all reasons for discounting are considered. One other reason, stimulus magnitude, was covered in Chapter 4. Other reasons for time discounting exist, such as those discussed in Cowen and Parfit (1992) and Frederick (2006). One reason relates to uncertainty: future values are sometimes discounted because they are believed to be less likely to occur. Another relates to infinite values: future values are discounted because otherwise there would be a mathematically intractable infinite series of values. These and other reasons for discounting may have spatial components and spatial analogs, but this matter is not pursued in this dissertation.

Chapter 3's objective was the synthesis and extension our current empirical understanding of how humans discount across space and time and the extent to which human values can be described in terms of discounting. To achieve this, the chapter reviewed existing empirical research on space-time discounting and presented a new survey. Survey results showed that people discount similarly across both space and time, in that people who answered a certain way on time discounting questions tended to answer in the same or similar ways on space discounting questions. Survey results also showed that human values can only be described in part via discounting, in that people expressed substantial degrees of support for non-consequentialist ethical frameworks, whereas discounting exists exclusively within consequentialist frameworks.

One caveat with Chapter 3 is that the discounting survey questions were quite general. The questions succeeded in obtaining basic information about how people discount across these dimensions, but the questions did not provide significant detail within any given dimension. For example, the survey did not examine the presence in non-time dimensions of the sorts of anomalies found in the empirical time discounting literature (e.g. Frederick et al. 2002; Scholten and Read 2010; Thaler 1981). The broad-but-simple questioning was a necessity given the constraints of the survey but nonetheless limits how much we have learned about the empirics of space-time discounting.

Another caveat with Chapter 3 concerns the survey sample population it used. The sample was a convenience sample consisting primarily of university undergraduates and

contained a fairly high portion of people who were active on environmental issues. It is thus difficult to extrapolate the results of the survey to the broader human population. It is entirely possible that the participants in this survey discount differently (and hold different limitations to discounting) than the broader population, but we do not know what this difference might be.

Chapter 4's objective was the demonstration of the practical value of the space-time discounting concept by applying it to three select cases in climate change adaptation. The first case, on crop indemnity payments, showed that spatial discounting can be as important as time discounting to achieving accurate project evaluations. In rough, simple terms, more accurate project evaluations are obtained from using higher spatial resolutions. The second case, on the Commonwealth of Nations, showed that how people discount across space in real-world settings can have irregular geometries based on the contours of the world people live in. Such irregularities are generally not found in time discounting. The third case, on migration and conflict, showed that spatial variations in climatic conditions, locations of human populations, and humans' degrees of concern for each others' welfare all can influence whether or not conflict will occur. These three cases demonstrate that including space in discounting is of much practical significance in a range of important applied settings.

One noteworthy caveat with Chapter 4 comes from the fact that the section generally employed coarse data. For example, the crop indemnity data were at the scale of the county-year, even though the phenomena in question operate at the scale of the individual household over shorter periods. The county-year data were the only data available, but higher-resolution data would have permitted a more accurate analysis. On the other hand, the coarse data used for this and other adaptation cases were still fully adequate to make some basic points about the importance of space to discounting in applied research.

Table 5.1 summarizes the core findings and key caveats of the dissertation.

**5.2.2. Integrating Theory, Empirics, and Application**

Chapters 2, 3, and 4 focused mainly (but not exclusively) on theory, empirics, and application, respectively. However, these three aspects of the dissertation are not isolated from each other. In some ways, they informed each other within the dissertation. In other ways, they have the potential to inform each other for future work. Indeed, the further insight gained from integrating theory, empirics, and application into one work is a core reason for including all three in this dissertation.

The dissertation's theory informed the empirics in several ways, all oriented towards developing a clearer understanding of how discounting factors into human moral psychology:

*The wording of the survey questions*. The theoretical emphasis on reasons for discounting informed the decision to have the survey questions focus exclusively on the welfare favoritism reason for discounting. In doing focusing on only one reason for

discounting, the survey avoids the ambiguity found in many other discounting surveys, in which results could be explained by any of several reasons for discounting. This ambiguity can be found in surveys of both time and space discounting. Thus the dissertation's theoretical discussion of reasons for discounting can further inform a broad range of future empirical discounting work.

| Core Findings |
| --- |
| Spatial discounting has strong theoretical basis, comparable to time discounting (Ch. 2) |
| Reasons for time discounting have spatial analogs and spatial components (Ch. 2) |
| DaVC proposed as a new discounting definition (Ch. 2) |
| People discount similarly across both space and time (Ch. 3) |
| People express support for non-consequentialist ethical frameworks (Ch. 3) |
| Higher spatial resolutions yield more accurate project evaluations (Ch. 4) |
| Real-world spatial discounting can have irregular geometries (Ch. 4) |
| Spatial discounting can influence whether or not conflict will occur (Ch. 4) |
| **Key Caveats** |
| Not all reasons for discounting are covered (Ch. 2) |
| Survey questions give coarse discounting descriptions (Ch. 3) |
| Survey sample population is not broadly representative (Ch. 3) |
| Agricultural indemnity case study uses coarse data (Ch. 4) |

Table 5.1: Core findings and key caveats of the dissertation. The chapters in which the findings and caveats are primarily located are in parentheses.

*The selection of empirical questions to explore*. The dissertation's theory developed space-time discounting and non-anthropocentric discounting all within a single discounting framework, most clearly expressed as the Discounting as Values Comparison framework in Chapter 2. The overwhelming majority of empirical work on discounting focuses exclusively on time and anthropocentric ethics. The survey presented in Chapter 3 extends the small handful of prior surveys that examine discounting across both space and time. The survey also offers the first dedicated studies of discounting across species and the limits to discounting as a paradigm for describing human values. In doing so, the dissertation's theory and empirics combine to establish rich new lines of empirical inquiry.

The dissertation's theory informed the applied work in several ways as well, all oriented towards a clearer understanding of how people can and should make decisions in applied settings:

*The importance of the resolution of spatial disaggregation in project evaluation*. The dissertation's spatial discounting theory suggests spatial disaggregation as an important consideration; this suggestion is demonstrated via the crop indemnity example in Chapter 4. This issue of resolution of spatial disaggregation appears whenever the project under evaluation has costs and benefits that are distributed over multiple points in space. The issue is especially important for global environmental issues, including climate change mitigation (on which, see below).

*The nuances of cooperation and conflict*.  The value typology and spatial discounting theory permit an enhanced understanding of cooperation and conflict, which is leveraged in the Commonwealth of Nations and migration examples presented in Chapter 4.  The value typology was helpful in distinguishing between the intrinsic and instrumental values of individuals cooperating or conflicting with each other: the individuals might (or might not) care about each other for their own sake or might (or might not) find each other useful.  The spatial discounting was helpful in clarifying the roles of the spatial locations of both the individuals involved and the other human and environmental factors, such as the Commonwealth of Nations institutional structure and the climatic drivers of migration.  These two case studies illustrate how the dissertation's theory can be used for enhanced understanding of a broad range of complex cooperation and conflict scenarios.

The dissertation's empirics informs discounting theory in one key way:

*The descriptive approach to discounting*.  Per one main interpretation of the approach, in policy and other decision making contexts, we should use temporal discount rates that match descriptions of how humans discount across time.  The dissertation's empirical work systematically assessed the extent to which humans' morals can be described in terms of time discounting alone.  In short, time discounting covers only a narrow portion of human values.  People also discount across space and hold significant support for non-consequentialist ethics, the latter of which cannot be described via discounting.  The key theoretical conclusion here from the dissertation's empirics is that the descriptive approach to discounting as it is commonly implemented is incomplete in the sense that it includes descriptions of only part of human discounting and morality.

The dissertation's empirics informs applied discounting work in several ways, related both to the descriptive approach to discounting and to how humans behave in cooperation and conflict scenarios:

*The descriptive approach to discounting*.  The conclusion here is similar to the conclusion for the theory.  That is, the empirical work suggests the need for expanded descriptions of human discounting and morality in the descriptive approach as the approach exists as a theoretical concept and as it is used in applied settings.  While these applied settings were not extensively discussed in this dissertation, they are nonetheless prominent, with climate change mitigation policy looming as perhaps the biggest example.

*The nuances of cooperation and conflict*.  The empirics offers an enhanced understanding of cooperation and conflict.  The insights to be gained here are mainly from spatial discounting: insights into the spatial patterns of how humans value each other can be used to help gauge where cooperation and conflict may arise.  In short, if humans value each other, then they are more likely to cooperate and less likely to be in conflict.  The dissertation's empirical work on spatial discounting provides some initial insights on this phenomenon; additional empirical work would be further illuminating. Meanwhile, the dissertation's empirical work on the limitations of discounting as a paradigm for

describing human values can also be relevant to cooperation and conflict, in particular to conflict. This connection follows from the existing observation that conflicts are often rooted not in traditional consequentialist cost-benefit morals, but in deontological (or quasi-deontological) sacred values. The dissertation's empirical work suggests the prevalence of such values. Further empirical work could clarify the prevalence and nature of sacred values, which could in turn inform conflict resolution efforts.

The dissertation's applied work informs discounting theory in several ways, mainly related to the complexities of the scenarios found in applied work:

*The irregular geometries of spatial discounting*. The irregularities found in applications such as the Commonwealth of Nations' adaptation efforts show that smooth spatial decay functions cannot always be found for spatial discounting. The irregularities of spatial discounting is an important theoretical insight that contrasts with the smooth decay functions commonly found with temporal discounting. While there may exist irregular temporal discount functions, they are less prevalent than irregular functions for spatial discounting, as the dissertation's applied work makes clear.

*The data limitations in project evaluation*. The crop indemnity data used in Chapter 4 exists only at the county scale, even though the project itself has impacts with variation at the household scale. This data limitation suggests a role for theory that can be used to extrapolate across scales, so as to improve project evaluation in these situations of limited data. Development of such extrapolation theory for space-time discounting would be quite useful for many project evaluation cases. Likewise, in the absence of such extrapolation theory, a separate theoretical insight obtained from this circumstance is that project evaluations should be approached with caution whenever data limitations exist.

The dissertation's applied work can inform empirical discounting work in several ways, mainly to use empirical work to help clarify the nature of some of the complexities found in applied work.

*The multiple factors that can influence discounting behavior*. The applied work found that multiple factors potentially influence discounting behavior. Survey research could help assess the importance of the various factors. For example, surveys of Commonwealth of Nations members could help assess the relative importance of welfare favoritism and the Commonwealth's instrumental value as factors influencing the Commonwealth's adaptation behavior. It is worth noting that this distinction between factors is heavily motivated by the dissertation's theoretical work on value typology and reasons for discounting.

*The roles of scale and institutions in discounting decisions*. One question raised by the dissertation's applied work is: to what extent do the Commonwealth of Nations' discounting decisions regarding climate change adaptation accurately follow the views of the citizenries of Commonwealth nations, as opposed to following the views of select Commonwealth officials or institutional procedures? Potentially, Commonwealth citizens do not fully agree with the decisions being made. Surveys of the citizens could

help clarify this, which in turn could be useful for guiding subsequent Commonwealth decisions. Similar survey work could be useful for other applied cases.

*The views of individuals who might come into conflict with each other.* Do individuals in competing groups discount each others' welfare? Do they hold sacred values that could play roles in a conflict, or in the resolution of a conflict? Do they hold other values that may be relevant? Survey work could help answer these questions, which could in turn help develop plans for conflict resolution.

Table 5.2 summarizes the ways in which the theoretical, empirical, and applied portions of the dissertation inform each other.

| Interrelations Between Theory, Empirics, And Application |
|---|
| Reasons for discounting theory informs the survey question wording (Ch. 2 to Ch. 3) |
| DaVC theory informs the selection of empirical questions (Ch. 2 to Ch. 3) |
| Spatial discounting theory informs spatial disaggregation in project evaluation (Ch. 2 to Ch. 4) |
| Value typology theory informs spatial discounting in cooperation and conflict (Ch. 2 to Ch. 4) |
| Moral psychology empirics informs descriptive approach to discounting theory (Ch. 3 to Ch. 2) |
| Moral psychology empirics informs descriptive approach to discounting policy (Ch. 3 to Ch. 4) |
| Spatial discounting empirics informs cooperation and conflict (Ch. 3 to Ch. 4) |
| Irregular geometries in applied settings informs spatial discounting theory (Ch. 4 to Ch. 2) |
| Data limitations in project evaluation informs spatial discounting theory (Ch. 4 to Ch. 2) |
| Factors influencing discounting can inform future empirical inquiry (Ch. 4 to Ch. 3) |
| Role of scale and institutions in discounting can inform future empirical inquiry (Ch. 4 to Ch. 3) |
| Discounting in conflict scenarios can inform future empirical inquiry (Ch. 4 to Ch. 3) |

Table 5.2: Summary of interrelations between the theoretical, empirical, and applied portions of the dissertation. The pairs of chapters in parentheses indicate the interrelations, as in "Ch. 2 informs Ch. 3."

## 5.3. Comparison of Spatial and Temporal Discounting

The dissertation has argued that spatial discounting deserves to be included alongside temporal discounting in overall conceptualizations of discounting. While spatial discounting is so deserving, this does not mean that spatial and temporal discounting are identical to each other. In light of the full set of findings of the dissertation, we can begin to see a clearer picture of the similarities and differences between spatial and temporal discounting.

### 5.3.1. Similarities Between Spatial and Temporal Discounting

There are several ways in which spatial and temporal discounting are similar to each other, spanning theoretical, empirical, and applied contexts.

*Underlying ethics.* On the most basic theoretical level, spatial and temporal discounting are essentially the same, in that both involve comparisons of values of consequences of actions. Because of this, both spatial and temporal discounting inevitably exist exclusively within consequentialist ethics. In the case of hybrid frameworks that contain

both consequentialist and non-consequentialist ethics, both spatial and temporal discounting can exist only within the consequentialist portions of the framework. Spatial and temporal discounting also have some similarities in terms of the specific forms of consequentialism involved. For example, if the consequentialism is anthropocentric, meaning that the consequences being valued are all human-oriented, then this anthropocentrism will apply equally to spatial and temporal discounting. But there are some differences in terms of underlying ethics, such as with respect to selfishness, as in the discussion of the temporally extended self below.

*Survey question responses*. The core empirical similarity between spatial and temporal discounting comes from survey research on how people discount. Prior survey work by Jones and Rachlin (2006) found that people discount across social distance according to hyperbolic discounting functions similar to those found in time discounting. Likewise, the new survey presented in Chapter 3 found strong correlations between how much people agreed to the principles of time discounting and how much people agreed to the principles of space discounting. This pair of results suggests the possibility of similar underlying cognitive mechanisms between spatial and temporal discounting, although the surveys' correlations do not directly inform us about any underlying causal mechanisms.

*Policy relevance*. Regarding applied research, the crop indemnity example in Chapter 4 demonstrated that spatial discounting can be every bit as significant to policy analysis as temporal discounting can. The crop indemnity example featured discounting due to consumption inequality, but similar results can be obtained via spatial and temporal variations in welfare favoritism and stimulus magnitude (though not necessarily via investment/arbitrage opportunity, on which see below). It is therefore noteworthy that policy analysis pays much more attention to time discounting than it does to space discounting, such as in climate change mitigation policy analysis, described further below. This systematic bias in policy analysis can lead to analytical mistakes.

## 5.3.2. Differences Between Spatial and Temporal Discounting

There are also several ways in which spatial and temporal discounting are different from each other, again spanning theoretical, empirical, and applied contexts. These differences touch on some fundamental physical differences between space and time.

*Investment vs. arbitrage*. Investment opportunity is a basic theoretical reason for time discounting. Its spatial analog is arbitrage opportunity, but this is an imperfect analog. The core difference between investment and arbitrage is that investment opportunities are widespread and easy to come by, whereas arbitrage opportunities are scarce and generally available only to attentive experts. This investment-arbitrage difference is not a mere quirk of our financial system: it points to something much deeper about space and time. In short, time keeps ticking in a way that space does not. Because of this, investments unfold across time in a way that they do not across space.

*The temporally extended self*. An empirical difference between spatial and temporal discounting derives from the fact that individual's life is extended in time in a way that it

is not extended in space.  For example, the Seth Baum alive today is connected to the Seth Baum alive one year from now in a way that is different from how the Seth Baum alive today is connected to any other individuals alive today.  Space and time are fundamentally different in this regard.  This difference matters for discounting in that it could bring me (or anyone else) to favor my own future welfare differently than I might favor the welfare of others alive today.  (Survey research could measure the extent to which this is the case for different individuals.)  Thus an ethical concept like selfishness may apply differently to time discounting than it does to space discounting.  To be sure, the Seth Baum alive today and the Seth Baum alive one year from now may be in some sense different people.  Likewise, it is easy to imagine that someone one might favor the welfare of certain contemporaneous individuals (e.g. close family members) more than the welfare of their own self at some later time.  But insofar as we can say that an individual is extended through time, then welfare favoritism across space is not a perfect analog to welfare favoritism across time.

*Irregular geometries*.  Even in applied settings, time discounting usually follows smooth decay functions such as exponential functions or hyperbolic functions.  However, with spatial discounting, functions with irregular geometries are commonly obtained.  This was demonstrated in the Chapter 4 case study of the Commonwealth of Nations.  In this case, spatial discounting was found to follow the irregular geometry of the borders of the Commonwealth.  Irregularities of this sort are not found in the empirical literature on time discounting, and indeed would make no sense.  In contrast, the spatial irregularities are both quite sensible and something we would expect across a broad range of contexts, given the contours of geophysical, political, and other boundaries.  The basic insight here is that variations in how we value phenomena across space can be highly irregular due to the irregularities in the spatial geometry of our planet even though such irregularities are in general not found across time.

*Stimulus magnitude variation*.  As discussed in Chapter 4, one reason for discounting across time and space is that the magnitudes of stimuli that we value vary across space and time.  But the variation is often not the same across space as it is across time.  For example, the magnitude of radiation from a nuclear weapons detonation decreases as one gets further from the detonation in both space and time.  The decrease is proportional to the inverse square of distance (i.e. it follows the inverse square law, neglecting complications such as wind) and decays exponentially over time (hence the radiation half life statistic).  This difference in stimulus magnitude is rooted in a simple physical distinction between space and time.  As additional complexities are introduced to the stimulus, such as wind in the case of nuclear weapons detonation, further asymmetries between the patterns of stimulus magnitudes across space vs. across time can be found.

## 5.4. Implications for Future Research

The treatment of space-time discounting in this dissertation is extensive, but it inevitably only covers a small portion of what can be said on the topic.  This section discusses several of the directions that future space-time research could go in, following the lead established in this dissertation.

### 5.4.1. Implications for Theoretical Research

*Reasons for discounting*.  For the theory of space-time discounting, a major remaining project is to examine the spatial components and spatial analogs to time discounting for a more comprehensive set of reasons.  This dissertation developed four reasons for space-time discounting: investment opportunity, consumption inequality, welfare favoritism, and stimulus magnitude.  While these are some of the most important reasons for discounting, a more comprehensive treatment would further strengthen space-time discounting theory.  As noted above, other reasons include those related to uncertainty and infinite values.

*Handling complexity*.  The applied work presented in Chapter 4 presents some difficult theoretical challenges.  The geometries of how people discount across space can be highly complex, such as when discounting follows irregular geopolitical boundaries like the Commonwealth of Nations.  Additionally, discounting parameters such as consumption may vary irregularly within a region, such as in Delaware for the crop indemnity example.  This complexity means that the smooth discounting functions developed for time discounting cannot be applied in these cases without significant loss of accuracy.  On the other hand, handling every detail of the complexity would present an insurmountable work load for analysts.  A challenge for new theoretical analysis is to develop methods for handling this complexity in a way that retains analytical accuracy without requiring too much work from analysts.

### 5.4.2. Implications for Survey Research

*Reasons for discounting*.  As discussed throughout the dissertation, there are several distinct reasons for discounting across both time and space.  Much existing survey research fails to isolate specific reasons for discounting.  For example, a survey question might ask people whether they prefer $100 now or $200 in one year.  Someone could choose $100 now because they favor their current welfare more (welfare favoritism), because they anticipate being much wealthier in one year (consumption inequality), or because they have the opportunity to invest $100 now bringing even more than $200 in one year (investment opportunity).  At a minimum, this sort of survey could reduce its ambiguity by asking survey participants to explain why they make the choices that they do.  Or, a survey could use alternative questions focusing on specific reasons for discounting.  The Chapter 3 survey focused on welfare favoritism by asking how strongly people agreed or disagreed with statements such as "The further into the future someone's life occurs, the less her/his life is worth."  A survey focused on consumption inequality could solicit people's beliefs about the relationship between consumption and welfare and beliefs about how consumption is distributed across space and time.  A survey focused on investment opportunity could ask people about the investment (or arbitrage, for spatial discounting) opportunities that they have, and how that factors into their discounting of money.  Any of these approaches would provide clearer information on how people discount, whether the survey is for time, space, or space-time discounting.

*Survey question schemes*. One limitation of the Chapter 3 survey is that it only used one question scheme, called the principle agreement approach. The principle agreement approach was well-suited to the goals of the chapter. This leaves opportunity for additional research exploring other survey schemes. A variety of schemes have been implemented for time discounting. These include asking people to make pairwise comparisons between values at different points in time, or asking people to state how much they would accept at one time in exchange for some fixed amount at another time. These schemes could be adopted for space and space-time discounting surveys. Another scheme that could be applied to any of time, space, and space-time discounting is conjoint analysis, which asks people to rate sets of values that are distributed across space and time. Surveys using any of these schemes would provide additional information about how people discount across space and space-time beyond the information provided in the Chapter 3 survey.

*Case-specific surveys*. Chapter 4 found irregular geometries of spatial discounting, in particular in the case of climate change adaptation assistance provided by the Commonwealth of Nations. Specifically, the Commonwealth was found to favor its own membership more than non-members, in that it provided more assistance to members than to non-members. However, the Chapter 4 analysis leaves some open questions. For example, do citizens of Commonwealth nations actually favor the welfare of other Commonwealth citizens over the welfare of non-Commonwealth citizens, or is the apparent favoritism in Commonwealth adaptation assistance due to other causes, perhaps related to the Commonwealth's institutional structure? Questions such as this can be informed by giving surveys about welfare favoritism to Commonwealth citizens. Likewise, countless other case-specific surveys could be given, teasing out the local nuances of how people discount across space and time.

*Non-consequentialist ethics*. Discounting survey research gains policy significance via the descriptive approach to discounting, in which discount rates used in policy are based on descriptions of how society discounts. However, this dissertation finds that (1) discounting exists only within consequentialist ethics; (2) people (as surveyed in Chapter 3) hold significant support for non-consequentialist ethics. These findings mean that discounting as a paradigm can only describe a portion of human values. This result in turn raises some significant questions that could be informed by survey research: (1) To what extent do people support consequentialist ethics vs. other forms of ethics? (2) What is the exact form of the non-consequentialist ethics that people support? The Chapter 3 survey provided only some initial information on both of these questions. Additional survey research could further explore these questions, providing valuable information on how to implement the descriptive approach to policy analysis whenever the approach is not restricting descriptions to just discounting.

### 5.4.3. Implications for Policy Analysis in General

*The choice of discount rates*. First and foremost, the findings of this dissertation reinforce the existing message that there is no one single correct time (or, for that matter,

space) discount rate to use for policy purposes.[34]  Any "correct" discount rate will depend on which ethical framework is in effect, and there is no one single ethical framework that will necessarily be in effect.  Indeed, debates about which discount rate to use are often ultimately debates about which underlying ethical framework should be in effect.  Furthermore, even given an ethical framework, there are still multiple discount rates across both time and space.  Discount rates can depend on, among other things, which numéraire is being used in the analysis, on what phenomenon it is that is being discounted, on what reason(s) we have for discounting this phenomenon, on what investment and arbitrage opportunities happen to be available, and what distributions of wealth happen to exist among the people affected by the policy under consideration.  For all of these reasons, we should resist the urge to seek out a single time or space discount rate that can be applied to any policy analysis.  Likewise, the existence of multiple and often context-specific discount rates points to an ongoing need for analysis that estimates "correct" discount rates given specific ethical frameworks and policy contexts.

*The descriptive approach*.  Second, this dissertation holds some substantial implications to the descriptive approach to discounting as it is applied to policy analysis.  The traditional descriptive approach only includes descriptions of how people discount across time.  This dissertation finds that people also discount across space and hold non-consequentialist ethics that cannot be expressed in terms of discounting.  Therefore, implementations of the descriptive approach should either expand what is being described to include spatial discounting and non-consequentialist ethics, or the implementations should include an argument for why they are restricting descriptions to time discounting.  If the descriptions are to become more inclusive, then new research will be needed both to form the descriptions (such as via the survey research discussed above) and to identify how these descriptions affect policy recommendations.  The implications of spatial discounting descriptions for policy recommendations may be relatively straightforward to identify given the strong parallels between spatial discounting and the more familiar temporal discounting.  However, there has been much less policy analysis using non-consequentialist ethics, leaving a correspondingly greater need for future research on this topic.

*Handling space*.  Third, the dissertation highlights the importance of spatial discounting and spatial disaggregation to policy analysis.  The Chapter 4 case study of crop indemnity payouts demonstrated that the failure to disaggregate costs and benefits across space and then discount them can lead to sizable analytical mistakes in policy analyses.  This finding is not unique to the crop indemnity case.  Instead, it applies to all cases in which there is inequality in consumption across space among the people receiving the costs and benefits of the policy.  Since there is in general spatial consumption inequality, in general this aspect of spatial discounting will matter for policy analysis.  The importance of handling spatial variation in consumption inequality can be further seen with an example from climate change mitigation.

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[34] An example of an existing message on this theme is from Drèze and Stern (1990:29), who write "We cannot, therefore, answer the question, 'What should be the shadow discount rate? without being told, or without our choosing, what the numeraire is to be."

### 5.4.4. Implications for Climate Change Mitigation Policy Analysis

As an example of how insights from this dissertation can be applied to major societal issues, let us revisit climate change mitigation, previously discussed in Section 1.2.4. While there has been much debate about how time discounting should be handled in mitigation policy analysis, relatively little has been said on spatial discounting. In light of the findings of this dissertation, several areas for enhancement to mitigation policy analysis are apparent.

First, this dissertation suggests the need for improved handling of spatial disaggregation in mitigation integrated assessment models. As noted in Section 1.2.4, several of these models feature some spatial disaggregation, generally in the range of 8 to 16 regions worldwide. However, the impacts of emissions occur at the scale of individual humans (or, potentially, sentient non-human animals, on which see below). As the crop indemnity example in Chapter 4 shows, the results of project evaluations can depend on the geometries of spatial disaggregation when there is spatial variation in the monetary costs and benefits of the projects under evaluation. Such variation exists for mitigation, and so the results of evaluations of mitigation projects will depend on the geometries of spatial disaggregation. Indeed, this result is found by Anthoff et al. (2009).

Chapter 4 further shows that the more accurate evaluations are those that use full spatial disaggregation. This poses a substantial challenge for mitigation, because full disaggregation would require accounting for at least every human being. A productive area for future work would be developing theory for extrapolating mitigation analysis across scales. Such analysis would take results from existing integrated assessment models and use them to estimate what results such models would obtain if they had full spatial disaggregation. As noted in Section 1.2.4, one promising approach is to disaggregate by income group instead of by region, as in the analysis of Chakravarty et al. (2009). Another promising approach is to identify a functional relationship between the resolution of spatial disaggregation in an integrated assessment model and the model's results. The relationship could be obtained by fitting a curve to data from model runs at various resolutions or potentially by analytic derivation from underlying model equations. Given this relationship, one could plug in individual-scale resolution and obtain an estimate for mitigation project evaluation with full spatial disaggregation.

A second implication of this dissertation for climate change mitigation is in the need for a broader set of ethical views used in mitigation policy analysis. These analyses almost invariably use a form of anthropocentric utilitarianism in which future utility may be discounted relative to present utility. The discount rate used here is sometimes justified via the "descriptive approach" to discounting in that the discount rate is a description of how society discounts. But the descriptions are only of how society discounts across time within anthropocentric ethics. As seen in Chapter 3, society also discounts across space, holds support for non-anthropocentric ethics, and holds support for non-consequentialist ethics, the latter of which cannot be expressed through discounting. A mitigation policy analysis that strives to follow descriptions of society's ethical views would need to include all these other views in the analysis. Including all these views in

the analysis would involve a substantial revision to the analysis and could also substantially change the policy results obtained from the analysis, though estimation of what results would be obtained is beyond the scope of this dissertation.

A related implication for mitigation concerns the views, including the discounting views, of non-human animals. Non-human animals' views are relevant to mitigation policy under the ethics of non-anthropocentric utilitarianism as well as to the ethical views that argue for the views or interests of all those affected by a decision to be included in the making of the decision. In other words, if decisions are to be based on a description of the views of society, then potentially the non-human animals affected by the decision should be included in this notion of "society". The non-human animals affected by mitigation decisions include a variety of wild animals (Schneider and Root 2001) as well as livestock animals (Steinfeld et al. 2006). Including the views of non-human animals poses an empirical challenge in that research cannot study the views of non-human animals via the same survey and other procedures that are used for humans. To the extent that the views of non-human animals are deemed to matter for policy purposes, much future research would be required to factor these views into an analysis.

## 5.5. Concluding Remarks

The core accomplishment of the dissertation is to build a foundation for the concept of space-time discounting. As established in this dissertation, space-time discounting has a solid theoretical basis, is an important feature of human moral psychology, and factors prominently in major societal issues. Prior work on time discounting is extensive; the core contribution of the dissertation is to identify space as being just as significant to discounting as time is. In doing so, the dissertation opens up fertile lines of inquiry on space-time discounting. In short, with this dissertation, a new paradigm for space-time discounting has emerged.

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M.S. Electrical Engineering, Northeastern University, May 2006
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**Select Publications**
Baum, Seth D., Destiny D. Aman, and Andrei L. Israel. "Public scholarship student projects for introductory environment courses". *Journal of Geography in Higher Education*, in press.

Baum, Seth D., Jacob D. Haqq-Misra, and Shawn D. Domagal-Goldman, 2011. "Would contact with extraterrestrials benefit or harm humanity? A scenario analysis". Acta Astronautica, vol. 68, no. 11-12 (June-July), pages 2114-2129.

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Baum, Seth, 2007. "Beyond the Ramsey model for climate change assessments". *Ethics in Science and Environmental Politics*, vol. 2007, pages 15-21.

**Select Awards**
2010 Best Presentation Award. Technology, Management and Policy Graduate Consortium.

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2009-2010 Public Scholarship Fellow, Pennsylvania State University.

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2007 Winning essay, Ethics of Climate Change essay contest, Economics/Business section, *Ethics in Science and Environmental Politics*.