Individual and group behaviors for sustainability and climate change

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ABSTRACT

Several behavioral theories in economics and other disciplines consider that a set of preferences determines individual and social decisions. Risk and time preferences (or intertemporal problem) are the examples of preferences that shape several individual behaviors, while prosociality, reciprocity and trust represent several collective or social behaviors. Despite the overarching roles of the preferences on people's progress and development, they are also considered the causes of several social and environmental problems. In modern times, sustainability has emerged as the significant social problem, reflecting climate change, environmental pollution, depletion of various resources and COVID-19.

A vast majority of literature links these problems with equality, fairness and justice, arguing that they emerge because of people's actions who only care their benefits without considering others, particularly future generations. Since the problems are complex and multifaceted, their solutions need to be identified at the same level. For instance: the current political system does not include children and future generations in its decision-making process (i.e., institutional level); households are reluctant to mitigate the sources of climate change and/or do not adequately adapt in response to it (i.e., household level); and myopic tendency of individuals (i.e., individual level). Given the trends in decision-making processes at different levels, the literature suggests that global communities need various strategies and interventions to maintain sustainability and resolve climate change for future generations' welfare. More particularly, scientists and policymakers indicate the necessity of addressing these problems at institutional, social, household and individual levels. However, little is known about whether and how these problems can be resolved at different levels of decision making. To fill these gaps, the studies in this thesis apply survey and experimental approaches and examine individual and group behaviors to resolve sustainability and climate change in Nepal and Japan under various levels of decision making.

The first study examines group behavior for intergenerational sustainability (IS) under various forms of democracy. IS has emerged as the most serious social problem reflecting climate change and accumulation of public debt in modern democratic societies, undermining the potential interests and concerns of future generations. However, little is known about whether or not deliberative forms of democracy with majority voting helps support at maintaining IS by representing future generations' potential interests and concerns. Intergenerational sustainability dilemma game (ISDG) was instituted with three forms of decision-making models with majority voting and examine how they maintain IS in laboratory experiments. In ISDG, a sequence of six generations is prepared where each generation consisting of three subjects is asked to choose either maintaining IS (sustainable option) or maximizing their own generation's payoff by irreversibly costing the subsequent generations (unsustainable option) with anonymous voting systems: (1) majority voting (MV), (2) deliberative majority voting (DMV) and (3) majority voting with deliberative accountability (MVDA). In MV and DMV, generations vote for their choices without and with deliberation, respectively. In MVDA, generations are asked to be possibly accountable for their choices to the subsequent generations during deliberation, and then vote. The analysis shows that decision-making models with only majority voting generally does not address IS, while DMV and MVDA treatments induce more and much more generations to choose a sustainable option than MV, respectively. Overall, the results demonstrate that deliberation and accountability along with majority voting shall be necessary in models of decision making at resolving IS problems and representing future generations' potential interests and concerns.

The second study empirically analyzes the effects of the economic and cognitive factors on farmers' adaptation behaviors in agricultural sector of Nepal. This research addresses what matters for farmers' responses to the climate change, hypothesizing that farm size, climatic perceptions and the interplay between the two are key determinants. A questionnaire survey was conducted with 1000 farmers in Nepal, collecting data on their adaptation responses, farm size, climatic perceptions and sociodemographic information in Nepal. With the data, the statistical analysis is conducted by employing the index to reflect farmers' effective adaptation responses. The result reveals that farmers take adaptations as the farm size becomes small or as they have good climatic perceptions & social network with other

farmers. It also shows that small-sized farmers tend to adapt much more in response to their climatic perceptions than do large-sized ones. Overall, this research suggests that agriculture may be losing responsiveness to climate change, as large-sized farmers become dominant by holding a majority of land in developing countries. Thus, it is advisable to reconsider the tradeoff between productivity and responsiveness to climate change regarding farm size as well as how large-sized farmers can be induced to adapt through their cognition, policies, social networking and technology for food security.

The third study in this thesis examines people's intertemporal and intergenerational choices for resource sustainability, and analyzes how these choices are affected by the degrees of uncertainty (or survival probability), successors' existence and accountability to the successors. Field experiments are conducted by instituting sustainability game (SG) where a user is probabilistically determined to live up to the next period, and the probabilities are parametrized to represent different uncertainty by strategy method. In SG, a subject is asked, each period, to choose either prioritizing her current payoffs by irreversibly overutilizing the resource (unsustainable option A) or sustainably utilizing the resource (sustainable option B) for the future. Three treatments are prepared: (i) "no successors" (NS) in which a subject decides between options A and B in each period until she dies without successors, (ii) "existence of successors" (ES) in which another subject takes over the game as a successor when it ends for one subject by her death, and (iii) "intergenerational accountability" (IA) in which each subject is asked to write and pass the reason for her decisions and advice to her successors. Results demonstrate that improved survival probability and successors' existence are keys to improve resource sustainability. In particular, provided with successors, "IA" is found to further contribute to the sustainability, and the IA's positive effect nonlinearly inflates with survival probability (or life expectancy). This implies that not only arranging a successor but also institutionalizing accountability between current users and successors shall drastically enhance resource sustainability, even when societies suffer from aging and depopulation.

Keywords: sustainability; democracy; deliberation; intergenerational accountability; decision making; majority voting; experimental research; future generations; climate change; agriculture; farm size; cognition; adaptations; perceptions; interplay; successors; uncertainty; survival probability

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Chapter 1

Introduction

Recent international political discourses aim to avoid the dangerous climate change by keeping global warming below $1.5°$C (IPCC, 2018). This means that global greenhouse gas emissions must be reduced to 50 % by 2050 (Schneider, 2001; Meinshausen et al., 2009; Peters et al., 2012; Jacquet et al., 2013). To meet the target, individuals, societies and countries are required to make substantial sacrifices on their current consumptions and transfer them to the future selves or others. These sacrifices demand several adjustments in individual and group behaviors, and may need either improvement in existing institutions or require introduction of additional mechanisms at different levels of decision making, i.e, at institutional, household and individual levels. This thesis can be considered an attempt to find the ways by investigating individual and group behaviors for sustainability and climate change in different levels of decision making, and examine the effects of some social devices on people's behaviors for sustainability.

Literature reports that some features of democracy, such as election cycles, the dominance of political interests and the existence of some myopic voters, develop short-term tendencies (or presentism) in people's attitudes and behaviors, inducing the current generation not to consider future generations (Smith, 2003; Thompson, 2010; MacKenzie and O'Doherty, 2011; MacKenzie, 2016, 2018; Saijo, 2020). The short-term tendencies in democracy are exacerbated, especially when people become autonomous and alienated from societies with limited social interactions, making themselves myopic (Jacobs and Matthews, 2012; List et al., 2013; Saijo, 2020). There are uprising voices and demands to address IS problems so that future generations' welfare, concerns and voices should be reflected in the current practices of democracy (Mansbridge, 2003; Caney, 2018; Bogacki and Letmathe, 2021). Public protests around Greta Thunberg can be considered such an example for future generations' voices in relation to climate change (Bogacki and Letmathe, 2021).

Representation of future generations' voices in decision-making processes is claimed to be challenging under a democratic system (Strandberg, 2008; Fishkin, 2009; Gronlund et al., 2009; Geissel and Newton, 2012; Dangelico and Pontrandolfo, 2013; MacKenzie, 2016; Stoiciu and Gherghina, 2020). In numerous democratic countries, children and/or women are not permitted to vote in elections, and it highlights that underrepresentation of some groups other than future generations emerges as a general social problem. Such an underrepresentation problem is present in IS problems, such as climate change, where future generations cannot participate in the current decision-making process as they are yet to born (MacKenzie, 2018; Shahen et al., 2021). It affirms that a democratic system may need some new devices, innovations, reforms or transformations for addressing the underrepresentation as not only social but also IS problems (Geissel and Newton, 2012; Gonzalez-Ricoy and Gosseries, 2016; Elstub and Escobar, 2019b,a; Allegretti, 2014; Pickering et al., 2020). A group of scholars argues that deliberative forms of democracy can influence the current generation to consider future generations and their potential interests and concerns, possibly inducing them to be more sustainable or future-oriented (Gronlund et al., 2010; MacKenzie, 2018).

Climate change has brought several devastating consequences to the agricultural sector, posing a serious challenge to farmers' welfare (Rosenzweig et al., 2013; IPCC, 2014). There is an urgent need for farmers to take necessary adaptation responses to minimize the consequences of climate change (McCarthy et al., 2001; IPCC, 2014).[1] In the last two decades, improvement in farmers' capacity has been recognized to be the key element in enhancing their adaptation responses in both developed and developing countries (Yohe and Tol, 2002; Smit and Wandel, 2006; Vincent, 2007; Fussel, 2007; Cinner et al., 2018). In particular, economic and cognitive factors are crucial for farmers' adaptive capacity (Grothmann and Patt, 2005). This study addresses farmers' responsiveness to climate change in relation to economic and cognitive factors by investigating their adaptations.

Similarly, past studies examine group behaviors for sustainability by using experimental approaches, focusing on users' social interactions. Fischer et al. (2004) analyze resource sustainabil-

[1]Adaptation is defined as the adjustment of agronomic practices, agricultural processes and capital investments in response to observed or expected climate change risks (Easterling et al., 2007; IPCC, 2014).

ity in a common pool experiment, showing that an existence of "intergenerational link" minimizes the groups' resource exploitation. Chaudhuri et al. (2006) and Chaudhuri et al. (2009) analyze group behaviors, finding that communication, such as leaving advice to the subsequent groups, promotes intergroup coordination. Hauser et al. (2014) analyze group behaviors for sustainability under voting and non-voting decision-making processes and show that voting is effective at maintaining it if the majority generational members are prosocials. Sherstyuk et al. (2016) examine welfare outcomes with infinitely-lived and finitely-lived groups, finding that the decisions in the current period influence the welfare of the agents in future periods creating challenges to retain dynamic externalities with multiple generations than in infinitely-lived generation. Kamijo et al. (2017) design and conduct a laboratory experiment with Japanese students, showing that an inclusion of an imaginary future generation in the decision-making process of the current generation can induce intergenerational sustainability. In two separate field experiments conducted in Bangladesh and Nepal, Shahrier et al. (2017b) and Timilsina et al. (2017) find the differences in urban and rural group behaviors for sustainability. They argue that the difference is mainly driven by a variation in capitalism in rural and urban areas. Overall, these studies demonstrate the influences of various devices on user's group behaviors for sustainability under intergenerational setting.

Limited studies has examined how individual and group behave for sustainability and climate change. Therefore, in this research, we first analyze generation (or group) behaviors in ISDG and test how deliberative forms of democracy (with voting) resolve IS. Next, we systematically explore how economic and cognitive factors and their interplay affect farmers' adaptation responses to climate change using survey data of Nepal. Finally, we analyze individual intertemporal and intergenerational behaviors for sustainability in relation to uncertainty (or survival probability), successors' existence and accountability to successors in a single analytical framework.

The later parts of this thesis organized as follows: Chapter 2 presents the experimental study that examines group behaviors for intergenerational sustainability under different forms of democracy, has a title "Deliberative forms of democracy and intergenerational sustainability dilemma." Chapter 3 presents the study entitled "How farm size and perceptions matter for farmers' adaptation responses to climate change in a developing country? Evidence from Nepal," that addresses how farmers' economic and cognitive behaviors and interplay the two factors affect their adaptation responses toward climate changes. The study entitled "Resource sustainability on life expectancy, successors and accountability in intertemporal and intergenerational settings," presents the details of field experiment conducted in Nepal and its main results, is in Chapter 4. Finally, Chapter 5 concludes how these three studies address how individual and group behaviors for sustainability and climate change are affected by different factors at various levels of decision making, and provides some suggestions for future research.

Chapter 2

Deliberative forms of democracy and intergenerational sustainability dilemma

2.1 Introduction

People generally consider democracy to be a better option than some authoritarian system, and believe that it represents people, their interests and concerns (Przeworski et al., 1999; Fiorino, 2018; MacKenzie and Caluwaerts, 2021). With this belief, contemporary societies have adopted democracy and succeeded in achieving various economic, social and political objectives, such as poverty reduction, job creation, education and improvements in health-care facilities. However, modern democratic societies face intergenerational sustainability (IS) problems, such as climate change, resource sustainability, public debt accumulation and environmental pollution, and these problems are reported to affect future generations' welfare (Shearman and Smith, 2007; Gonzalez-Ricoy and Gosseries, 2016; Hansen and Imrohoroglu, 2016; Steffen et al., 2018; Caney, 2018; Bamber et al., 2019). IS problems arise when the current generation fails to consider the interests and concerns of future generations into their decision-making processes under a democratic system (Thompson, 2010; Gonzalez-Ricoy and Gosseries, 2016; MacKenzie, 2018).

Literature reports that some features of democracy, such as election cycles, the dominance of political interests and the existence of some myopic voters, develop short-term tendencies (or presentism) in people's attitudes and behaviors, inducing the current generation not to consider future generations (Smith, 2003; Thompson, 2010; MacKenzie and O'Doherty, 2011; MacKenzie, 2016, 2018; Saijo, 2020). The short-term tendencies in democracy are exacerbated, especially when people become autonomous and alienated from societies with limited social interactions, making themselves myopic (Jacobs and Matthews, 2012; List et al., 2013; Saijo, 2020). There are uprising voices and demands to address IS problems so that future generations' welfare, concerns and voices should be reflected in the current practices of democracy (Mansbridge, 2003; Caney, 2018; Bogacki and Letmathe, 2021). Public protests around Greta Thunberg can be considered such an example for future generations' voices in relation to climate change (Bogacki and Letmathe, 2021).

Representation of future generations' voices in decision-making processes is claimed to be challenging under a democratic system (Strandberg, 2008; Fishkin, 2009; Gronlund et al., 2009; Geissel and Newton, 2012; Dangelico and Pontrandolfo, 2013; MacKenzie, 2016; Stoiciu and Gherghina, 2020). In numerous democratic countries, children and/or women are not permitted to vote in elections, and it highlights that underrepresentation of some groups other than future generations emerges as a general social problem. Such an underrepresentation problem is present in IS problems, such as climate change, where future generations cannot participate in the current decision-making process as they are yet to born (MacKenzie, 2018; Shahen et al., 2021). It affirms that a democratic system may need some new devices, innovations, reforms or transformations for addressing the underrepresentation as not only social but also IS problems (Geissel and Newton, 2012; Gonzalez-Ricoy and Gosseries, 2016; Elstub and Escobar, 2019b,a; Allegretti, 2014; Pickering et al., 2020). A group of scholars argues that deliberative forms of democracy can influence the current generation to consider future generations and their potential interests and concerns, possibly inducing them to be more sustainable or future-oriented (Gronlund et al., 2010; MacKenzie, 2018). However, little is known how deliberative forms of democracy with voting can resolve IS problems and represent future generations' potential interests and concerns.

We systematically examine how two deliberative forms of democracy with majority voting enhance IS as compared to majority voting without deliberation. One of the specific IS problems is described by "intergenerational sustainability dilemma" (ISD), which is a situation where the current generation chooses to maximize (or sacrifice) its own benefits without (or for) considering future generations, compromising (or maintaining) IS (Kamijo et al., 2017; Shahrier et al., 2017b; Shahen et al., 2021). Thus, we institute intergenerational sustainability dilemma game (ISDG) with three forms of decision-making models with majority voting by experimentally manipulating prevoting components and examine how they maintain IS in laboratory experiments. In ISDG, a sequence of six generations is prepared where each generation consisting of three subjects is asked to choose either maintaining IS (sustainable option) or maximizing their own generation's payoff by irreversibly costing the subsequent generations (unsustainable option) with anonymous voting systems: (1) majority voting (MV), (2) deliberative majority voting (DMV) and (3) majority voting with deliberative accountability (MVDA). In MV and DMV, generations vote for their choices without and with deliberation, respectively. In MVDA, generations are asked to be possibly accountable for their choices to the subsequent generations during deliberation, and then vote. Our analysis shows that decision-making models with only majority voting generally does not address IS, while DMV and MVDA treatments induce more and much more generations to choose a sustainable option than MV, respectively. Overall, this study contributes to the literature by demonstrating that deliberation and accountability shall be necessary in decision-making models with majority voting at resolving IS problems. The message can be considered important when democratic countries and societies seek to address intergenerational fairness and/or justice along with an underrepresentation problem of future generations as argued by Caney (2018).

2.2 Theoretical section

The concept of democracy is too broad to cover in the limited space of a single study and there exists numerous definitions of democracy (May, 1978; Elliott, 1994; Przeworski et al., 1999; Dahl, 2001; Diamond and Plattner, 2006). For example, May (1978) defines "democracy as a responsive rule *qua* necessary correspondence between acts of governance and the desires with respect to those acts of the persons who are affected." Przeworski et al. (1999) defines democracy as a form of rules, and Dahl (2001) refers to democracy as actual governments that meet the following criteria: effective participation, voting equality, enlightened understanding, agenda control and inclusions of adults. Regardless of the aforementioned variations, it appears to take two main forms: (i) direct democracy and (ii) representative democracy. Direct democracy allows people to equally and directly participate in the decision-making process, such as discussion, voting or other acts of politics, and the examples include electronic, participatory and/or deliberative forms of democracy (Przeworski et al., 1999; Geissel and Newton, 2012; Warren, 2017; Haas, 2019). Representative democracy allows people to participate in-directly in the decision process and choose the representatives that make decisions on behalf of them. The examples include parliamentary and presidential forms of democracy (Przeworski et al., 1999; Diamond and Plattner, 2006). This study focuses on deliberative forms of democracy with voting in a class of direct democracy, considering that it is the first step to analyze their effects on human behaviors in IS under laboratory settings.

Several scholars have attempted to characterize democracy through models of decision making (Austen-Smith and Banks, 1996; Austen-smith and Feddersen, 2006; Jackson and Tan, 2013). The model of decision making is defined as a function which takes the votes (or choices) as input from the members in a group or society, delivering a collective decision as output (List, 2018). The model of decision making is claimed to consist of two components (i.e., components of models of decision making): (1) Prevoting component – a prior environment for people to engage, communicate and discuss socially on the common concerns, issues and agendas; and (2) Voting component – a rule that aggregates individual independent choices to a collective decision (Austen-Smith and Banks, 1996; Jacobs and Matthews, 2012; List, 2018). Deliberation and voting are regarded as components of the decision-making models, and majority voting is widely adopted (Warren, 2017). Literature suggests two main models of deliberative decision making: a pure deliberation model where participants deliberate and reach (or aim to reach) consensus for a collective decision without individual voting; and a mixed model of deliberation where participants deliberate and make a collective decision through individual voting (Austen-Smith and Banks, 1996; Jacobs and Matthews, 2012; List et al., 2013; List, 2018). Some theories suggest that deliberation (i.e., pure deliberation model) can play the following roles: (i) it enhances responsiveness to the people, groups and agendas (Warren, 2017); (ii) it connects people's preferences to a collective will by potentially generating epistemic and ethical goods through their reasons and arguments (Estlund, 2009; Mercier and Landemore, 2012; Landemore, 2013) and (iii) it helps to make a collective decision by agreements and commitments to the decision (Habermas, 1984; Elster, 1997; Habermas, 1994; Chambers, 2003; Mansbridge, 2003; Delli Carpini et al., 2004; Mansbridge et al., 2010; MacKenzie, 2018; MacKenzie and Caluwaerts, 2021). Warren (2017) argues that deliberation is weak to be able to represent some groups, such as young and ethnic groups, suggesting that some supplementary or complementary components, such as voting, may be necessary.

Past literature has examined the influence of the mixed model (i.e., deliberation is supplemented by individual voting) on human behaviors and the problem of underrepresentation for some groups by conducting surveys or controlled experiments (Strandberg, 2008; Dietz et al., 2009; Gronlund et al., 2009; Goeree and Yariv, 2011; Gherghina and Geissel, 2017, 2020; Setala, 2017; Setala et al., 2020). Luskin et al. (2002) conduct deliberative polls in UK and find that deliberation affects public preferences on some policies. List et al. (2013) find that the deliberation before voting brings a higher proximate single-peakedness in voters' preferences than the majority voting only utilizing deliberative polls data. In experimental studies, for example, Simon and Sulkin (2002) analyze the role of deliberation, concluding that deliberation enhances equitable outcomes for intra-generational members. Goeree and Yariv (2011) experimentally evaluate the effects of deliberation under various decision-making rules and demonstrate that it improves the efficiency of institutional decisions. Persson et al. (2012) analyze people's behaviors through field experiments and find that deliberation with voting increases perceived legitimacy of democratic procedure compared to non-voting. Ideally, deliberative forms of democracy should come with active participation of stakeholders and it may be necessary to include possible underrepresented groups in a decision-making process (Habermas, 1996). Stoiciu and Gherghina (2020) analyze the role of deliberation for underrepresentation problems, finding that it promotes inclusion of opinions from women, various social strata, ethnic and other minorities. However, another group of studies points out that deliberation may not be sufficient to resolve underrepresentation of some groups, especially young and uneducated people (Dalton et al., 2001; Jeydel and Steel, 2002; Gronlund et al., 2009; Strandberg, 2008; Gherghina and Geissel, 2017, 2020; Setala, 2017; Setala et al., 2020; Barbosa, 2020).

In the context of IS problems, future generations tend to be underrepresented in collective decision making (MacKenzie, 2016, 2018; Bogacki and Letmathe, 2021). The difficulty arises because future generations can neither communicate nor represent their voices with the current generation, especially when they do not have overlapping life time. For instance, climate change problems shall adversely affect future generations that are not born yet, however, such unborn future generations do not have any means to convey what they want to the current generation in the decision-making process. Several researchers have empirically and experimentally studied IS problems, employing some decision-making models of deliberation and/or voting (Fischer et al., 2004; Setala et al., 2010; Himmelroos and Christensen, 2013; Hauser et al., 2014; Sherstyuk et al., 2016; Fochmann et al., 2018; Kamijo et al., 2019; Nakagawa et al., 2019; Dryzek and Niemeyer, 2019; Katsuki and Hizen, 2020; Pandit et al., 2021; Bogacki and Letmathe, 2021; MacKenzie and Caluwaerts, 2021). Gronlund et al. (2009) compare people's knowledge and opinions on long-run energy politics under traditional face-to-face and online deliberation, suggesting that both settings enhance only people's knowledge. Setala et al. (2010) conduct pre-post surveys and deliberation on people's knowledge for the use of nuclear power plants, finding that deliberation promotes their knowledge than without deliberation. Himmelroos and Christensen (2013) examine public opinions on the use of nuclear power plants through conducting quasi-experiments, demonstrating that deliberation with high-quality arguments brings people's opinion changes. Hauser et al. (2014) analyze group behaviors for IS by conducting intergenerational goods games and suggest that voting reduces the exploitation of resources by restraining defectors. MacKenzie and Caluwaerts (2021) conduct online experiments and analyze group decisions for climate policies, showing that deliberation induces groups to support the policies.

Another group of studies focuses on how ISD can be resolved by deliberation or some institutions to represent future generations through conducting ISDG laboratory and/or field experiments under non-overlapping generation settings. Kamijo et al. (2017) conduct ISDG laboratory experiments with a student subject pool and show that introduction of a imaginary future generation (IFG) who are assigned to represent future generations in deliberation enhances IS. Shahrier et al. (2017b) and Timilsina et al. (2021a) conduct ISDG field experiments using a subject pool of the general public in urban and rural areas of Bangladesh and Nepal, respectively, and show that rural people choose sustainable options much more often than do urban ones. Shahrier et al. (2017a) further conduct ISDG field experiments in Bangladesh with subjects of urban people, demonstrating that future ahead and back mechanism (FAB that asks people to take the standpoint of future generations and to think about their requests to the current generation) induces people to choose sustainable options. Timilsina et al. (2019) conduct ISDG field experiments with a subject pool of general people in Nepal and conclude that intergenerational accountability (IA that asks people to be accountable for their decisions to future generations) is effective at maintaining IS. Katsuki and Hizen (2020) address people's behaviors under some voting rules in laboratory settings, finding that they fail in enhancing IS. Overall, these studies demonstrate that some attempts and institutions (with deliberation), such as IFG, FAB and IA, shall be able to address underrepresentation of future generations as well as to maintain IS.

In political science, *accountability* refers to a responsibility of decision makers on behalf of people spanning the obligations to report, explain and answer for the resulting consequences where people can sanction (or reward) the decision makers (Przeworski et al., 1999). Accountability holds when decision makers and receivers are engaged in two-way communication, and it is established that people become fair and/or just when they are accountable for their decisions (Tetlock, 1983, 1985). In the context of IS problems, such a two-way communication between the current and future generations is not always possible especially in the long-run perspective of non-overlapping generations (Shahen et al., 2021), and the only possible communication path is unidirectional or one-way communication from the current to future generations. Given this state of affairs, this research suggests IA mechanism along with deliberation in which people in the current generation are asked to be accountable for their decisions and leave their written reasons & advice to future generations, hypothesizing that IA brings fair and sustainable decisions of the current generation for IS.

In some real-life decision-making contexts, societies deliberate and conclude with majority voting on some salient and/or long-term problems, such as Brexit (in UK) and other instances. For examples, countries (e.g., Ireland and Iceland), political parties (e.g., Alternativet Party of Denmark, Czech Pirate Party of Czech and Demos Party of Romania), country representatives (e.g., UN) and officials follow deliberation and/or voting for making decisions whose influence affect future generations in the long run (Geissel and Newton, 2012; Vodova and Voda, 2020; Gad, 2020; Gherghina and Geissel, 2020; Gherghina and Stoiciu, 2020). In summary, not only the literature but also real-world social movements reveal that underrepresentation of future generations is considered a fundamental problem for democracy and IS (Habermas, 1984, 1994; Chambers, 2003; Mansbridge, 2003; Delli Carpini et al., 2004; Warren, 2017; MacKenzie, 2018; MacKenzie and Caluwaerts, 2021). To address the problem, we hypothesize that deliberation and/or IA induce people in the current generation to represent future generations' interests and concerns (or to be fair and/or just across generations), enhancing IS. Specifically, this research examines how two models of deliberative decision making with individual voting enhance IS as compared with individual voting without deliberation by conducting laboratory experiments. The following hypotheses are posed:

- **Hypothesis** 2.1: Intragenerational deliberation and individual voting (i.e., DMV) results in higher IS than only with individual voting (i.e., MV).
- **Hypothesis** 2.2: Intragenerational deliberation with intergenerational accountability and individual voting (i.e., MVDA) results in higher IS than only with individual voting (i.e., MV).

To test the two hypotheses, we empirically compare and characterize the probabilities for generations to choose a sustainable option across three models of decision-making, that is, MVDA, DMV, and MV, including other control variables (SVO, sociodemographic factors, and others) that will be discussed in the subsequent section. One important measurement is the probability for generations to choose a sustainable option, and it is considered a good approximation of IS. Because IS increases in the probabilities, the two hypotheses follow that probabilities for generations to choose a sustainable option are the highest in MVDA, the second in DMV, and the last in MV, respectively.

From a game theoretical view, choosing an unsustainable option is a Nash equilibrium (NE) strategy, as well as a dominant strategy for each generation in the IS dilemma game, because it maximizes their own payoff, irrespective of how other generations chose in the past and will choose in the future within the same sequence. On the other hand, all allocations in the IS dilemma game are Pareto-optimal in the sense that every allocation cannot be Pareto-improved by any other feasible allocation. For example, when every generation keeps choosing an unsustainable option, the resulting allocation is still considered Pareto-optimal. These features of the IS dilemma game arise from the fact that the current generation unidirectionally affects future generations, representing how it is challenging to maintain sustainability (Kamijo et al., 2017; Shahrier et al., 2017b; Saijo, 2020; Katsuki and Hizen, 2020).

There exists a unique allocation that leads to sustainability and maximizes the sum of payoffs for all the generations (i.e., social welfare) in the IS dilemma game. When every generation keeps choosing a sustainable option, the resulting allocation shall be considered socially desirable by not only maintaining sustainability, but also maximizing the sum of payoffs for all generations. The theoretical prediction suggests that people choose an unsustainable option and fail to maintain IS under the IS dilemma game in any model of decision-making. However, some behavioral and experimental studies in economics establish that people do not always follow NEs and dominant strategies in some situations (McKelvey and Palfrey, 1992; Binmore, 1994; Ochs, 1995; Goeree and Holt, 1999; Charness and Rabin, 2002; Holt and Roth, 2004; Garcia-Pola et al., 2020).

2.3 Experimental design

2.3.1 Experimental setup

We conducted laboratory experiments by following the IS dilemma game, a social value orientation (SVO) game and questionnaire surveys for each subject's critical thinking disposition, empathic concern, and sociodemographic information. Experiments were carried out in the laboratory of the Kochi University of Technology (KUT) with a total of 312 Japanese students, including 145 females and 167 males, aged between 18 and 23. The subjects were recruited from the student subject pool of KUT with various specializations, such as economics, engineering, management, and natural sciences. We used the laboratory experiments with student subjects due to the following reasons: (i) conducting laboratory experiments with KUT student subjects is cost-effective under our research budget and time constraints (Belot et al., 2015; Frechette, 2015; Nguyen, 2020), and (ii) university student subjects are homogeneous with respect to cognitive abilities, age, and other sociodemographics, and some confounding factors are avoided to test experimental treatment effects (Levitt and List, 2007; Alatas et al., 2008; Roe and Just, 2009; Falk and Heckman, 2009). Since our experiments were carefully designed to minimize the confounding factors, it is our belief that the directions and magnitudes of the treatments' effects from our laboratory experiments are reliable for external validity to a certain extent, as argued in

Levitt and List (2007) and Falk and Heckman (2009). At the same time, it shall be desirable to conduct some follow-up field or social experiments with subjects of the general public to rigorously establish the external validity in future.

Intergenerational sustainability dilemma game (ISDG)

We implement ISDG following the laboratory and field experiments of Kamijo et al. (2017) and Shahrier et al. (2017b). Building upon previous ISDG experiments, we add a new element of individual voting mechanism to the experimental design, the details of which are discussed later in this section. ISDG consists of a sequence of six generations. A "generation" is a group of three members, while in a "sequence," six chronologically arranged generations share the same resource (X) one after another. In ISDG, each generation is asked either to maintain intergenerational sustainability (IS) by choosing option B (sustainable option) or to maximize their own generation's payoff by choosing option A, imposing an irreversible cost to the subsequent generations (unsustainable option). By choosing option A, each generation receives a share of X. On the other hand, the generation receives a share of $X - 900$ by choosing option B.

We randomly assign each generation to the 1st, 2nd, $\ldots$ and 6th generations, respectively. The current generation's decision affects the subsequent generations such that subsequent generations' shares decline irreversibly and uniformly by 900 when the current generation chooses option A, otherwise not. For instance, suppose that $X = 3600$ and the 1st generation chooses option A. Then, the 2nd generation will face a game in which they receive 2700 and 1800 for choosing options A and B, respectively. However, if the 1st generation chooses option B, the second generation faces the same decision environment as that of the 1st generation faces. That is, when the 1st generation chooses option B, the 2nd generation faces the game receiving 3600 and 2700 by choosing options A and B, respectively. Following the same rules, the game continues for the subsequent generations (i.e., between ith and $i + 1$th generations) in a sequence. Hence, option B can be considered the "sustainable option," whereas option A is the choice that compromises IS and can be considered as the "unsustainable option."

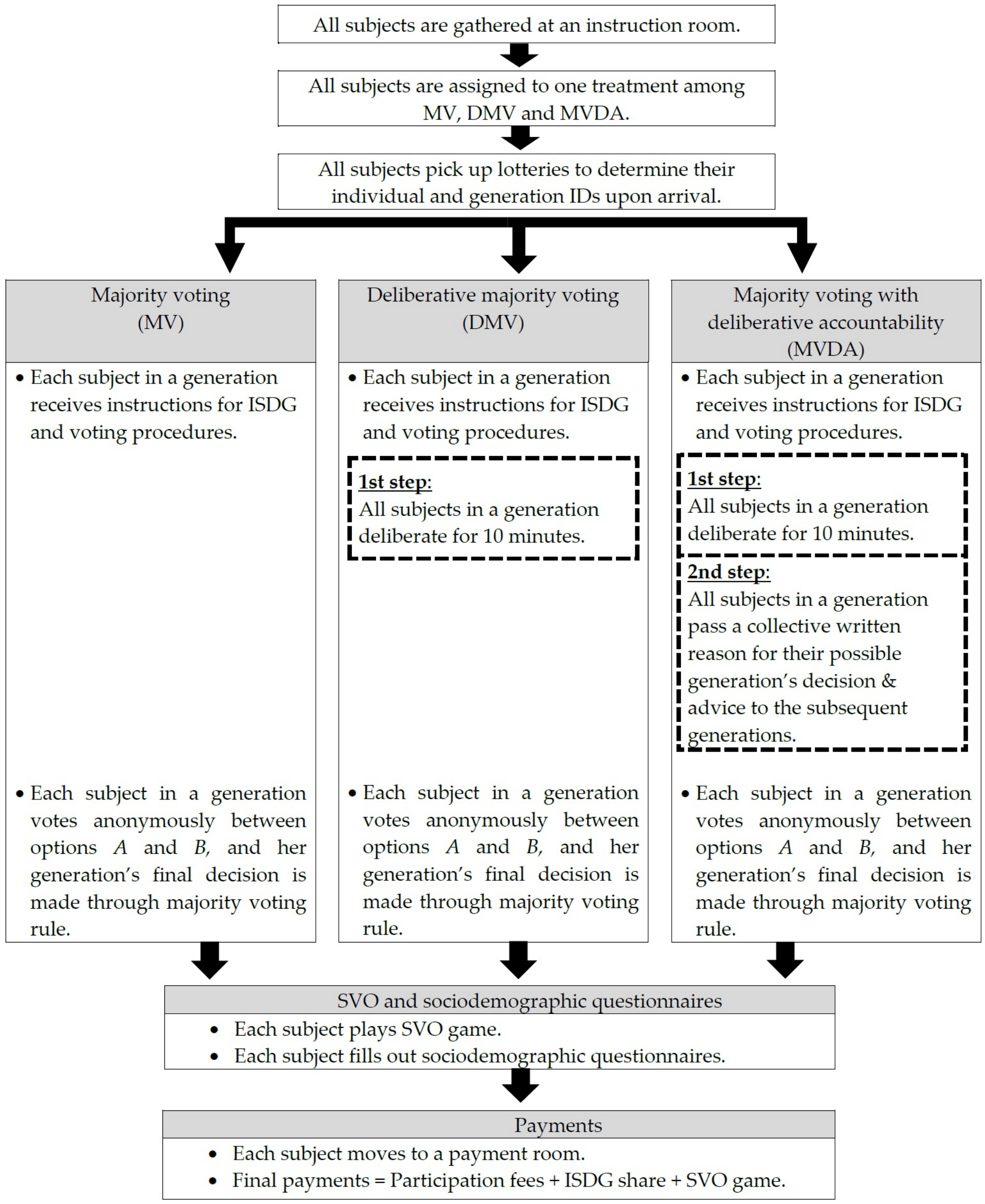


Figure 2.1: A flow chart of the procedures for one session.

In the experiments, the 1st generation starts the game with a share of $X = 3600$ experimental points, by choosing option A, the generation earns 3600 points, where by choosing option B, the generation earns 2700 points. Consequently, members of this generation split the points equally among themselves and each member earns 1200 points by choosing option A and 900 points by choosing option B as a generation share, respectively. ISDG experiment is designed in a way that the 5th and 6th generations possibly face the situation in which options A and B are associated with zero and negative shares, respectively. When the generations from the 1st to the 4th choose option A, then the 5th generation will face the game in which they receive generation shares of zero points and -900 points by choosing options A and B, respectively. If the generation's share is negative, say, $-Z$, each generation member will receive the equal points of $-Z/3$. When the subjects receive negative points, each of them needs to refund $Z/3$ points to the experimenter. In such situations, the points of $Z/3$ are deducted from each member's participation fee of 600 points so that individual payoff becomes at least nonnegative (See appendix).

As shown in figure 2.1 are three treatments namely, (1) majority voting (MV), (2) deliberative majority voting (DMV) and (3) majority voting with deliberative accountability (MVDA) that are as follows:

- **MV** (base group treatment): Three members in a generation are asked to cast their anonymous and independent votes for option A or option B. The members in a generation see the faces of each other, but they are not allowed to communicate before they vote. After each member's voting, the generation decision between options A and B is made by majority rule. Specifically, the majority rule means that the generation decision is made as A (or B) if two or all three members vote for option A (or option B).

- **DMV**: Three members in a generation are asked to deliberate over choosing between options A and B up to 10 minutes before they vote. After that, the members cast their anonymous and independent votes for option A or option B. The generation decision is made by majority rule as in MV.

- **MVDA**: Three members in a generation are asked to deliberate and collectively provide reasons & advice for their possible generation decision to the subsequent generations over choosing between options A and B up to 10 minutes. When the generations are not the 1st one, they receive reasons & advice from the previous generation(s) before deliberation. After that, the members cast their anonymous and independent votes for option A or option B. The generation decision is made by majority rule as in MV and DMV.

Social value orientation (SVO) and psychological factors

We use the "slider method" to identify the subjects' social preferences by understanding their social value orientation (SVO) (Murphy et al., 2011). SVOs are already well established to be stable for a long time (See, e.g., Van Lange et al. (2007) and Brosig-Koch et al. (2011)). The slider method consists of 6 items where each subject is asked to share an amount of money or points with another subject. Each item consists of nine pairs of distributions for self and the other. The average allocation of oneself $\overline{A_s}$ and average allocation for the $\overline{A_o}$ are computed from all 6 items. Then, 50 is subtracted from $\overline{A_s}$ and $\overline{A_o}$ to shift the base of the resulting angle to the center of the circle $(50, 50)$. The index of a subject's SVO is given by SVO = arctan $\frac{(\overline{A_s}-50)}{(\overline{A_o}-50)}$. We combine "altruist (SVO $> 57.15°$)" and "prosocial ($22.45° <$ SVO $< 57.15°$)" types into a single category of "prosocial;" "individualist ($-12.04° <$ SVO $< 22.45°$)" and "competitive (SVO $< -12.04°$)" to "proself" as it is often done in psychology research for presenting results in a simple way. The subjects are informed in detail that their total payoffs from the SVO game are dictated by their own and anonymous pair's choices. The subjects are instructed about the game rules, points and total payoffs they receive from the game. The subjects perform the SVO tasks individually and submit their sheets to research assistants (RAs). RAs calculate the total payoff by randomly matching between the subjects from the same days session.

2.3.2 Experimental procedures

The first author administered the experiments with research assistants (RAs). One session comprises ISDG, SVO, sociodemographic questionnaires and payments. For each session, 18 subjects ($= 6$ generations) were gathered at an instruction room, and one treatment among MV, DMV and MVDA was randomly assigned (Figure 2.1). We announced that no communications were allowed without any permission. Then, the 18 subjects read and watched written and video instructions for ISDG. We also made an oral presentation, conducting Q&A and quizzes for double-checking subjects' understanding. Unless the subjects correctly answered, we did not proceed to ISDG. At the beginning of ISDG, each subject drew a chip from a bag to determine his/her sequence (i), generation (j) and individual IDs (k). Each chip displays a letter (e.g., P, Q, R) corresponds to $i \cdot j$ - k (Figure 2.2). In each session, the i takes one letter out of three from $\{P, Q, R\}$ and j takes one number out of $\{j', j'+1\}$ for $j' = \{1, 3, 5\}$ (e.g., $j = \{1, 2\}$ when $j' = 1$; $j = \{3, 4\}$ when $j' = 3$). In figure 2.2, for example, $P1$ and $P2$ corresponds to j' and $j' + 1$ when $j' = 1$ for the sequence $i = P$. The k takes one number out of $\{1, 2, 3\}$ as an individual ID in a generation. The subjects whose generation IDs belong to a class of $i \cdot j'$ (e.g., $P1, Q1, R1$) first moved to different game rooms and went through ISDG. Those with $i \cdot j' + 1$ (e.g., $P2, Q2, R2$) stayed in the instruction room and filled out SVO and questionnaires, while waiting. Second, the subjects with $i \cdot j' + 1$ moved to the game rooms and went through ISDG as the next generation, after confirming that the subjects with $i \cdot j'$ finished and were ready to get back to the instruction room to complete SVO and questionnaires. In this step, we were careful about the routes and logistics in the way that the subjects with $i \cdot j' + 1$ neither meet those with $i \cdot j'$ nor find which room each subject in the previous generation was in.

One RA was present in each game room, and three subjects in a generation were guided to take their respective independent seat according to the individual IDs and to check their understanding about the prevoting procedures per treatment (See figure 2.1 for the detailed procedures per treatment). The members were also guided to observe the previous generations' decisions and their payoffs between options A and B on a white board in the room. When subjects were in the 1st generation, the RA told them that they did not have any previous generation. After confirming the understanding and situations associated with payoffs in ISDG, subjects went through all the procedures per treatment under the RA's support, and each subject anonymously and independently voted for option A or option B. The RA counted their votes, announcing the generation decision by majority voting rule in each room. The three subjects recorded their individual and generation decisions and returned to the instruction room, finalizing the remaining tasks, such as SVO and sociodemographic questionnaires. Finally, the subjects received their payments with some exchange rates according to their decisions. The payment for each subject was calculated as a summation of his/her earnings from the (i) participation fee, (ii) ISDG with

1 point $= 2$ JPY and (iii) SVO game with 1 point $= 1$ JPY where each subject receives on average 300 JPY, 1970 JPY and 900 JPY, respectively. In total, 17 sessions were completed and 312 subjects (or 104 generations) participated where one session was conducted with 24 subjects.

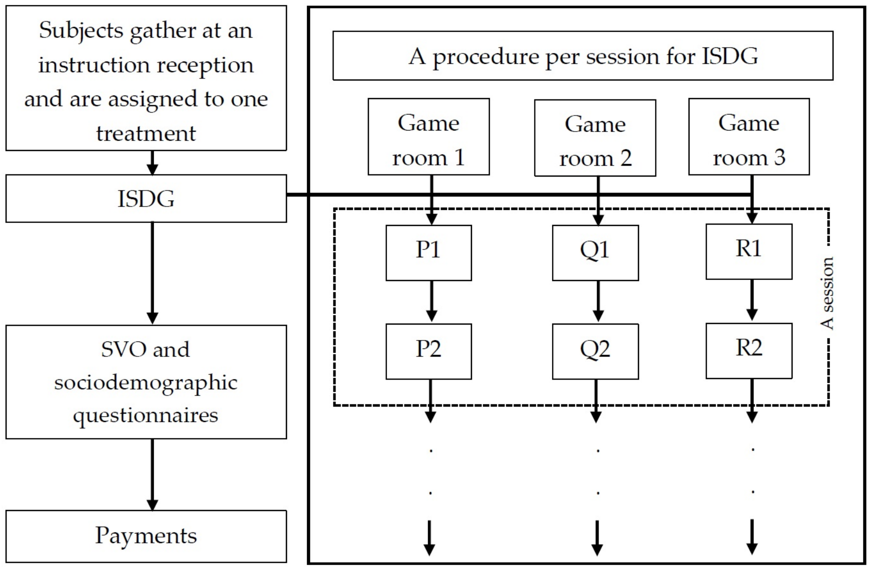


Figure 2.2: A flow chart of the procedures for one session.

2.4 Results

Table 2.1 presents the definitions and descriptions of sociodemographic and psychometric variables used in the analyses. A total of 312 (104) subjects (generations) participate in the experiments with 105 (35), 99 (33) and 108 (36) in majority voting (i.e., MV), deliberative majority voting (i.e., DMV) and majority voting with deliberative accountability (i.e., MVDA) treatments, respectively (See table A2.3 in appendix). Similarly, 46.47 % female subjects participate in the experiments, and the percentages are 51.42 %, 43.43 % and 44.44 % in MV, DMV and MVDA treatments, respectively. These facts reflect that there is a proper gender balance across the treatments. Past literature establishes that gender affects attitudes and behaviors and might bring differences in preferences between males and females in some contexts of economic decision making (Croson and Gneezy, 2009).

Table 2.2 presents the frequencies and the percentages of generation choices between options A and B in ISDG by treatments. As shown, only 2 (5.71 %) of the total 35 generations choose option B

Table 2.1: Definitions & descriptions of the variables.

Variables	Definitions & descriptions
Dependent variables	
Choice B	A dummy variable that takes 1 if a generation chooses option B; otherwise, 0.
Independent variables	
Treatment dummies (Base group = MV)	
DMV	A dummy variable that takes 1 if a generation is in DMV treatment; otherwise, 0.
MVDA	A dummy variable that takes 1 if a generation is in MVDA treatment; otherwise, 0.
Sociodemographic and psychometric variables	
Prosocial	A number of members in a generation whose social value orientation is categorized as "prosocial."
Gender	A number of female members in a generation.
Empathic concern	Summation of a subject's empathic concern measured in 5-points Likert scale, ranging from 0 to 28 points.
Personal distress	Summation of a subject's personal distress measured in 5-points Likert scale, ranging from 0 to 28 points.
Critical thinking disposition	Summation of subject's critical thinking dispositional scale measured from 5-points Likert scale, ranging from 13 to 65 points.

Table 2.2: The frequencies and percentages of generation choices between options A and B by treatments.

	Frequency and percentage of option B choice			
Choices A or B	MV (N = 35)	DMV (N = 33)	MVDA (N = 36)	Overall (N = 104)
A	33 (94.29 %)	29 (87.88 %)	26 (72.22 %)	88 (84.62 %)
B	2 (5.71 %)	4 (12.12 %)	10 (27.78 %)	16 (15.38 %)
Subtotal	35 (33.66 %)	33 (31.73 %)	36 (34.61 %)	104 (100 %)

Note: MV vs. DMV ($\chi^2 = 0.867, P = 0.352$), MV vs. MVDA ($\chi^2 = 6.151, P = 0.013$) and DMV vs. MVDA ($\chi^2 = 2.610, P = 0.106$)

in MV. Among the 33 generations, 4 (12.12 %) choose option B in DMV. Of the total 36 generations, 10 (27.78 %) choose option B in MVDA. The results show that generation choices of option B are higher in DMV and MVDA than those in MV. To test whether the distributions of generation choices between options A and B are independent of the treatments, we perform chi-squared (χ^2) test by taking the following pairs: MV vs. DMV, MV vs. MVDA and DMV vs. MVDA, using the frequencies as summarized in table 2.2. A null hypothesis is that the distribution of generation choices between options A and B are the same for each pair of treatments. The results reject the null hypothesis for MV vs. MVDA. However, we fail to reject the null hypotheses for MV vs. DMV and DMV vs. MVDA. Overall, the results confirm that the distributions of the generation choices between options A and B in MVDA are different from those in MV.

For a robustness check, we apply nonparametric test by considering the correlation among the

Table 2.3: Marginal effects of independent variables on the probability of option B choice in logit regressions (base group = option A choice).

	Option B choice		
	Model 1	Model 2	Model 3
Independent variables			
Treatment dummies (base group = MV)			
DMV	0.064*	0.087**	0.070*
	(0.038)	(0.040)	(0.040)
MVDA	0.221***	0.140***	0.138***
	(0.042)	(0.036)	(0.036)
Sociodemographic and psychometric variables			
Prosocial		0.116***	0.112***
		(0.016)	(0.016)
Gender			−0.016
			(0.016)
Empathic concern			0.019***
			(0.006)
Personal distress			−0.016**
			(0.007)
Critical thinking disposition			1.964×10^{-4}
			(0.006)
Observations (generations)	104	104	104

Note: (1) Standard errors clustered at the sequence level are in parenthesis, (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$ and (3) Marginal effects are calculated at the same means of independent variables.

observations of generation choices within a sequence. To this end, we cluster the generation choices at a sequence level. There is a total of 19 sequences, six each in MV and DMV, while there are seven in MVDA. We calculate the average for each sequence of generations that choose option B and run Mann-Whitney test to confirm the null hypotheses that the distributions of the averages for the sequences are the same in each pair of treatments. We find that the distributions of averages for the sequences of generations that choose option B are different and significant at 1 % for MV vs. DMV, MV vs. MVDA, and DMV vs. MVDA, respectively. Overall, the generations in DMV and MVDA appear to choose option B more often than those in MV treatment.

Finally, to characterize the effects of treatments on generation choices of option B, we run logit regression by taking generation choices between options A and B as the dependent variable that takes unity when a generation chooses option B, otherwise zero. The independent variables are the treatment dummies (DMV and MVDA), a number of prosocial members in a generation (prosocial), average critical thinking disposition, average empathic concern and average personal distress and gender (a number of females in a generation). Since generation decisions are taken at the generational level, we take an average or a summation of independent variables for the analyses (See the definitions of independent variables in table 2.1). We report the marginal effects of the treatment dummies and other independent variables from models 1 to 3 in table 2.3. The marginal effects of the treatment dummies can be considered causal due to their random assignments (Angrist and Pischke, 2009). In model 1, we present the marginal effects of the treatment dummies. In model 2, we add a number of prosocial individuals in a generation. Finally, in model 3, we further add other sociodemographic variables, such as gender, average critical thinking disposition, average empathic concern and average personal distress, for a robustness check.

Models 1, 2 and 3 in table 2.3 show that the marginal effects of DMV on generation choices of option B are economically and statistically significant ($P = 0.076$). They demonstrate that the generations in DMV have 7 % higher probability of choosing option B than those in MV, holding all other factors fixed. We also find that the marginal effects of MVDA on generation choices of option B are economically and statistically significant ($P < 0.01$), reflecting that the generations in MVDA have 13.8 % higher probability of choosing option B than those in MV. In summary, deliberation and accountability (i.e., DMV and MVDA treatments) result in higher percentages of option B choices than without deliberation (i.e., MV treatment). The results support hypotheses 2.1 and 2.2, being consistent with the theories related to deliberation, such as “the theory of communicative actions,” advocating that deliberation among the participants along with reasoning helps achieve better social outcomes (Habermas, 1984).

We conduct further analysis by running logit regressions to estimate the IA effect on generation choices of option B. For this, we take DMV treatment dummy as the base group, excluding the observations in MV. Our result shows that the generations in MVDA are 5 % more likely to choose option B than those in DMV (See table A5 in appendix). The result can be interpreted as an additional effect of IA on generation choices of option B. This result supports our hypothesis 2.3 that intragenerational deliberation with intergenerational accountability (i.e., MVDA treatment) results in higher percentages in generation choices of option B than does deliberation (i.e., DMV treatment). Note that generation members in MVDA need to deliberate about the reasons & advice for their possible decision between options A and B. We realize that those who choose option B have often written *"we should not harm others,"* and/or *"we feel bad to hurt others, therefore, we have chosen option B."* as part of their reasons & advice. Such statements imply that IA might have influenced the generation members to be sympathetic with and/or take future generations' perspective, choosing option B. On the other hand, generations that choose option A have typically written *"we choose option A since it gives us more points,"* and *"we should think about ourselves, not about others,"* reflecting their self-maximization motives. Overall, IA appears to function as a one-way communication device via receiving and giving reasons & advice over generations for maintaining IS in comparison with DMV treatment where such a communication opportunity is missing.

Models 2 and 3 in table 2.3 show that a number of prosocial members per generation is economically and statistically significant ($P < 0.01$) (See also table A2.4 in appendix). The results demonstrate that the generations are 11.2 % more likely to choose option B with an increase in prosocial members per generation. The results are consistent with previous studies that find the positive influence of prosociality on people's behaviors for IS (Hauser et al., 2014; Shahrier et al., 2017b; Kamijo et al., 2017; Timilsina et al., 2017). The result in table 2.3 shows that the generations are 1.9 % more likely to choose option B when the average empathic concern of generation members increases by one additional point ($P < 0.01$). Our result is consistent with previous findings, showing that empathic concern induces people to value others' benefits (Kirman and Teschl, 2010; Artinger et al., 2014; Font et al., 2016). The result shows that the generations are 1.6 % less likely to choose option B with an additional unit increase in average personal distress of a generation members, implying that personal distress might induce people to make more unsustainable choices (Sapolksy, 2017).

2.5 Conclusion

We institute ISDG with three forms of decision-making models by experimentally manipulating prevoting components and examine how they maintain IS in laboratory experiments. Game theory predicts that generations choose an unsustainable option in ISDG, and our results in the base group (MV) are in line with the prediction. Other two models of deliberative decision making (i.e., DMV and MVDA) are found to be more effective than MV. We also find that a majority of generations still chooses an unsustainable option in all treatments. The results imply that maintaining IS shall be very challenging with majority voting, especially when generations are neither biologically nor socially connected, i.e., non-overlapping generation. However, when deliberation and one-way communication (IA) from the current generation to future generations are introduced along with majority voting, generations choose to be sustainable.

Deliberative theories and the associated empirical studies reveal that the effect of deliberation is context-specific as argued before, and it is well known that the deliberation effect can be either positive or negative to have a socially desirable outcome (Habermas, 1994; Pettit and Rabinowicz, 2001; List, 2006; MacKenzie, 2018; Delli Carpini et al., 2004; Warren, 2017). Delli Carpini et al. (2004) summarize that deliberation can be ineffective or counterproductive in some situations. Game theory also predicts that a majority of people should choose an unsustainable option as suggested by NE and dominant strategies. These facts imply that ISDG can be interpreted to be one specific situation where deliberative forms of democracy with voting does not have a huge positive effect on IS. The interpretation appears to reflect our results that the percentages of generations that choose a sustainable option in DMV and MVDA treatments remain low around 12.12 % and 27.78 %, respectively.

We conjecture that people in MVDA treatment are engaged more seriously in deliberation than those in DMV treatment through being accountable (i.e., writing and leaving their reasons & advice to future generations, i.e., IA mechanism), inducing people to choose a sustainable option. We raise the three possible channels: (i) warm-glow (or guilt aversion), (ii) legacy motive (as a cooperator) and (iii) moral commitment (Charness and Dufwenberg, 2006; Thompson, 2010; Fox et al., 2010;

MacKenzie, 2018; Wade-Benzoni, 2019). First, people in the current generation may feel warm-glow or guilt aversion by leaving nice reasons & advice to future generations associated with a sustainable option choice (MacKenzie, 2018). Second, IA might have functioned as a one-way communication device for the current generation to have a legacy motive of being a cooperation initiator or successor, giving an opportunity of receiving and sending generations' decisions with reasons & advice (Kotre, 1996, 2011; Timilsina et al., 2019; Wade-Benzoni, 2019). Third, IA might have triggered people to have a moral commitment across generations in the sense that being accountable is known to signify fairness and/or justice concerns in people's judgment and decisions (Tetlock, 1983, 1985; Self et al., 2015). Thompson (2010) and MacKenzie (2018) also argue that children and/or future generations are main subjects of such a moral commitment.

Nearly 60 % of the countries and four billion people of the world have adopted democratic institutions in the last century (Roser, 2018). Most of these democratic countries and populations rely on anonymous voting to make important social or political decisions that have future consequences for the subsequent generations without requiring deliberation and accountability. Importantly, it is very likely that societies and countries will continue voting as a democratic mechanism in future (Hill, 2013). In the real world, however, there are several examples of deliberation and accountability practices (See Geissel and Newton (2012); Vodova and Voda (2020); Gherghina and Geissel (2017); Gad (2020); Stoiciu and Gherghina (2020)). Some mini-publics, local assemblies (called "gram shabhas") and ad hoc committees are reported to be successful in development activities by introducing deliberation practices in collective decision making, materializing their social goals (MacKenzie and O'Doherty, 2011; Geissel and Newton, 2012; Ban et al., 2012; Warren and Gastil, 2015; Parthasarathy and Rai, 2017; Setala, 2017; Setala et al., 2020). Wales has attempted to institutionalize public accountability for future generations' wellbeing that can be considered one example of accountability practices in public policy (Davies, 2016, 2017). To resolve not only for IS but also for the problem of underrepresentation of future generations, it shall be necessary to institutionalize deliberation and accountability, as far as democracy remains as a main form of political systems (Gad, 2020; Stoiciu and Gherghina, 2020). Although it would be challenging to implement large-scale deliberative and accountability processes, there are several advanced technologies that could enable this, such as social media and online platforms (Strandberg, 2008; Gronlund et al., 2009). It is our belief that deliberation and accountability are integral elements for human societies to transition to be sustainable, and it shall be possible when technologies are integrated with democratic systems.

Finally, we note some limitations and possibilities for future research. First, we should not overlook that generations fail in ensuring IS under three models of decision making, implying that some drastic change or new forms of social institutions along with democracy may be necessary as discussed in literature (Kamijo et al., 2017; Shahrier et al., 2017b; Saijo, 2019; Bogacki and Letmathe, 2021; Saijo, 2020). Second, we only consider direct democracy as experimental treatments in this research. However, in the contemporary world, representative (or indirect) democracy is popular. It is important to examine IS under some forms of indirect democracy in the future. Third, as posited by Habermas, the deliberation in our experiment does not satisfy the "ideal speech" condition (Habermas, 1984, 1994), and the number of generation members is limited to be three. Future studies should be able to investigate IS by extending the deliberation conditions, such as the number of generation members. Fourth, this study includes only Japanese students from the student subject pool of KUT so that the effects of treatments can be under or overestimated. Future studies in this domain should examine IS by taking subjects from a general public pool for external validity. These caveats notwithstanding, we believe that this work is an essential step as experimental research, suggesting how two forms of deliberative democracy can enhance IS and represent potential interests of future generations.

Chapter 3

How do farm size and perceptions matter for farmers' adaptation responses to climate change in a developing country? Evidence from Nepal

3.1 Introduction

Climate change has brought several devastating consequences to the agricultural sector, posing a serious challenge to farmers' welfare (Rosenzweig et al., 2013; IPCC, 2014). There is an urgent need for farmers to take necessary adaptation responses to minimize the consequences of climate change (McCarthy et al., 2001; IPCC, 2014).[1] In the last two decades, improvement in farmers' capacity has been recognized to be the key element in enhancing their adaptation responses in both developed and developing countries (Yohe and Tol, 2002; Smit and Wandel, 2006; Vincent, 2007; Fussel, 2007; Cinner et al., 2018). In particular, economic and cognitive factors are crucial for farmers' adaptive capacity (Grothmann and Patt, 2005). This study addresses farmers' responsiveness to climate change in relation to economic and cognitive factors by investigating their adaptations.

Farm size is one of the key economic factors for farmers' agricultural activities in response to climate change (Ullah et al., 2019; Kumar et al., 2020). Several studies examine adaptations in relation to farm size, focusing on subsistence farmers by conducting questionnaire surveys (Eitzinger et al., 2018; Ontl et al., 2017; Trinh et al., 2018; Abid et al., 2019; Khan et al., 2020; Ahmed et al., 2021). A group of studies shows positive associations between farm size and farmers' adaptation responses (Piya et al., 2012; Ashraf et al., 2014; Belay et al., 2017; Trinh et al., 2018). For instance, a recent study by Jiao et al. (2020) analyzes adaptation decisions and intensities, showing that farm size matters only for

[1] Adaptation is defined as the adjustment of agronomic practices, agricultural processes and capital investments in response to observed or expected climate change risks (Easterling et al., 2007; IPCC, 2014).

the intensities. Another group of studies reports negative associations between farm size and adaptation responses to climate change (Deressa et al., 2010; Uddin et al., 2014; Amare and Simane, 2017). For example, a study by Khan et al. (2020) investigates adaptation choices, and demonstrates that farm size inhibits farmers from choosing some adaptations, such as irrigation time changes and the use of short duration varieties. Overall, the literature establishes that farm size is an influential factor for farmers' adaptation responses to climate change. However, the directions and magnitudes of the influence of farm size are mixed with positive and negative associations.

Past literature examines the relationship between farmers' or people's climatic perceptions and responses to climate change by conducting questionnaire surveys (Below et al., 2012; Niles et al., 2013; Abid et al., 2016; Ndamani and Watanabe, 2015; Azadi et al., 2019; Soubry et al., 2020).[2] Arbuckle Jr et al. (2013) analyze climatic perceptions and attitudes in the United States, indicating that farmers tend to display positive attitudes toward adaptations when they perceive climate change. Islam et al. (2016) analyze the relationship between climatic perceptions and willingness to pay (WTP) for flood mitigations by taking a sample of 1011 people in Bangladesh, and show that people with correct perceptions tend to have higher WTP than those without them. Abid et al. (2019) examine climatic perceptions and adaptation intentions by taking 450 farmers from Pakistan as a sample, finding the positive effects of the perceptions on their intentions. Khanal et al. (2018) and Khanal and Wilson (2019) investigate adaptations by taking the Nepalese samples, showing that farmers who believe in climate change adapt more than those who do not. Overall, these studies establish that farmers or people tend to respond to climate change when they perceive climate change or have correct perceptions of temporal trends in climate variables.

There is a growing number of studies that indicates the negative effects of climate change on farmers in developing countries (Parry et al., 2004; Chinowsky et al., 2011; Wheeler and von Braun, 2013; Bandara and Cai, 2014). These countries possess some characteristics, that make them relatively vulnerable to climate change compared to developed countries, such as (i) clear realizations of climate change (i.e.,

[2] Climatic perception is defined as a state of opinions and/or awareness toward the changes in climate variables (Ruiz et al., 2020).

a rise in temperature and changes in rainfall patterns), (ii) agriculture-based economies and (iii) people's limited cognitive, economic and technological capacities to adapt (Yohe and Tol, 2002; Smit and Wandel, 2006; Mertz et al., 2008). Nepal is a developing country that possesses the characteristics where agriculture has been a major source of income and employment.[3] A considerable portion of Nepalese farmers are still subsistence farmers who rely on rainfall for production, and Nepal is one of the countries most affected by climate change (Malla, 2009; Manandhar et al., 2010; Pandit et al., 2014; Practical Action, 2014; IPCC, 2014; Shrestha et al., 2019). Specifically, incidences of floods, droughts, heat and cold waves have increased over time because of climate change, suggesting that the negative impacts on agriculture can only be reduced through adaptations (Manandhar et al., 2010; Piya et al., 2012; Gentle and Maraseni, 2012; Gurung et al., 2012; Pant, 2013; Poudel et al., 2017; Khanal and Wilson, 2019; Thakuri et al., 2019; Khanal et al., 2018, 2020; Budhathoki et al., 2020; Khanal et al., 2021). Thus, it is important to investigate how farmers in Nepal, i.e., a representative country among developing ones, adapt to climate change.

Previous studies indicate that socioeconomic and cognitive factors play substantial roles in improving farmers' adaptive capacities and their responses to climate change (Piya et al., 2012; Khanal and Wilson, 2019; Budhathoki et al., 2020). However, there have been few studies on farmers' adaptations in relation to farm size and cognitive factors. Given this scarcity, we empirically investigate what matters for farmers' adaptation responses to climate change, focusing on their farm size and climatic perceptions. We conduct a questionnaire survey with 1000 farmers in Nepal, and collect data on their adaptation responses, farm size, climatic perceptions and sociodemographic information. With the data, we conduct statistical analysis by employing an index reflecting farmers' effective adaptation responses. The novelty of this study lies in (i) covering a wide range of farmers from subsistence to large-sized commercial farmers and (ii) analyzing how Nepalese farmers' adaptations differ by farm size, climatic perceptions and the interplay between them in a single empirical framework. This study contributes to the literature by addressing farmers' adaptability and their resilience against climate

[3]Agriculture in Nepal contributes about 27.1 % to the gross domestic product (GDP) and employs nearly 61 % of the population (Ministry of Finance, 2020).

change in Nepal and developing countries with similar contexts, being suggestive for achieving the UN Sustainable Development Goals (SDGs) (Acuti et al., 2020; Khanal et al., 2021).

3.2 Theoretical framework and hypotheses

Economic theories suggest that farmers' objectives are profit (or production) maximization and cost minimization, and the associated empirical approaches, such as the profit or production function approach, are used to estimate the effects of inputs and interventions on agricultural outputs and profits (Sadoulet and De Janvry, 1995; Evenson and Pingali, 2007; Ntakyo and van den Berg, 2019). However, these approaches cannot be applied in some situations, especially when farmers vary in terms of their objectives as well as the types (or a number) of crops they grow. In Nepalese agriculture, farmers' objectives are observed to be heterogeneous in that some farmers follow cost minimization and others follow production maximization depending on the farm size and context. This study deals with a wide range of farms of different size who have distinct objectives by growing heterogeneous crops, and this poses a difficulty in applying the economic approaches for our empirical analysis. Considering these facts and contexts, we adopt sociocognitive approaches to analyze farmers' adaptation responses to climate change and combine them with some economic factors, such as farm size, agricultural training and other variables.

Literature suggests that economic and cognitive factors are important for farmers' adaptations to climate change (Brondizio and Moran, 2008; Abid et al., 2019). Two sociocognitive theoretical models, (i) protection motivation theory (Rogers, 1983; Rogers and Prentice-Dunn, 1997) and (ii) private proactive adaptation model to climate change (Grothmann and Patt, 2005), argue that economic factors, cognition and their interaction characterize people's adaptation responses. In economics, it is established that firm size and their flexibility (or adaptability) have an inverse relationship (Mills and Schumann, 1985; Fiegenbaum and Karnani, 1991; Lin et al., 2019). In agriculture, large-sized farmers are not flexible enough to adjust their activities as compared to small-sized farmers (Uddin et al., 2014; Khan et al., 2020). However, little is known about how farm size, climatic perceptions and the interplay between them affect farmers' adaptations to climate change in a single analytical framework. Given this state of affairs, we propose the following three hypotheses: (i) Hypothesis 3.1: Farm size influences farmers' adaptations to climate change, (ii) Hypothesis 3.2: Climatic perceptions induce farmers to take adaptations to climate change and (iii) Hypothesis 3.3: There exists an interplay between farm size and climatic perceptions on farmers' adaptations.

3.3 Methodology

3.3.1 Study areas and data collection

The primary data were collected from the former five development regions (Eastern, Central, Western, Mid-Western and Far-Western), covering ten districts of Nepal as shown in figure 3.1.[4] This study was carried out from December 5, 2013 to February 2, 2014. The districts were randomly selected for broad geographic coverage.[5] One rural or urban municipality or metropolitan city was randomly identified in each selected district where agriculture was the main occupation for most households. After consulting with selected site officers, we identified one or two wards for the study. A list of households (HHs) was obtained from the site office for each identified ward as a sampling frame and utilized to select HHs to be surveyed. Using a systematic random sampling method, we identified 25-55 HHs for each ward and collected information of a total of 1000 HHs from the study areas (see table A3.1 in the Appendix).

The questionnaires were prepared in the local Nepali language, pre-tested with non-sampled HHs and finally administered to the sampled HHs in the study areas. We hired ten graduate students from Agriculture and Forestry University (AFU), who worked as research assistants (RAs) in this study. The RAs received a one-day orientation session that covered the study's objectives. They additionally received instructions to collect informed consent from the HHs, which ensured the anonymity of the

[4]Nepal underwent administrative reform in 2017, where development regions were either replaced or revised to be provinces (see table A3.1 in Appendix).

[5]The study areas included only hill and terai districts since the agricultural activities are primarily carried out in such areas.

individual information obtained in the surveys. Finally, the RAs administered the questionnaire survey and obtained the necessary information from the study areas under the direct supervision of the first author.

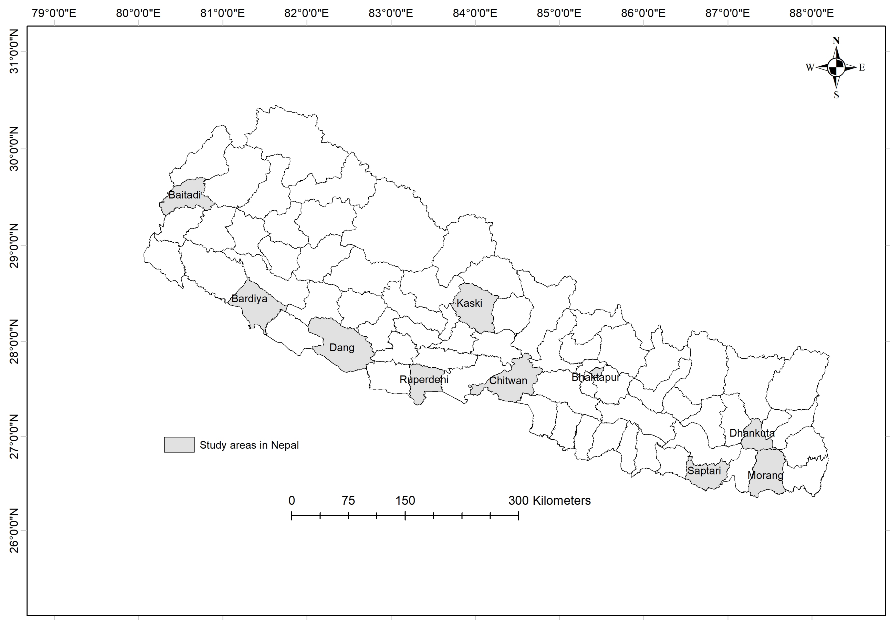


Figure 3.1: A map of Nepal showing the study areas.

3.3.2 Key variables

We ask several questions to the HH heads (hereafter, farmers), and obtain farm-related information, such as farm size (or land), adaptations and the land area covered by each adaptation. We also collect information related to cognitive & non-cognitive factors, such as climatic perceptions and education, and other sociodemographic variables from farmers (see table 3.1 for details). By following Piya et al. (2012) and Below et al. (2012), we prepare a list of adaptations to be able to ask farmers whether or not they engage in a particular adaptation. Since not all listed adaptations might necessarily be applied by farmers in the study areas, we pre-tested, revised the list and included it in the final questionnaire. Farmers can adjust farm activities depending on external factors, such as prices, demand, income along with climate change. Thus, we explicitly ask the farmers to report only those adjustments (i.e., adaptations) from the list that are taken in response to climate change. Following the list, each farmer j is asked two questions: (1) Have you adopted a particular adaptation "a_i" in your farm? and (2) To what extent does the "a_i" cover your farm (or land) "w_{ij}?"

Based on these questions and answers, we calculate two outcome variables or measurements for effective adaptation responses to climate change: AdaptN and AI. The respective value of AdaptN (the number of adaptations) for the jth farmer is calculated as follows:

$$\text{AdaptN}_j = \sum_{i=1}^{n} a_{ij} \tag{3.1}$$

where subscript i indicates an index of adaptations for $i = 1, \ldots, n$, and a_{ij} is a dummy variable for adaptation i that takes a value of 1 if the jth farmer adapts; otherwise, it takes 0. The respective value of AI (adaptation index) for the jth farmer is calculated as follows:

$$\text{AI}_j = \sum_{i=1}^{n} a_{ij} w_{ij} \tag{3.2}$$

where $w_{ij} = \frac{\text{Farm-size coverage of } a_{ij}}{\text{Total land of the } j\text{th farmer}}$ with $0 \leq w_{ij} \leq 1$, following Below et al. (2012) and Khanal and Wilson (2019). The theoretical values of the AdaptN_j and AI_j range from 0 to n.

Suppose that the jth farmer engages in two adaptations of a_{1j} and a_{2j} with 75 % and 60 % farm-size coverage, respectively. In this case, the AdaptN_j is 2, while the AI_j is 1.35 $(= 1 \times 0.75 + 1 \times 0.60)$. Thus, the value of AI_j depends not only on whether the jth farmer takes a particular adaptation (a_i) but also on the extent to which each adaptation a_i covers his/her farm size, i.e., w_{ij}. The difference in the two measurements of AdaptN_j and AI_j lies in whether to consider a weight for each adaptation. AdaptN_j considers only the incidences of all adaptations and the associated sum by assuming that each adaptation covers an entire farm (i.e., $w = 1$). However, it is crucial to consider a weight for each adaptation (Below et al., 2012; Khanal and Wilson, 2019). Therefore, we consider both AdaptN_j and AI_j in analyzing farmers' adaptation responses for the purposes of comparison and robustness checks.

Farm size and climatic perceptions are two major independent variables in this study. To make a uniform unit of measurement, the farm size of the jth farm is first recorded in the local unit (Kattha), and it is computed to hectares (ha) by multiplying it with a conversion factor of 0.0333 $(= \frac{1}{30})$.[6] Following

[6]Note that 1 hectare $=$ 30 Kattha $= 10000$ square meters.

Table 3.1: Definitions & descriptions of the variables.

Variables	Definitions & descriptions
Dependent variables	
# of adaptations (AdaptN)	A total number of adaptations taken by the farmer.
Adaptation index (AI)	An aggregate index value for the farmer calculated as the summation of all adaptations weighted by their respective proportion of farm-size coverage.
Independent variables	
Cognitive & non-cognitive variables	
Climate perception index (CPI)	A number of perceived changes in temperature, rainfall, drought, hot waves, cold waves and flood by the farmer within the last 20 years that ranges between 0-8.
Farming experience	Years of agricultural experience of the farmer.
# of agricultural trainings	A number of agricultural trainings taken by the farmer in the last 5 years.
Years of schooling	The highest level of schooling for the farmer.
# of social networks	A number of social groups where the farmer is engaged in.
Access to information	A dummy variable that takes 1 if the farmer has access to agricultural information; otherwise, 0.
Sociodemographic variables	
Marginal farmer	A dummy variable that takes value 1 if the farm size of the farmer is < 0.16 ha; otherwise, 0.
Small farmer	A dummy variable that takes value 1 if the farm size of the farmer is ≥ 0.16 ha & < 0.33 ha; otherwise, 0.
Medium farmer	A dummy variable that takes value 1 if the farm size of the farmer is ≥ 0.33 ha & ≤ 1.00 ha; otherwise, 0.
Large farmer	A dummy variable that takes value 1 if the farm size of the farmer is > 1.00 ha; otherwise, 0.
# active family members	The number of economically active family members of the farmer.
HH annual income	The amount of monetary (NPR) earnings of the farmer's family members.
Gender (base group = female)	A dummy variable that takes 1 if the farmer is male; otherwise, 0.
Distance to agricultural services	Distance in kilometers (km) for the farmer to reach the nearest agricultural service center.
Market distance	Distance in kilometers (km) for the farmer to reach the nearest market.

Thapa et al. (2019) and Kumar et al. (2020), farmers are categorized into four dummies based on their farm size: (i) marginal farmer (farm size < 0.16 ha), (ii) small farmer (0.16 ha $\leq$ farm size < 0.33 ha), (iii) medium farmer (0.33 ha $\leq$ farm size $\leq$ 1.00 ha) and (iv) large farmer (farm size $>$ 1.00 ha). Hereafter, these farm-sized variables are expressed to be farm-size dummies. For climatic perceptions, we ask eight questions to farmers regarding how they have perceived the changes in eight climate variables: summer temperature, winter temperature, drought, cold waves, hot waves, rainfall frequency, intensity and flood over the last 20 years (Manandhar et al., 2010; Below et al., 2012; Piya et al., 2012; Shrestha et al., 2019). An example of such questions is "Have you noticed the changes in the pattern of summer temperature in the last 20 years?" If yes, each farmer proceeds with being asked to report his/her perception of the temporal trend as an increase or a decrease. We record farmers' replies for all eight questions and later compute each of them to be either 1 or 0. If the farmer perceives a change, i.e., either an increase or a decrease, we assign the value as 1, otherwise, we assign it as 0. Finally, we calculate the aggregate climatic perception index (CPI) to be the sum of all perception-related answers by the jth farmer to the questions on the eight climate variables (Below et al., 2012; Shrestha et al., 2019).

3.3.3 Statistical analysis

This study first calculates, analyzes and interprets the mean, median, standard deviation, minimum and maximum of the key variables. Second, it conducts some statistical analyses, such as Mann-Whitney nonparametric tests, to identify some qualitative relations between the key variables. To quantitatively examine the relationship between adaptation responses as the dependent variables and the independent variables, the Poisson and median regression models are employed. We choose the Poisson regression for characterizing AdaptN_j because it is a variable of nonnegative integers with relatively few observations for each count. We are interested in estimating the effect of an independent variable on AdaptN_j with the assumption that AdaptN_j follows the Poisson distribution conditional on a vector of the independent variables, $\mathbf{X}$. The likelihood function of AdaptN_j conditional on the observations of $\mathbf{X}$ is expressed as:

$$\text{Prob}(\text{AdaptN}_j = h|\mathbf{X} = \mathbf{x}_j) = \exp[-\exp(\mathbf{x}_j\boldsymbol{\alpha}')][\exp(\mathbf{x}_j\boldsymbol{\alpha}')]^h/h!, \quad h = 0, 1, 2, \ldots, n \tag{3.3}$$

where subscript j is the farmer's ID, $\mathbf{x}_j = (1, x_{1j}, x_{2j}, \ldots, x_{kj})$ is a vector of independent variables observed from the jth farmer, $\boldsymbol{\alpha} = [\alpha_\ell]_{\ell=0}^k = (\alpha_0, \alpha_1, \ldots, \alpha_k)$ is a vector of coefficients associated with $\mathbf{x}_j$ to be estimated and h is the number of adaptations the jth farmer takes. The estimate for each coefficient of the vector $\boldsymbol{\alpha}$ is obtained via the quasi-maximum likelihood estimation method for the Poisson regression based on equation (3.3) (Ramirez and Shultz, 2000; Cameron and Trivedi, 2005; Wooldridge, 2019). Each estimated coefficient can be interpreted as a percentage change with $100 \times \alpha_\ell$ (or [$\exp(\alpha_\ell) - 1$]$\times 100$) in $\mathbb{E}(\text{AdaptN}_j|\mathbf{X})$ when one continuous (or dummy) independent variable increases by one unit (or from zero to one), holding other factors constant.

We use median regression to analyze the relationship between AI_j and the independent variables as specified in equation (3.4) because the AI does not follow a normal distribution on the Shapiro-Wilk tests (Kraska-Miller, 2009; Corder and Foreman, 2014). Median regression is considered more appropriate than the mean-based regression in characterizing a nonnormal dependent variable in relation to independent variables (Koenker and Bassett, 1978; Koenker and Hallock, 2001). Mathematically, median regression is expressed as follows:

$$\text{AI}_j = \mathbf{x}_j\boldsymbol{\beta}' + \epsilon_j \tag{3.4}$$

where AI_j is the dependent variable of the adaptation index for farmer j, $\mathbf{x}_j = (1, x_{1j}, x_{2j}, \ldots, x_{kj})$ is the vector of the independent variables, $\boldsymbol{\beta} = (\beta_0, \beta_1, \ldots, \beta_k)$ is a vector of the coefficients associated with $\mathbf{x}_j$ to be estimated via the least absolute distance estimation method and ϵ_j is an error term. Each coefficient is interpreted as a change in the AI median when one continuous (or dummy) independent variable increases by one unit (or from zero to one), holding other variables constant. The results from the Poisson and median regression models are demonstrated and compared between AdaptN and AI associated with the same set of independent variables.

3.4 Results

Table 3.2 presents summary statistics of the variables across farm size. The results indicate that farmers engage in agricultural activities on 0.83 ha of land (farm size) on average. Regarding farming experiences, farmers do not differ considerably in terms of farm size, having approximately 20 years of average experience. Farmers participate in agricultural trainings 0.34 times, and the averages are $0.28, 0.28, 0.35$ and 0.42 for marginal, small, medium and large farmers, respectively. This suggests that farmers tend to participate in agricultural trainings as farm size increases. Farmers generally attain a formal education level of 6.38 years of schooling, and they are engaged in 1.43 social networks, such as cooperative and farm field schools. The averages of schooling years for marginal, small, medium and large farmers are $5.96, 6.97, 6.11$ and 6.63, respectively, implying that farmers tend to have higher education level as farm size increases. With respect to social networks, the averages are $1.37, 1.44, 1.47$ and 1.38 for marginal, small, medium and large farmers, respectively, demonstrating no considerable differences in social networks across farm size.

About 50.00 % of the farmers have access to agricultural information, while the percentages are observed to be approximately 50.00 %, 44.00 %, 50.00 % and 55.00 % for marginal, small, medium and large farmers, respectively. It appears that access to agricultural information does not significantly differ among farmers. The average size of economically active family members (i.e., the labor force) is 3.43, while the averages are not substantially different across farm size. In the study areas, 87.00 % of the farmers are identified to be male and the percentages are similar across farm size. The overall average household (HH) annual income for farmers is 346 thousand NPR, and it appears that farmers' incomes rise from 271.59 to 438.76 thousand NPR as farm size increases. Farmers have average distances of 3.23 km and 2.70 km to reach the nearest agricultural extension services and the market, respectively and the distances do not significantly differ across farm size. Overall, the summary statistics suggest that farmers are similar in terms of agricultural training, education level, active family size, gender, distances to agricultural services and the market, while they differ in terms of social networks, access to information and HH annual income.

Table 3.2: Summary statistics of the variables by farm size.

Variables	Farm-size dummy				
	Marginal farmer ($N = 147$)	Small farmer ($N = 208$)	Medium farmer ($N = 426$)	Large farmer ($N = 218$)	Overall ($N = 999$)
Dependent variables					
# of adaptations (AdaptN)					
Mean (Median)[1]	7.97 (6.00)	7.54 (6.00)	7.73 (7.00)	8.19 (8.00)	7.82 (7.00)
SD[2]	5.43	4.68	4.32	4.34	4.58
Min	0.00	0.00	0.00	0.00	0.00
Max	22.00	24.00	24.00	24.00	24.00
Adaptation index (AI)					
Mean (Median)	2.52 (2.00)	1.62 (1.22)	1.00 (0.52)	0.79 (0.25)	1.31 (0.86)
SD	2.03	1.52	1.15	1.04	1.49
Min	0.00	0.00	0.00	0.00	0.00
Max	9.91	9.50	6.95	5.00	9.91
Independent variables					
Cognitive & non-cognitive variables					
Climate perception index (CPI)					
Mean (Median)	5.07 (5.00)	5.06 (5.00)	4.82 (5.00)	5.18 (5.00)	4.99 (5.00)
SD	2.43	2.21	2.21	2.10	2.22
Min	0.00	0.00	0.00	0.00	0.00
Max	8.00	8.00	8.00	8.00	8.00
Farming experience					
Mean (Median)	21.93 (21.00)	19.07 (19.00)	19.90 ((20.00)	19.31 (18.00)	19.89 (20.00)
SD	12.07	12.13	11.40	12.00	11.80
Min	1.00	1.00	1.00	1.00	1.00
Max	50.00	50.00	70.00	60.00	70.00
# of agricultural trainings					
Mean (Median)	0.28 (0.00)	0.28 (0.00)	0.35 (0.00)	0.42 (0.00)	0.34 (0.00)
SD	0.86	0.72	1.02	1.03	0.94
Min	0.00	0.00	0.00	0.00	0.00
Max	5.00	5.00	15.00	10.00	15.00
Years of schooling					
Mean (Median)	5.96 (6.00)	6.97 (8.00)	6.11 (7.00)	6.63 (8.00)	6.38 (8.00)
SD	4.63	4.85	5.06	5.15	4.98
Min	0.00	0.00	0.00	0.00	0.00
Max	17.00	15.00	18.00	17.00	18.00
# of social networks					
Mean (Median)	1.37 (1.00)	1.44 (1.00)	1.47 (1.00)	1.38 (1.00)	1.43 (1.00)
SD	1.09	1.09	1.11	1.11	1.10
Min	0.00	0.00	0.00	0.00	0.00
Max	4.00	4.00	5.00	4.00	5.00
Access to information					
Mean (Median)	0.50 (0.00)	0.44 (0.00)	0.50 (0.50)	0.55 (1.00)	0.50 (0.00)
SD	0.50	0.50	0.50	0.50	0.50
Min	0.00	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00	1.00
Sociodemographic variables					
# of active family members					
Mean (Median)	3.49 (3.00)	3.17 (3.00)	3.49 (3.00)	3.55 (3.00)	3.44 (3.00)
SD	2.06	1.69	1.66	1.52	1.71
Min	1.00	0.00	0.00	1.00	0.00
Max	15.00	12.00	13.00	11.00	15.00
Gender (base group = female)					
Mean (Median)	0.84 (1.00)	0.87 (1.00)	0.86 (1.00)	0.89 (1.00)	0.87 (1.00)
SD	0.36	0.34	0.35	0.31	0.34
Min	0.00	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00	1.00
HH annual income ('000)					
Mean (Median)	271.59 (229.00)	239.72 (188.50)	376.24 (240.00)	438.76 (2900.00)	346.06 (240.00)
SD	232.98	209.98	689.37	608.40	552.62
Min	0.00	0.00	0.00	0.00	0.00
Max	1480.00	1730.00	8400.00	5940.00	8400.00
Distance to agricultural services					
Mean (Median)	2.99 (3.00)	3.05 (2.50)	3.52 (3.00)	2.98 (2.50)	3.23 (3.00)
SD	2.38	2.67	3.17	2.87	2.90
Min	0.00	0.00	0.00	0.00	0.00
Max	12.00	15.00	18.00	12.00	18.00
Market distance					
Mean (Median)	2.37 (1.50)	2.93 (1.50)	2.80 (1.50)	2.49 (1.50)	2.70 (1.50)
SD	2.88	3.68	3.66	3.50	3.53
Min	0.00	0.00	0.00	0.00	0.00
Max	20.00	18.00	25.00	19.00	25.00

Notes: marginal farmer (farm size < 0.16 ha), small farmer (0.16 ha $\leq$ farm size < 0.33 ha), medium farmer (0.33 ha $\leq$ farm size ≤ 1.00 ha) and large farmer (farm size > 1.00 ha).

[1] Median values are in parentheses.

[2] SD indicates standard deviation.

Figure 3.2 is a bar graph to present the percentages of farmers who have perceived some changes in eight climate variables over the last 20 years. A majority of farmers has perceived changes in summer temperature, winter temperature, rainfall intensity, rainfall frequency and drought, whereas approximately 50.00 %, 38.00 % and 22.00 % of them perceive cold waves, hot waves and floods, respectively. The results imply that climate change is perceived as an ongoing phenomenon in the study areas, and Nepalese farmers' perceptions are consistent with previous literature (Manandhar et al., 2010; Piya et al., 2012; Khanal and Wilson, 2019; Shrestha et al., 2019). To understand how the perceptions vary across farm size, we calculate the perceptions to be a climate perception index (CPI) for comparison (table 3.2). The overall mean and median values of CPI are found to be 4.99 and 5.00, respectively, ranging between 4.82 and 5.18 across farm size. These values demonstrate that farmers have homogeneous climatic perceptions.

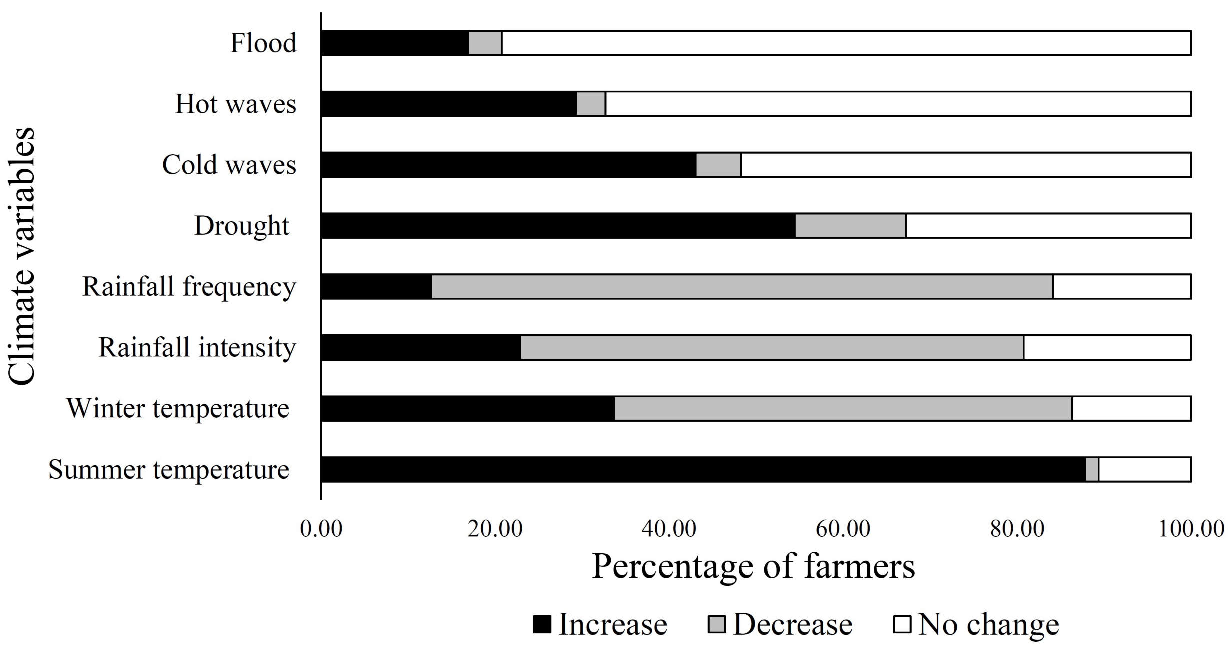


Figure 3.2: Bar graph of the percentage of farmers perceiving changes in climate variables.

Table 3.2 shows that farmers take 8.00 adaptations on average with the median value of 7.00 and some variation across farm size. The median AdaptNs are 6.00 for both marginal and small farmers, while they are 7.00 for medium and large farmers, respectively. There is a tendency for farmers to take adaptations as farm size increases. The tendency is confirmed from figure 3.3(a), which depicts boxplots of AdaptN by farm size. We run the Mann-Whitney test to examine distributional differences in AdaptNs across farm size, and apply it to every pair of different-sized farmers. The null hypothesis is that the distributions of AdaptNs between two different-sized farmers are the same. Table 3.3 shows that the null hypothesis is rejected only for the pair of small and large farmers at 5 % level ($P < 0.05, z = -2.017$). This implies that farmers' adaptations do not statistically depend on farm size, while we note a tendency for large-sized farmers to take adaptations.

The value of the average AI for farmers is 1.31, while the averages are $2.52, 1.62, 1.00$ and 0.79 for marginal, small, medium and large farmers, respectively (table 3.2). The average AIs are not only different from one another but also tend to decline when farm size increases, i.e., from marginal to large farmers. The results imply that farmers curb adaptation coverage as farm size increases. The tendency is confirmed from figure 3.3(b), that demonstrates the boxplots of AIs across farm size. We run the Mann-Whitney test to examine distributional differences in AIs across farm size, and apply it to every pair of different-sized farmers. The null hypothesis is that the distributions of AIs between two different-sized farmers are the same. Table 3.3 shows that the null hypotheses are rejected for all pairs of farmers at 1 % level, suggesting that AIs statistically depend on farm size.

Table 3.4 reports adaptations and the percentages of farmers taking them by farm size. The results reveal that farmers' adaptation responses vary across farm size. For example, nearly 38 % of large farmers use the pump irrigation method as an adaptation, while the percentages are 65.55 %, 52.40 % and 64.55 % for marginal, small and medium farmers, respectively. Only about 1.00 % of large farmers adapt mixed cropping, while more than 28.00 % of marginal, small and medium farmers take it. There are considerable differences between large farmers and other farmers in some adaptations, such as supplementation with organic/FYM or inorganic fertilizers. More than 63.00 % of marginal, small and medium farmers adapt inorganic and/or organic supplements, while only less than 36.00 % of large farmers take them. Overall, these results suggest that the kinds and actions of farmers' adaptation responses highly depend on farm size, indicating the possible reasons for the tendencies of AdaptN and AI, as observed in figure 3.3.

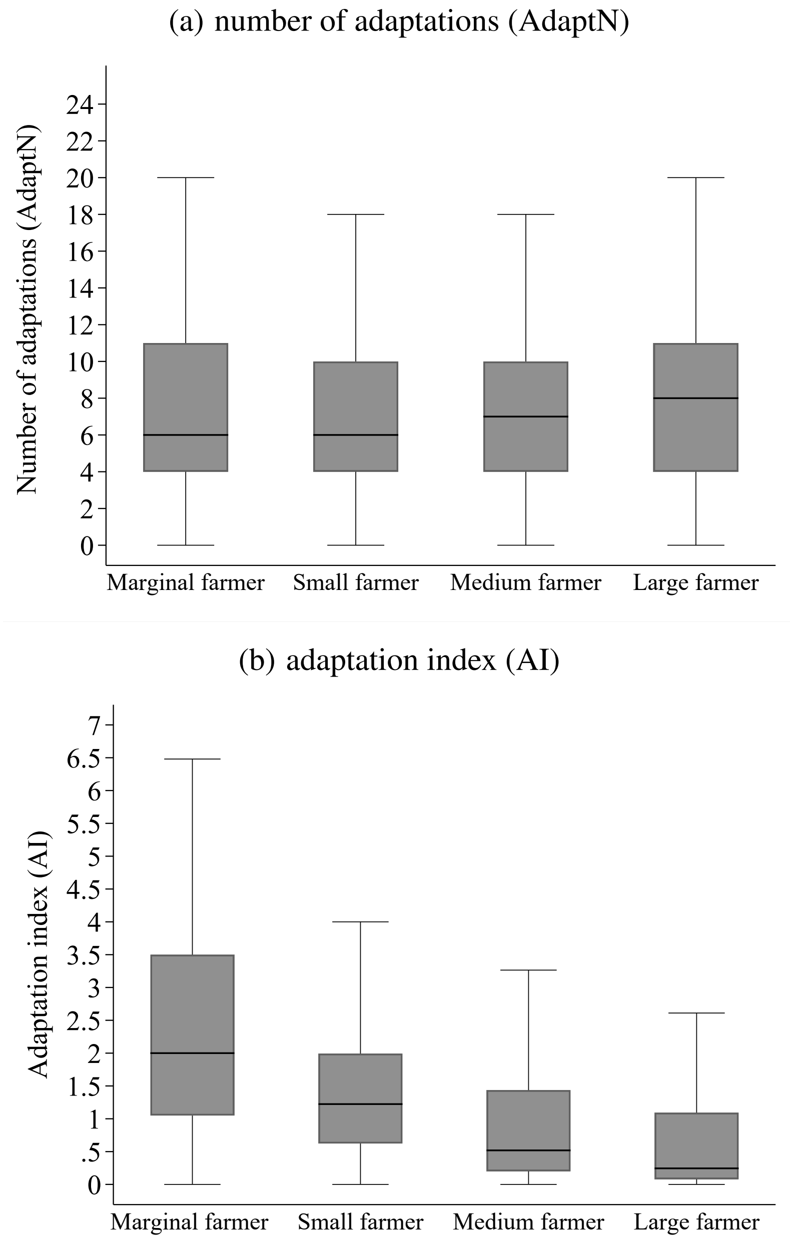


Figure 3.3: Box plots of (a) the number of adaptations (AdaptN) and (b) the adaptation index (AI) by farm size.

Table 3.5 reports the estimated coefficients of the independent variables on AdaptN in the basic Poisson regression model along with the standard errors and statistical significance. Based on the basic model, other specifications as well as interaction terms are proposed to check the robustness of the results. The main results are found to remain qualitatively the same in all models. We primarily focus on reporting the effects of farm size, CPI, agricultural trainings, social networks, access to information,

Table 3.3: Mann-Whitney test of a number of adaptation (AdaptN) and adaptation index (AI) by farm size.

	Test	
Pair of different-sized farmers	AdaptN	AI
Small vs. marginal farmer	−0.259	−4.611***
Medium vs. small farmer	1.175	−6.695***
Large vs. medium farmer	1.390	−3.939***
Medium vs. marginal farmer	0.623	−9.341***
Large vs. small farmer	2.017**	−8.083***
Large vs. marginal farmer	1.335	−9.427***

Notes: (i) *** $P < 0.01$, **$P < 0.05$ and * $P < 0.10$; and (ii) marginal farmer (farm size $<$ 0.16 ha), small farmer (0.16 ha $\leq$ farm size $<$ 0.33 ha), medium farmer (0.33 ha $\leq$ farm size $\leq$ 1.00 ha) and large farmer (farm size $>$ 1.00 ha).

HH annual income, distances to agricultural service and the market on AdaptN, because they are of particular interest in drawing implications in this research or stand statistically significant in the models.

The coefficients of farm-size dummies on AdaptN are not statistically significant through models 1, 3 and 5. However, the coefficients for the medium-farmer dummy become statistically significant at 1 % to 5 % level when we include interaction terms between the farm-size dummies and CPI in models 2, 4 and 6. Model 2 demonstrates that medium farmers are likely to have additional 60.64 % AdaptN compared to marginal farmers (the base group), holding other variables fixed. The results could be because medium farmers consist of both motivations and/or affordability to take adaptations compared to other-sized farmers, as pointed out by previous studies (Piya et al., 2012; Jiao et al., 2020). Overall, the results suggest that farm size does not strongly influence farmers to adapt, except for medium farmers through the interaction with CPI.

The coefficients of CPI are statistically significant and positive at 1 % level in models 3 and 5, and they remain so at the same level, when we include interaction terms between farm-size dummies and CPI in models 2, 4 and 6. For instance, model 3 shows that farmers tend to take additional 6.10 % AdaptN when CPI improves by one unit. Previous studies similarly find that farmers' adaptations are highly affected by their climatic perceptions (Deressa et al., 2009; Khanal and Wilson, 2019; Azadi

Table 3.4: Percentage of farmers taking adaptations by farm size.

	Percentage (%)				
Adaptations	Marginal farmer ($N = 147$)	Small farmer ($N = 208$)	Medium farmer ($N = 426$)	Large farmer ($N = 218$)	Overall ($N = 999$)
Soil and water management					
Pump irrigation	65.55	52.40	64.55	37.79	64.16
Surface irrigation	25.17	38.46	37.79	17.61	35.34
Bucket irrigation	41.50	29.33	33.33	11.97	31.53
Ridge/terrace construction	44.90	38.46	41.55	24.41	20.32
Mulching	10.88	15.38	9.62	20.19	17.52
Sprinkle irrigation	3.40	8.65	10.80	6.34	9.61
Deep tillage	9.52	5.77	11.27	3.99	9.11
Growing hedges	12.24	10.10	8.22	3.05	8.71
Cover crops	4.08	6.25	7.75	2.35	6.21
Construction of reservoirs & channels	2.04	0.96	3.05	1.17	1.90
Diversion ditches	4.76	0.96	2.11	1.17	1.90
Water harvesting and/or plastic ponds	0.00	0.48	0.94	0.47	1.50
Adjustment of crop and farm management					
Supplement with inorganic fertilizers	73.47	63.46	71.83	35.68	69.87
Supplement with organic fertilizers/farm yard manure	72.11	66.35	69.01	33.57	68.17
Crop rotation	36.73	23.56	26.76	14.79	62.36
Adjustments to sowing date	17.69	28.37	41.31	20.19	34.73
Adoption of high yielding varieties	29.93	30.29	31.46	21.83	33.43
Mixed cropping	31.29	28.37	30.99	0.94	28.03
Applying nutrient amendments	31.97	26.44	19.95	9.62	24.12
Adoption of short maturing varieties	17.69	9.62	12.21	8.92	13.61
Adoption of different resistant varieties	17.69	9.62	12.21	8.92	13.62
Afforestation	14.29	16.35	11.50	4.46	12.31
Fallowing the land	17.01	5.77	6.81	5.16	8.81
Restoring degraded lands	2.04	4.33	3.52	2.11	3.60
Revegetation	1.36	4.33	3.99	1.41	3.40
Farm extension outside wards	2.04	2.40	2.58	1.64	2.60
Farm extension within wards	3.40	2.88	1.41	0.47	2.00
Aquaculture	0.68	0.00	1.88	2.58	2.33

Notes: marginal farmer (farm size < 0.16 ha), small farmer (0.16 ha $\leq$ farm size < 0.33 ha), medium farmer (0.33 ha $\leq$ farm size ≤ 1.00 ha) and large farmer (farm size > 1.00 ha).

Table 3.5: Estimated coefficients of the independent variables on a number of adaptations (AdaptN) in the Poisson regressions.

	Number of adaptations (AdaptN)					
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Independent variables						
Farm-size dummies						
(base group = marginal farmer)						
Small farmer	−0.055	0.242	−0.083	0.209	−0.108*	0.173
	(0.071)	(0.203)	(0.062)	(0.197)	(0.063)	(0.185)
Medium farmer	−0.031	0.474***	−0.046	0.389**	−0.030	0.417***
	(0.062)	(0.168)	(0.054)	(0.162)	(0.056)	(0.160)
Large farmer	0.027	0.323*	−0.006	0.267	0.014	0.317*
	(0.066)	(0.189)	(0.058)	(0.181)	(0.056)	(0.179)
Climate perception index (CPI)	–	0.120***	0.061***	0.116***	0.050***	0.107***
		(0.025)	(0.008)	(0.024)	(0.008)	(0.025)
Interaction terms						
(base group = marginal farmer)						
Small farmer × CPI	–	−0.053	–	−0.052	–	−0.051
		(0.034)		(0.032)		(0.031)
Medium farmer × CPI	–	−0.090***	–	−0.081***	–	−0.083***
		(0.028)		(0.026)		(0.027)
Large farmer × CPI	–	−0.054*	–	−0.049*	–	−0.055*
		(0.031)		(0.029)		(0.029)
Other cognitive & non-cognitive factors						
Farming experience	–	–	−0.002	−0.002	−0.001	0.001**
			(0.002)	(0.002)	(0.002)	(0.002)
# of agricultural trainings	–	–	0.075***	0.076***	0.078***	0.080***
			(0.016)	(0.016)	(0.017)	(0.017)
Years of schooling	–	–	0.012***	0.012***	0.011***	0.011**
			(0.004)	(0.004)	(0.004)	(0.004)
# of social networks	–	–	0.121***	0.116***	0.118***	0.113***
			(0.015)	(0.015)	(0.015)	(0.014)
Access to information	–	–	−0.090***	−0.091***	−0.075**	−0.076**
			(0.035)	(0.035)	(0.035)	(0.031)
Sociodemographic factors						
# of active family members	–	–	–	–	0.007	0.007
					(0.010)	(0.010)
Gender (base group = female)	–	–	–	–	0.01	0.086
					(0.058)	(0.058)
HH annual income	–	–	–	–	−0.063***	−0.062***
					(0.176)	(0.018)
Distance to agricultural services	–	–	–	–	−0.034***	−0.035***
					(0.008)	(0.008)
Market distance	–	–	–	–	0.015***	0.015***
					(0.004)	(0.004)
Constant	2.076***	1.427***	1.575***	1.277***	2.352***	2.025***
Observations	999	999	989	964	963	963
Wald-χ^2	2.65	60.16***	181.76***	193.62***	287.23	290.56***

Note: (1) Robust standard errors are in the parentheses; (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$; and (3) marginal farmer (farm size < 0.16 ha), small farmer (0.16 ha $\leq$ farm size < 0.33 ha), medium farmer (0.33 ha $\leq$ farm size $\leq$ 1.00 ha) and large farmer (farm size $>$ 1.00 ha).

et al., 2019; Soubry et al., 2020), suggesting that climatic perceptions need to be improved to influence their adaptations. Our results also confirm that farmers' climatic perceptions are positively associated with their adaptations in a consistent and robust manner.

The interaction terms between the medium-farmer (large-farmer) dummy and CPI are statistically significant at 1 % to 10 % level in models 2, 4 and 6. Since the coefficients of the interaction terms in these models are negative, the relationship between farm-size dummies and CPI appears to reflect substitutability for one another. To statistically confirm the relationship, we calculate the marginal effects of CPI on AdaptN for medium and large farmers based on the estimated coefficients in models 2, 4 and 6. We identify that the marginal effects of CPI for medium and large farmers are not statistically significant, implying that farmers' adaptations in response to CPI do not practically depend on farm size.

Some variables, such as agricultural training, social networks and the distance to agricultural services, show statistically consistent and positive tendencies toward AdaptN. Farmers are likely to have additional 8.00 % AdaptN when they receive one unit of agricultural training. Past studies similarly argue that trainings can help farmers acquire adaptation-related knowledge and skills, supporting them in increasing responses (Piya et al., 2012; Trinh et al., 2018; Diallo et al., 2020). This result implies that Nepalese farmers tend to adapt to climate change when they receive training, which is in line with the literature. Farmers are identified to take additional 11.30 % AdaptN when the social network increases by one unit. The positive effect may be because social networks function as social devices for Nepalese farmers (i) to learn adaptations from other farmers and (ii) to receive financial support, such as credits, in enhancing their adaptation responses. The role of social networks is well established in economics and sociology literature to overcome imperfect knowledge about new technologies (Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006; Yamogo et al., 2018). The results suggest that social networking, such as cooperatives and farmers' field schools, is crucial for farmers' adaptation abilities and capacities. Farmers tend to have an increase in AdaptN by about 1.50 % when distance to the market increases by 1 km. The result can be supported by the findings in Below et al. (2012), because farmers whose fields are away from markets diversify production methods and/or try to reduce risks associated with climate. Overall, these results suggest that farmers' adaptations are positively associated with agricultural training, social networks and market distance.

Farmers with access to agricultural information tend to reduce AdaptN by 7.32 % compared to farmers without access. This result suggests that agricultural information is substitutable for farmers' adaptations in the Nepalese context. This result contradicts previous findings that show the positive influence of agricultural information on farmers' adaptations (Deressa et al., 2009; Tambo and Abdoulaye, 2011; Khanal and Wilson, 2019; Asma et al., 2021). We posit that Nepalese farmers do not have to take additional adaptations when agricultural information becomes available due to geographical and/or farming practices. Farmers are likely to reduce AI by about 6.20 % when their HH annual income rises by 1 %. This may imply that having high HH income does not motivate farmers to take adaptations, or that low-income farmers are motivated to reduce their risks by diversifying agricultural activities, as argued in Chambers (1987). Farmers tend to reduce AdaptN by about 3.50 % when the distance to agricultural services increases by 1 km. We argue that farmers who cultivate in close proximity to agricultural services are benefited by extension workers' frequent visits and suggestions, leading them to adapt. This result is consistent with past studies (Piya et al., 2012; Abid et al., 2019; Kumar et al., 2020) in that the extension of agricultural services is identified to be crucial for farmers' activities and productions. Overall, these results suggest that farmers' adaptations are negatively associated with agricultural information, HH annual income and the distance to agricultural services.

Table 3.6 reports the estimated coefficients of the independent variables on AI in the basic median regression model along with the standard errors and statistical significance. Building on the basic model, other specifications as well as interaction terms are proposed for robustness check, and the results do not differ qualitatively in the models. Thus, we only report the effects of the main independent variables on AI. The coefficients of farm-size dummies on AI are statistically significant at 1 % level in models 1, 3 and 5 with negative signs, and the tendencies remain the same in a coherent manner, even when we include interaction terms between farm-size dummies and CPI in models 2, 4 and 6. For instance, model 1 shows that small farmers take 0.776 less AI than marginal farmers, holding other variables fixed. Likewise, model 1 demonstrates that medium and large farmers tend to reduce AI by 1.480

Table 3.6: Estimated coefficients of the independent variables on the adaptation index (AI) in median regressions.

Variables	Adaptation index (AI)					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Independent variables						
Farm-size dummies						
(base group = marginal farmer)						
Small farmer	−0.776***	0.083***	−0.658***	0.199	−0.730***	0.123
	(0.229)	(0.368)	(0.144)	(0.337)	(0.147)	(0.352)
Medium farmer	−1.480***	−0.303	−1.406***	−0.274	−1.438***	−0.227
	(0.216)	(0.319)	(0.127)	(0.292)	(0.130)	(0.301)
Large farmer	−1.750***	−0.937**	−1.680***	−0.842***	−1.766***	−0.865**
	(0.215)	(0.375)	(0.142)	(0.343)	(0.146)	(0.359)
Climate perception index (CPI)	–	0.217***	0.021	0.232***	0.017	0.245***
		(0.048)	(0.019)	(0.045)	(0.021)	(0.061)
Interaction terms						
(base group = marginal farmer)						
Small farmer × CPI	–	−0.188**	–	−0.207***	–	−0.203***
		(0.076)		(0.054)		(0.057)
Medium farmer × CPI	–	−0.253***	–	−0.256***	–	−0.278***
		(0.074)		(0.049)		(0.055)
Large farmer × CPI	–	−0.179**	–	−0.199***	–	−0.215***
		(0.072)		(0.046)		(0.054)
Other cognitive & non-cognitive factors						
Farming experience	–	–	0.004*	−0.004	0.003	0.004
			(0.004)	(0.004)	(0.004)	(0.004)
# of agricultural trainings	–	–	0.102**	0.108**	0.081*	0.083*
			(0.045)	(0.044)	(0.046)	(0.046)
Years of schooling	–	–	0.004	0.007***	0.005	0.001
			(0.009)	(0.009)	(0.009)	(0.009)
# of social networks	–	–	0.135***	0.127***	0.101***	0.102***
			(0.038)	(0.038)	(0.049)	(0.039)
Access to information	–	–	0.093	0.063***	0.137	0.120**
			(0.085)	(0.084)	(0.088)	(0.064)
Sociodemographic factors						
# of active family members	–	–	–	–	0.027	0.025
					(0.026)	(0.027)
Gender (base group = female)	–	–	–	–	0.214	0.201
					(0.132)	(0.132)
HH annual income	–	–	–	–	−0.018	−0.016
					(0.047)	(0.047)
Distance to agricultural services	–	–	–	–	−0.012	−0.007
					(0.016)	(0.016)
Market distance	–	–	–	–	−0.015	−0.015
					(0.013)	(0.013)
Constant	2.000***	1.017***	1.48***	0.613***	1.672***	0.677***
Observations	999	999	989	989	963	963
Pseudo R-squared	0.105	0.117	0.125	0.137	0.131	0.145

Note: (1) Standard errors are in the parentheses; (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$; and (3) marginal farmer (farm size < 0.16 ha), small farmer (0.16 ha $\leq$ farm size < 0.33 ha), medium farmer (0.33 ha $\leq$ farm size ≤ 1.00 ha) and large farmer (farm size > 1.00 ha).

and 1.750, respectively, as compared to marginal farmers. The results support Hypothesis 3.1 that farm size influences farmers' adaptations to climate change. The results can be attributed to the inflexibility of large-sized farmers to take adaptations compared to small-sized farmers as cumulative investments and/or efforts to do so become large (Uddin et al., 2014; Khanal and Wilson, 2019). It is also argued that large-sized farmers lack motivations and tend to overlook small cost-effective adaptations as their adaptation option (Khan et al., 2020). This argument is in line with table 3.3 in that large-sized farmers tend not to take small adaptations, such as mixed cropping and changes in irrigation and nutrient amendments, as compared to small-sized farmers. Overall, the results imply that farmers do not take adaptations as farm size becomes large.

The coefficients of CPI on AI are not statistically significant in models 3 and 5. However, they become statistically significant with positive signs at $1\,\%$ level, when we include interaction terms between farm-size dummies and CPI in models 2, 4 and 6. The estimated coefficients of CPI on AI range between 0.215 and 0.245, demonstrating that farmers take adaptations by $0.215 \sim 0.245$ when their CPI increases by one unit. This result supports Hypothesis 3.2 that climatic perceptions induce farmers to take adaptations to climate change. The results in table 3.5 and past studies similarly find that farmers' adaptations are positively influenced by or associated with their climatic perceptions (Deressa et al., 2009; Khanal and Wilson, 2019; Azadi et al., 2019; Soubry et al., 2020). Our results with respect to CPI are considered another corroboration to establish the positive association between farmers' CPI and AI in a consistent and robust manner, and suggest that interactions between climatic perceptions and farm size shall be key for characterizing farmers' adaptations.

The interaction terms between farm-size dummies and CPI are statistically significant at $1\,\%$ level in models 2, 4 and 6. Since the coefficients of the interaction terms in these models are negative, the relationship between farm-size dummies and CPI seems to reflect substitutability for one another. The results can be interpreted to mean that farmers reduce adaptations in response to CPI when the farm size becomes large. For instance, model 2 shows that marginal farmers take additional 0.217 AI when their CPI increases by one unit. However, small and large farmers only take additional 0.029 $(= 0.217 - 0.188)$ and 0.038 $(= 0.217 - 0.179)$ AI, respectively, when their CPI increases by one unit.

The result also shows that medium farmers even reduce AI by 0.036 ($= 0.217 - 0.253$) when their CPI improves by one unit. These results support Hypothesis 3.3 that there exists an interplay between farm size and climatic perceptions on farmers' adaptations. The results could again be due to the relative (i) inflexibility or inability of large-sized farmers to take adaptations when they perceive climate change and/or (ii) their insensitivity toward climate variables as compared to small-sized farmers. The results imply that farmers' adaptations in response to CPI significantly depend on farm size, demonstrating that agricultural policies must be customized for effective adaptation responses according to their climatic perceptions, farm size and interaction.

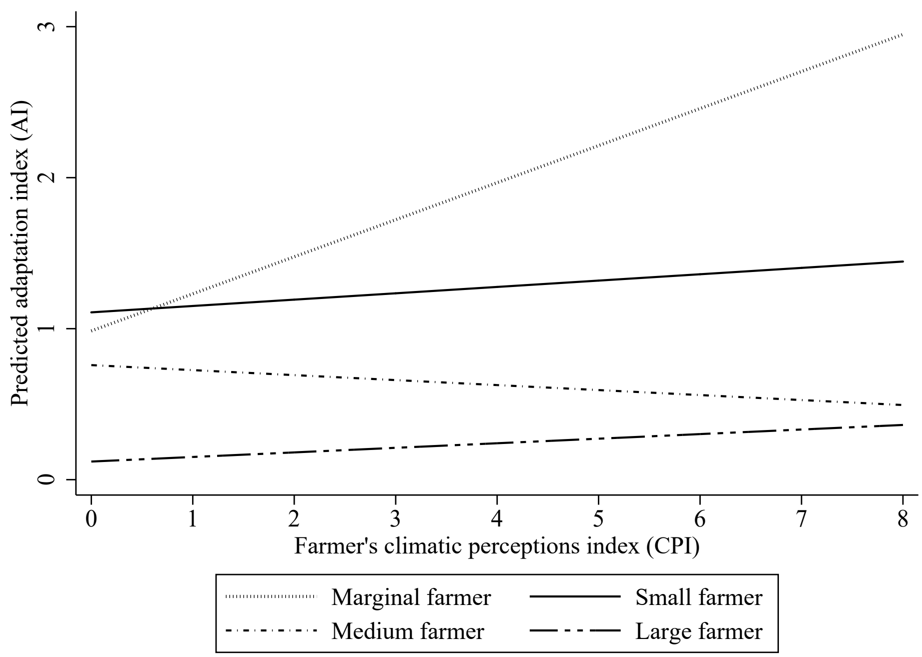


Figure 3.4: Predicted adaptation index (AI) over CPI (farmer's climatic perception) across farm size.

The coefficients of some variables, such as agricultural trainings and social networks, are statistically significant with positive signs at 1 % to 10 % levels in models 3 through 6. Model 3 demonstrates that farmers take additional 0.102 AI when agricultural training increases by one unit, holding other variables fixed. Training may help farmers acquire adaptation-related knowledge and skills, thereby supporting them to increase adaptation (Piya et al., 2012; Trinh et al., 2018; Diallo et al., 2020). Model 3 shows that farmers take additional AI by 0.135 when their social network increases by one unit. We argue that social networks enable farmers (i) to learn about adaptations from other farmers and (ii) to receive various forms of assistance, such as credit and labor, thereby enhancing their adaptation responses. Our results are supported by past studies that report the positive influence of social networks on adopting new technologies in agriculture (Foster and Rosenzweig, 1995; Bandiera and Rasul, 2006; Yamogo et al., 2018). Overall, these findings suggest that agricultural trainings and social networks positively influence farmers to take adaptations.

We find that the interaction terms between farm-size dummies and CPI play an important role in characterizing AI. To quantitatively clarify the interactions, we calculate and plot the median AI over CPI as a prediction for different-sized farmers (holding other independent variables at the sample means) based on the estimated results in model 6 of table 3.6, which we call "predicted AI." Figure 3.4 shows the predicted AIs over CPI for marginal, small, medium and large farmers, presenting that the intercepts and slopes are idiosyncratic across farm size. The slopes of the predicted AIs for the small, medium and large farmers are almost flat, meaning that these farmers generally tend not to take additional adaptations when their CPI improves, or tend to be insensitive to their own climatic perceptions. On the contrary, the slope of the predicted AI for marginal farmers is positive and steep, meaning that the marginal farmers take additional adaptations when their CPI improves, or tend to be positively sensitive to their own climatic perceptions. Furthermore, the entire plot of median AI prediction is located or becomes low as the farm size gets large, which is due to estimated differences in the interaction terms and intercepts of model 6. In summary, the results graphically and quantitatively corroborate that not only farmers' AIs, but also their responses to CPI, are likely to decline with farm size.

We finally summarize and compare the results from the two different models of the Poisson and median regressions associated with AdaptN and AI in tables 3.5 and 3.6. Both regressions find that farm size, climatic perceptions, agricultural trainings and social networks can be key determinants to be positively associated with AdaptN and AI, being economically and statistically significant, at least in some models. On the other hand, there are three main differences between the two regressions. First, HH income, distance to agricultural services and market distance are significant (or insignificant) for AdaptN (or AI). Second, farm size does not matter much for AdaptN, while it is an important predictor for AI, in addition to interactions with farmers' climatic perceptions. Third, the AI responses to climatic perceptions differ across farm size, while the AdaptN responses do not. Literature indicates that using AdaptN has some potential problems: (i) each adaptation is assumed to be equally weighted, but farmers take adaptations at different scales (scale problem), and (ii) not all adaptation responses are uniformly important, but farmers will have different priorities (priority problem) (Below et al., 2012; Esham and Garforth, 2012; Niles et al., 2015; Khanal and Wilson, 2019). Thus, it is suggested to consider a weight of each adaptation to correct the problems (Below et al., 2012; Khanal and Wilson, 2019). Khanal and Wilson (2019) develop AI and demonstrate its importance by considering a weight of each adaptation. Building upon the literature, we believe that the results of AI median regressions are more plausible than those of AdaptN regressions, reflecting what is going with Nepalese farmers' adaptations to climate change.

Our findings provide specific countermeasures and suggestions to respond to climate change for Nepalese farmers and other developing countries with similar contexts. Since large-sized farmers are found to take adaptations less effectively in response to climatic perceptions than small-sized farmers, some policies or programs are necessary to be formulated in relation to farm size. As we posited before, large-sized farmers fail to adapt potentially because they are either overconfident or ignorant about the consequences of climate change. Therefore, it is crucial to design policies and education programs targeting large-sized farmers, and to induce them to correct overconfidence or ignorance for the purpose of enhancing their responses to climatic perceptions. Nepal has adopted an early warning system that is primarily oriented toward providing information about the changes in temperature and rainfall to farmers (Gautam and Phaiju, 2013; Cools et al., 2016; Rai et al., 2020). We suggest that the system can be further customized to include concrete information that may contain possible crop losses, the associated expected income and wealth losses by farm size. Since government and non-governmental organizations (NGOs) mostly focus only on subsistence farmers and overlook large-sized farmers, the countermeasures and suggestions by farm size can be reflected in the National Adaptation Programme of Action (NAPA) and the Local Adaptation Plan of Action (LAPA) frameworks of Nepal and other developing countries (Ministry of Environment, 2010; Gautam et al., 2018; Government of

Nepal, 2014).

Large-sized farmers hold more than 60 % of the total land area in Nepal. Similar patterns are observed in many other developing countries of Asia and Africa (Central Bureau of Statistics, 2013; Sugden et al., 2016; Government of India, 2016; Jayne et al., 2016; Anseeuw et al., 2016; Sitko and Chamberlin, 2016; Thapa et al., 2019). Some public programs, such as land consolidation, have been implemented to establish medium-sized or large-sized farm units by merging small-sized farmers' lands for the purpose of enhancing their economic scale, productivity and food security (Thapa and Niroula, 2008; Sugden et al., 2020). However, this trend of such land consolidation for creating large-sized farmers may bring about unexpected adverse effects on agriculture in the context of climate change. This research suggests one warning, that is, agriculture may lose its ability or capacity to swiftly or sensitively adapt and respond to climate change, irrespective of farmers' climatic perceptions. Thus, it is advisable to reconsider the tradeoff between farm productivity and responsiveness to climate regarding farm size as well as how large-sized farmers can be induced to adapt through their cognition, policies, social networking and technology.

3.5 Conclusion

This study has investigated what matters for farmers' adaptation responses to climate change, hypothesizing that farm size, climatic perceptions and the interplay between them are key determinants for farmers' adaptation responses. We conduct a questionnaire survey with 1000 farmers in Nepal, collecting data on their adaptation responses, farm size, climatic perceptions and sociodemographic information. The analyses reveal that farmers tend to take additional adaptation responses as farm size becomes small or if they have good climatic perceptions & social networks with other farmers. The findings also show that small-sized farmers tend to adapt much more in response to their climatic perceptions than do large-sized farmers, confirming the insensitivity of large-sized farmers to climate change in Nepal. Overall, this research suggests that agriculture may be losing responsiveness to climate change, as large-sized farmers become dominant by holding a majority of land in developing countries. Thus, it is advisable to reconsider the tradeoff between productivity and responsiveness to climate change regarding farm size as well as how large-sized farmers can be induced to adapt through their cognition, policies, social networking and technology for food security.

Chapter 4

Resource sustainability on life expectancy, successors and accountability in intertemporal and intergenerational settings

4.1 Introduction

Recent international political discourses aim to avoid the consequences of climate change by keeping global warming below 1.5°C (IPCC, 2018). This means that global greenhouse gas emissions must be reduced to 50 % by 2050 (Schneider, 2001; Meinshausen et al., 2009; Peters et al., 2012; Jacquet et al., 2013). To meet the target, individuals, societies and countries are required to make substantial sacrifices on their current resource consumptions and transfer them to the future. Scientific reports indicate that people's current resource consumptions are about 1.6 times higher than the existing environment can regenerate, and such over consumptions are resulted in negative externalities, such as pollution and irreversible biodiversity loss over the time, posing a serious challenge to resource sustainability (IPCC, 2018; IPBES, 2019).[1] Literature suggests that resources can only be sustained when it is maintained intertemporally and intergenerationally (Dasgupta and Mitra, 1983; Pezzey, 1992, 1997; Howarth, 1998; Roemer, 2010). Thus, this study seeks to address when and how people sustain resources considering temporal dimension and uncertainty.

Intertemporal choices are of central importance in many economic decisions, where costs and rewards occur at different points in time (Loewenstein, 1988; Krysiak, 2008; Moreira et al., 2015; Ericson and Laibson, 2019). Past studies theoretically or empirically analyze users' intertemporal choices in relation to various contexts and/or levels of uncertainty (Horowitz, 1992; Roelofsma, 1996; Carbone,

[1]It is reported that the current global rate of biodiversity loss is nearly 100 times higher than the average over the past 10 million years, while animal species, such as fish, birds and mammals, alone have declined by a 68 % in last five decades (WWF, 2020).

2006; Creedy and Guest, 2008; Figuieres et al., 2017). A group of study empirically examines people's intertemporal choices, focusing on the effects of demographic characteristics, such as age, without considering uncertainty. For instance, Silverman (2003) conducts a meta-analysis of 33 studies and finds that female tend to discount future rewards lower than those of male. A review from Moreira et al. (2015) examine the association between intertemporal choices and age, reporting that young people tend to discount the future rewards more than adults do. Another group of studies considers that people make crucial economic decisions when they experience uncertainty, such as disasters and uncertainty about the future (Yaari, 1965; Kreps and Poteus, 1978; Horowitz, 1992; Creedy and Guest, 2008; Walther, 2010; Chuang and Schechter, 2015). For instance, Hey and Dardanoni (1988) experimentally analyzes intertemporal consumptions, finding that people's consumptions vary when they face uncertainty. Li et al. (2011) analyze intertemporal choices in relation to the Wenchuan Earthquake in China, and show that survivors' tendencies to discount future rewards drastically decline after the earthquake. Cassar et al. (2017) analyze intertemporal choices and demonstrate that people who experience the 2004 Tsunami tend to be more impatient than those who do not experience it. On the other hand, Callen (2015) experimentally examines people's intertemporal choices, finding that uncertainty (i.e., disaster) induces people to wait for future benefits. Overall, these studies suggest the influences of uncertainty on people's intertemporal choices for various economic behaviors.

Literature experimentally analyzes individual and/or group behaviors for sustainability under intergenerational setting (Schotter and Sopher, 2006; Chaudhuri et al., 2008; Jacquet et al., 2013). Some studies focus on group behaviors for sustainability in relation to various factors and social devices (Chaudhuri et al., 2006, 2009; Kamijo et al., 2017; Shahrier et al., 2017b; Timilsina et al., 2017). Fischer et al. (2004) analyze resource sustainability in a common pool experiment, showing that an existence of "intergenerational link" minimizes the groups' resource exploitations. Hauser et al. (2014) analyze group behaviors for sustainability by conducting intergenerational goods games, and suggest that median voting reduces the overexploitation of resources by restraining defectors. Sherstyuk et al. (2016) examine efficiency of a dynamic externality game in the laboratory, showing the difficulty of resolving sustainability intergenerational setting than infinitely-lived decision makers. Kamijo et al.

(2017) design and conduct a laboratory experiment with Japanese students, and find that an inclusion of an imaginary future generation in the decision-making process of the current generation can induce intergenerational sustainability. Shahrier et al. (2017a) and Shahen et al. (2021) conduct field and laboratory experiments in Bangladesh and Japan, demonstrating that an introduction of future ahead and back mechanism (FAB) in decision-making process induces groups and individuals for sustainability, respectively. Timilsina et al. (2019) and Koirala et al. (2021) conduct field and laboratory experiments in Nepal and Japan, and show that an introduction of intergenerational accountability (IA) in decision-making process induces groups and individuals for sustainability, respectively. Overall, these studies demonstrate the difficulties and influences of various factors on individual and/or group behaviors, and suggest some devices for resolving sustainability under intergenerational settings.

Previous studies theoretically analyze people's choices under intertemporal and intergenerational settings (Solow, 1974; Sandler and Smith, 1976, 1982; Dasgupta and Mitra, 1983; Pezzey, 1992, 1997; Howarth, 1991). These studies primarily focus to conceptualize whether or not intertemporally efficient resource allocations lead for intergenerational equity, arguing that such allocations to be sustainable. For instance, Solow (1974) suggests intergenerational equity to be an equal consumption per capita at each period time, i.e., intertemporal. However, little is known about users' intertemporal and intergenerational choices for resource sustainability within a single empirical framework. We seek to experimentally examine intertemporal and intergenerational choices for sustainability in relation to life expectancy as an uncertainty, an existence of successors and intergenerational accountability (IA) within a single experimental framework. Thus, we conduct field experiments by instituting sustainability game (SG) where a user is probabilistically determined to live up to the next period, and the probabilities are parametrized to represent different life expectancy by strategy method. In SG, a subject is asked, each period, to choose either prioritizing her current payoffs by irreversibly overutilizing the resource (unsustainable option A) or sustainably utilizing the resource (sustainable option B) for the future. Three treatments are prepared: (i) "no successors" (NS) in which a subject decides between options A and B in each period until she dies without successors, (ii) "existence of successors" (ES) in which another subject takes over the game as a successor when the game ends for one subject by his/her death, and (iii) "intergenerational accountability" (IA) in which each subject is asked to write and pass the reason for her decisions and advice to her successors.

This study finds that long life expectancy and successors' existence are keys to improve sustainability. In particular, provided with successors, "IA" (i.e., accountability to successors) is found to further contribute to both intertemporal and intergeneration sustainability, and the IA positive effect nonlinearly inflates with life expectancy. This implies that not only arranging a successor but also institutionalizing accountability between current users and successors shall drastically enhance sustainability, even when societies suffer from aging and depopulation. The novelty of this paper lies in its experimental setup, which incorporates individual life expectancy and an absence (or an existence) of successors together with intergenerational accountability (IA) in a single analytical framework and considers the non-overlapping users recruited from the general public. Overall, this study contributes to the literature of resource economics by demonstrating that an improvement in life expectancy, successors' existence and accountability to the successors shall be necessary for intertemporal and intergenerational resource sustainability. The message can be considered important for several aging and depopulating societies and countries.

4.2 Methods and materials

4.2.1 Experimental setup

We conducted field experiments in urban and rural areas of Nepal. As an urban area, we selected the capital city, Kathmandu, and as a rural area, we selected the districts of Sindhupalchok and Dhading (Figure 4.1). The experiments were implemented under the direct supervisions of the first author and supported by research assistants (RA). Two wards were randomly selected from each of the study areas based on the 2011 National Population and Housing Census (Central Bureau of Statisics, 2012). We used a list of households (HHs) residing in the respective wards to identify the subjects. For this, we utilized various reports of respective rural or urban municipalities or metropolitan cities. Based on the HHs lists, we selected non-repeating HHs' members as our subjects following a method of systematic random sampling. Assuming the 90 % response rate, we adjusted the number of the selected HHs' members for our experiments. Then, we invited the selected HHs members through the local key informants. The experiments were conducted at various places, such as Ministry of Forestry and Environment (MoFE), administrative units, local schools and other centers, consisting of sufficient rooms and a necessary experimental environment.

Sustainability game (SG)

We design and conduct the experiments by instituting sustainability game (SG) in which a user is probabilistically determined to live up to the next period, and different life expectancy is incorporated as survival probabilities parametrized by a strategy method. In SG, a subject is asked, each period, to choose either prioritizing his/her current payoffs by irreversibly overutilizing the resource or sustainably utilizing the resource for the future. For instance, suppose that the resource and its associated payoff are X and 1200 points, respectively. The subject is then asked to choose either option B (sustainable) and receive 900 $(= 1200 - 300)$ points, or option A (unsustainable) and receive 1200 points. With subject's every choice of option A, the points associated with option A in the subsequent periods irreversibly decreases by 300 points. This means that the points declines permanently. On the other hand, if the subject chooses option B, the points in the subsequent periods remains the same that of the current period, meaning that he/she will face an identical decision-making environment in the subsequent periods. For example, if subject's decisions are options $ABAB$ in the 1st, 2nd, 3rd and 4th periods, respectively. Then, the payoff for the subject is the sum of all points for decisions made by him/her, i.e., 3000 $(= 1200 + 600 + 900 + 300)$. Therefore, each subject knows that his/her current decision between options A and B affects the payoff associated with X in the subsequent periods.

To systematically incorporate various values of life expectancy in the game, we parameterize five different survival probabilities, using a strategy method.[2] The incorporated parameters of the survival probabilities are $0.95, 0.75, 0.50, 0.25$ and 0.10 where each parameter indicates subject's life ex-

[2]The strategy method is based on the random lottery incentive method which is widely used in experimental economics (See Cubitt et al. (1998) for details.)

pectancy. For instance, the subject having 0.95 survival probability (Scenario 1) implies that he/she is 95 % likely to survive in the next period of the game. In this way, the rest of the survival probabilities can be expressed in the following percentages: 75 % (Scenario 2), 50 % (Scenario 3), 25 % (Scenario 4) and 10 % (Scenario 5). Following the procedure, each subject makes repeated decisions under five scenarios, and his/her respective payoff for each scenario is calculated separately. However, only one payoff associated with one of the scenarios is randomly selected as his/her final SG payoff. Since every scenario and associated payoff have an equal probability to be selected as the final payoff, we assume that the subject has continued the game and tried his/her best to earn as much as he/she can in all scenarios until the game ends.

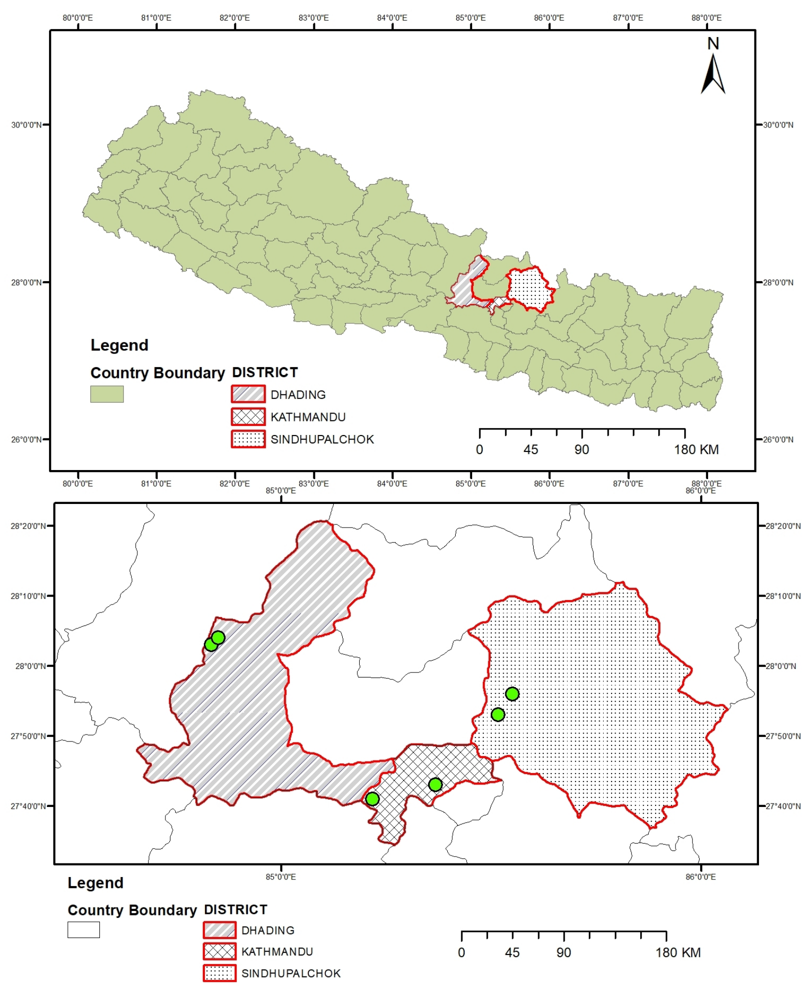


Figure 4.1: A map of Nepal showing the study area.

For each subject, the game ends in two ways: (i) an occurrence of a red chip before the subject makes a decision between options A and B or (ii) the payoff associated with option B reaches zero. We prepare a set of lotteries that consists of white (or red) chips, where a white (or a red) chip indicates a probability p $(1-p)$ of the subject's survival (or death) in the game. Three treatments are prepared: (i) no successors (NS), (ii) existence of successors (ES) and (iii) intergenerational accountability (IA) as shown in figure 4.2, and they are explained as below:

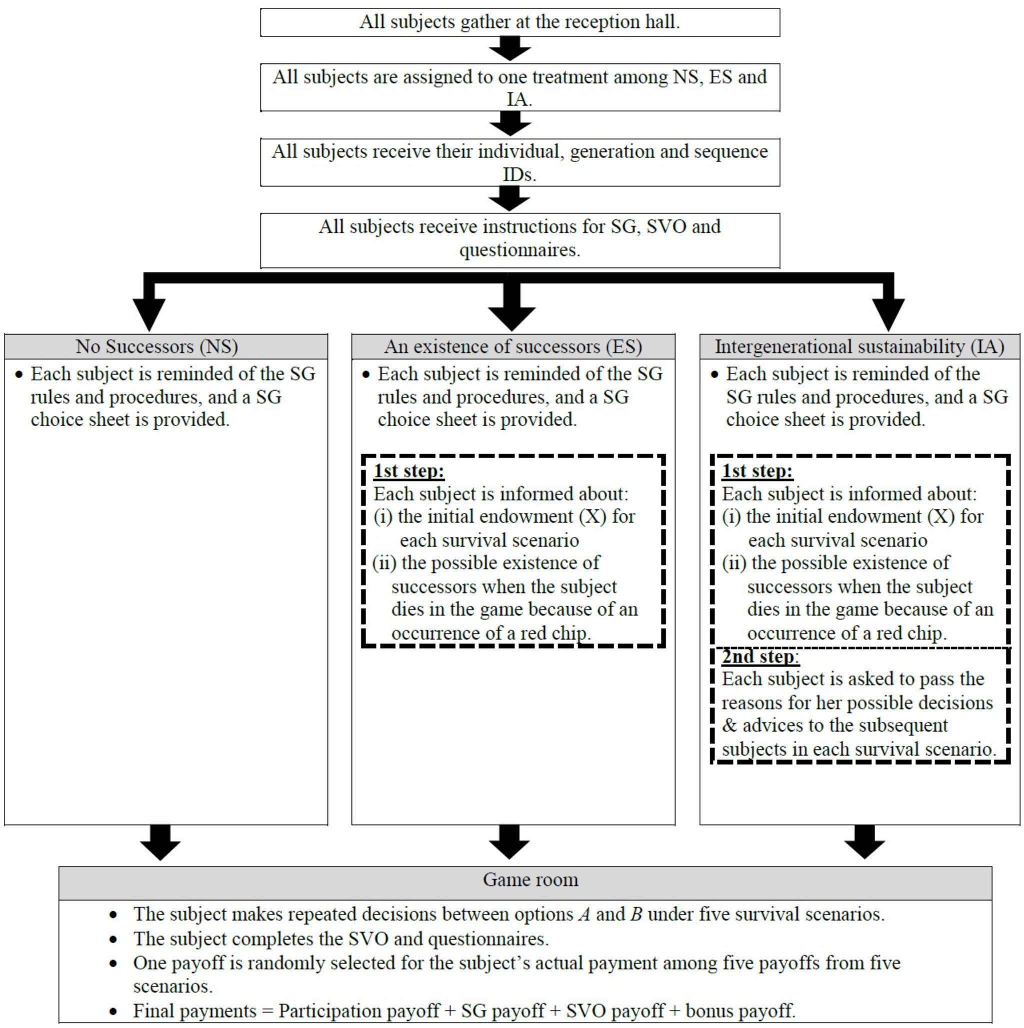


Figure 4.2: A flow chart of procedures for a subject to participate in the experiment.

- **NS**: A subject is asked, each period, to choose either option A (unsustainable) to maximize her current payoff by possibly imposing an irreversible cost in the subsequent periods or choose option B to maintain the sustainability without costing the subsequent periods (sustainable). Following the same rule, each subject makes choices between options A and B under five survival scenarios. This treatment represents a society where there is no successors to care and continue the resources, reflecting most of the depopulating societies.

- **ES** (base group treatment): A subject chooses between options A and B with a notion that the subsequent subjects (i.e., successors) will replace her after game ends for her with an occurrence of a red chip. Following the same rule, each subject makes choices under five survival scenarios. This treatment represents most contemporary societies with successors to care and continue the resources. This treatment represents an ideal society that consists of successors to care and continue the resources.

- **IA**: Each subject is additionally asked to transfer a set of reasons & advice for her decisions to the subsequent subjects (i.e., successors), while we keep other decision-making environment identical to ES treatment. We assure that each subject's written reasons & advice are passed to his/her subsequent successors. This treatment represents the societies where people file their experiences, knowledge, lessons and pass these details to their successors.

Based on these treatments, four hypotheses in our experiments are posed as follows:

- **Hypothesis** $4.1a$: *Subjects with no successors (i.e. NS) results in small terminal period per subject than the subjects with existence of successors (i.e. ES).*

- **Hypothesis** $4.1b$: *Subjects with no successors (i.e. NS) results in lower resource utilization periods (i.e. RUP) than the subjects with existence of successors (i.e. ES).*

- **Hypothesis** $4.2a$: *Subjects with existence of successors along with intergenerational accountability (i.e. IA) results in greater terminal period per subject than the subjects only with existence of successors (i.e. ES).*

- **Hypothesis** $4.2b$: *Subjects with existence of successors along with intergenerational accountability (i.e. IA) results in greater resource utilization periods (i.e. RUP) than the subjects only with existence of successors (i.e. ES).*

We first generate two outcome variables (i) terminal period per subject for each survival scenario and (ii) resource utilization period (RUP). Terminal period is the aggregate number of subject's intertemporal discrete decisions between options A and B for each scenario until he/she is in the game. RUP is the aggregate number of subjects' intergenerational decisions between options A and B for each scenarios made by the subjects who share same initial resource stock (X), i.e., initial endowment until it is exhausted. To address the research questions and test the hypotheses, we empirically compare and characterize terminal period per subject in each survival probability and RUP across three treatments, and included other control variables (SVO, sociodemographic factors and others) that will be discussed in the subsequent subsection. Two important measurements are subjects' likelihood to have a greater number of terminal period and RUP, and they are considered good approximation of resource sustainability (Kamijo et al., 2017; Timilsina et al., 2017; Koirala et al., 2021). Since sustainability increases in the probabilities, the four hypotheses follow that probabilities for subjects to have additional terminal period per subject or RUP are the highest in IA, the $2nd$ in ES and the least in NS, respectively.

Social value orientation (SVO) and socioeconomic variables

We use the "slider method" to identify the subjects' social preferences by characterizing their social value orientation (SVO) (Murphy et al., 2011). SVOs are well-established to be stable for a long time (Brosig-Koch et al., 2011; Van Lange et al., 2007). The method consists of 6 items. Each subject is instructed the rules, payoff structures ("bonus points") and actual money that he/she would receive at the end of the game. We maintain the subject's anonymity and his/her decisions confidential to create a necessary condition to take his/her independent choices. Once the subject completes his/her choices, we calculate the total points that he/she earned in this game by randomly matching one subject to the another anonymous subject. Based on the subject's distributions between himself/herself and the other anonymous partner, we categorize each subject either as "proself" or as "prosocial." We also ask subject's several other sociodemographic information, such as region dummy, age, education, family structure, family size, occupation and marital status.

4.2.2 Experimental procedures

The first author administered the experiments with research assistants (RAs). One session comprises of SG, SVO, sociodemographic questionnaires and payments where $20 \approx 32$ subjects gathered at an instruction room. At the beginning, we announced no communication is allowed during the experiments. Once arrived to the reception hall, the subjects were randomly assigned to one treatment among NS, ES and IA for each session (Figure 4.2). We then distributed the instruction materials to the subjects. The instruction materials were in local language (Nepali) and included the rules, procedures and payoff structures of SG and SVO games. The experimenter or RA explained the instruction materials and questionnaire surveys to the subjects. Thereafter, each subject received a unique identity number (ID) that includes individual and sequence information. We prepared four game rooms where the subjects played SG. Based on subjects' unique IDs, the experimenter prepared four separate lists of subjects (known to the experimenters only) by randomly dividing all subjects in the session. As shown in figure 4.3, each list consisted of the subjects to be sent to one of the game rooms where a RA was assigned to conduct. Thereafter, the experimenter sent one subject to one game room, which means that there were four subjects (P_1, Q_1, R_1 and S_1). Rest of the subjects filled out SVO and questionnaires, while waiting at reception hall. Once the four subjects completed their tasks at game rooms, next four subjects (P_2, Q_2, R_2 and S_2) proceeded to the game rooms in a similar manner that previous four did. In this way, the rest of the subjects continued the game (Figure 4.3).

In each booth, one RA was present to facilitate the experiment. The RA provided a SG choice sheet along with information about the initial resource endowment (X) to the subject and reminded the rules and procedures one more time.[3] The subject made several repeated decisions in all five scenarios one

[3]The information of initial resource X of specific scenario was provided to the subject at a time.

by one and completed the additional tasks depending upon the treatment. Then, the subject filled up the SVO and questionnaires if it was not completed before. In this way, four subjects (P_1, Q_1, R_1 and S_1) accomplished SG, SVO and questionnaires. Then, a RA randomly matched each subject's SVO with the another subject's SVO to determine their individual payoffs. Finally, the RA calculated the final payment for each subject. The final payment is a summation of participation fee, SG, SVO and bonus payoffs with an exchange rate of 1 point $= 1$ NPR (Figure 4.2).[4] In a similar manner, the rest of the subjects continued the game until the session ended. On average, each subject received 550 NPR (≈ 5 USD) in the experiments. Each session took approximately 1.5 - 2 hours to conclude. Finally, we completed 19 sessions with 311 subjects and obtained a total of 1555 observations (311 subjects $\times$ 5 scenarios). The number of the subsequent subjects (N) for each session ranged from 5-8 in all booths.

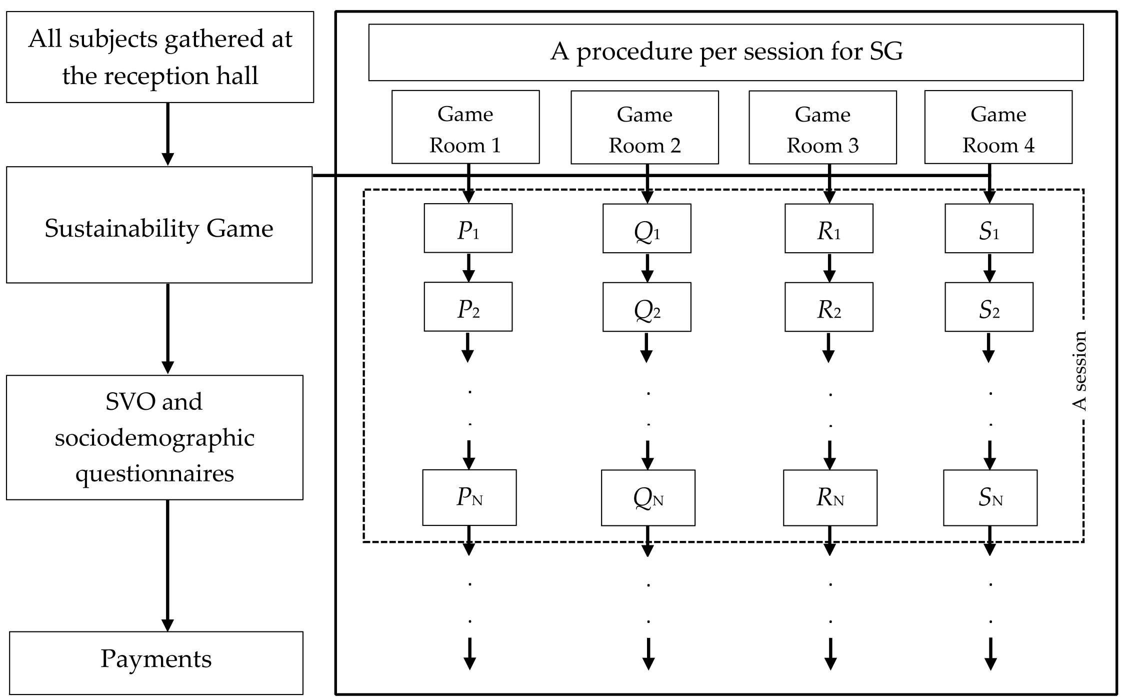


Figure 4.3: A flow chart of the procedures for one session.

[4]In SG, each subject have five subtotal payoffs from each of the scenarios. However, only one subtotal payoff was selected as the final SG payoff for the subject by using a lottery following Cubitt et al. (1998).

4.3 Results

Table 4.1 reports the definitions and descriptions of the dependent and the independent variables used in the analyses. A total of 311 subjects participate in the experiments with 95, 101 and 115 in "no successors" (NS), "existence of successors" (ES) and "intergenerational accountability" (IA) treatments, respectively. Table 2.2 compares summary statistics of independent variables across treatments. Regarding regions, about 47 % (53 %) of the subjects are from the rural (urban) area, and the values are 49 % (51 %), 51 % (49 %) and 40 % (60 %) in NS, ES and IA treatments, respectively. This means that there is no considerable differences in the distributions of the rural (or urban) subjects in NS and ES treatments, while the subjects in IA treatment slightly vary across regions. Regarding the age, the overall average subjects' age is about 36 years, while the averages lie in between 30 to 39 in all treatments. This means that the subjects are of similar age in all treatments, and suggests that they are economically active population.[5] Subjects receive an education of 12 years of schooling on average and the values remain around 12 to 13 in all treatments, meaning that they can understand instructions and take decisions in the experiments. Overall, the results demonstrate that the subjects do not differ significantly in terms of region, age and education by treatments.

Regarding family structure and size, about 57 % of the subjects are from joint families where each family consists of 5.00 members on average. The averages of family structure are about 41 %, 65 % and 62 % for NS, ES and IA, respectively, while the averages of family sizes for treatments are about 5.00. This means that subjects tend to vary in terms of family structure by treatments, while there is no difference in terms of family size. In terms of gender, about 47 % of female subjects participate in the experiments, while the values are 56 %, 46 % and 42 % for NS, ES and IA, respectively. These results reflect that there is balanced gender distributions across the treatments. Regarding marietal status, a majority (i.e., 73 %) of the subjects are married, and the values are about 86 %, 74 % and 61 % in NS, ES and IA, respectively. Nearly 54 % of the subjects are associated with agricultural occupation in NS, ES and IA, respectively, while the rest are government employees, entrepreneurs and other service

[5]Population in between 15 to 59 years of age is defined to be an economically active population in Nepal (Central Bureau of Statisics, 2014).

Table 4.1: Definitions & descriptions of the variables.

Variables	Definitions & Descriptions
Dependent variables	
Sustainable choice (base group = option A)	A dummy variable that takes 1 if the subject chooses option B; otherwise, 0.
Terminal period (TP)	A summation of the subject's choices between options A and B in each survival scenario.
Resource utilization period (RUP)	A variable that equals to TP in NS or a summation of TP (intergenerational resource users (IRU)) for each survival scenario in ES and IA.
Treatment dummies	
(Base group = ES)	
NS	A dummy variable that takes 1 if the subject is in NS treatment; otherwise, 0.
IA	A dummy variable that takes 1 if the subject is in IA treatment; otherwise, 0.
Parameters	
Survival probability	A variable that represents the subject's life expectancy in SG.
Initial resource endowment (X)	Resource endowment (X) with which the subject starts in SG.
Decision periods	A number of decisions between options A and B taken by the subject in each survival probability.
Sociodemographic variables	
Rural (base group = urban)	A dummy variable that takes 1 if the subject belongs to a rural area; otherwise, 0.
Prosocial (base group = proself)	A dummy variable that takes 1 if the subject's social value orientation is characterized as "prosocial;" otherwise, 0.
Age	Subject's age in year.
Education	Subject's education in years of schooling.
Family structure	A dummy variable that takes value 1 if the subject belongs to a joint family; otherwise, 0.
Family size	A total number of family members of the subject.
Gender (base group = male)	A dummy variable that takes 1 if the subject is female; otherwise, 0.
Agricultural engagement (base group = others)	A dummy variable that takes value 1 if the subject's occupation is agriculture; otherwise, 0.
Marital status (base group = unmarried)	A dummy variable that takes value 1 if the subject is married; otherwise, 0.

holders. About 53 % of the subjects are identified to have "prosocial" social value orientation and the percentages are almost identical across the treatments, meaning that subjects do not differ significantly in terms of SVO by treatments. Overall, the results suggest that the subjects differ in terms of family structure, while they tend to have variations in relation to family size, gender, occupation and SVO across treatments.

In the experiments, each subject takes a number of decisions given the initial endowment he/she receives. The subjects receive approximately 993.76 NPR on average before they start in the experiment with a minimum and maximum values of 300.00 NPR and 1200.00 NPR, respectively. The subjects start with 1200.00 NPR on average with zero SD in NS, meaning that they receive same amount of initial endowment in this treatment. The values of averages & SDs are about 862.00 and 939.00 NPR & 343.00 and 313.00 NPR for ES and IA, respectively. The differences in averages and SDs imply that the subjects do not receive equal initial endowments in ES and IA.

Table 4.3 presents medians (means) of terminal period per subject and resource utilization periods (RUPs) over the scenarios (or survival probabilities) in NS, ES and IA treatments. The results show that terminal period per subject monotonically increases as scenarios advances from 1 to 5. For instance, the overall median (mean) terminal period per subject is 1.00 (1.12) in scenario 1, while the values are 2.00 (1.94) and 8.00 (10.34) in scenarios 3 and 5, respectively. The results reveal similar patterns for RUPs across scenarios, demonstrating that RUPs medians (mean) are 5.00 (5.26), 6.00 (6.82) and 42.00 (62.57) in scenarios 1, 2 and 5, respectively. Subjects' such tendencies are confirmed by figures 4.4(a) and 4.4(b) that show bar graphs of medians of terminal period per subject and RUP, respectively, across the scenarios. We run the Mann-Whitney test to examine distributional differences in terminal periods (or RUPs) across survival probabilities, and apply it to every pair of scenarios. The null hypothesis is that the distributions of terminal periods (or RUPs) between two scenarios are the same. The results show that null hypotheses are rejected for all pairs of scenarios at 1 % level. The results imply that subjects' intertemporal or intergenerational choices for resource sustainability are statistically dependent on survival probability.

Table 4.3 shows considerable differences in terminal period per subject and RUP across treatments.

Table 4.2: Summary statistics of independent variables by treatments.

Variables	Treatments NS ($N = 95$)	ES ($N = 101$)	IA ($N = 115$)	Overall ($N = 311$)
Rural				
Mean (Median)	0.49 (0.00)	0.51 (1.00)	0.40 (0.00)	0.47 (0.00)
SD	0.50	0.50	0.49	0.50
Min	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00
Age				
Mean (Median)	37.89 (37.00)	39.47 (40.00)	30.99 (28.00)	35.78 (34.00)
SD	14.18	14.36	10.60	13.54
Min	17.00	18.00	14.00	14.00
Max	79.00	72.00	65.00	79.00
Education				
Mean (Median)	11.52 (14.00)	11.59 (15.00)	12.84 (15.00)	12.03 (15.00)
SD	5.16	5.15	4.92	4.92
Min	3.00	3.00	3.00	3.00
Max	16.00	16.00	20.00	20.00
Family structure				
Mean (Median)	0.41 (0.00)	0.65 (1.00)	0.62 (1.00)	0.57 (1.00)
SD	0.49	0.48	0.49	0.49
Min	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00
Family size				
Mean (Median)	5.07 (5.00)	5.37 (5.00)	4.63 (4.00)	5.00 (5.00)
SD	1.77	2.25	1.62	1.94
Min	2.00	1.00	1.00	1.00
Max	12.00	14.00	12.00	14.00
Gender				
Mean (Median)	0.56 (1.00)	0.46 (0.00)	0.42 (0.00)	0.47 (0.00)
SD	0.50	0.49	0.50	0.50
Min	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00
Agricultural engagement				
Mean (Median)	0.52 (1.00)	0.53 (1.00)	0.56 (1.00)	0.54 (1.00)
SD	0.50	0.50	0.50	0.50
Min	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00
Marital status				
Mean (Median)	0.86 (1.00)	0.74 (1.00)	0.62 (1.00)	0.73 (1.00)
SD	0.34	0.44	0.49	0.44
Min	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00
Prosociality				
Mean (Median)[1]	0.52 (1.00)	0.54 (1.00)	0.54 (1.00)	0.53 (1.00)
SD	0.50	0.50	0.50	0.50
Min	0.00	0.00	0.00	0.00
Max	1.00	1.00	1.00	1.00
Initial endowment (X)				
Mean (Median)	1200.00 (1200.00)	861.98 (900.00)	939.13 (1200.00)	993.76 (1200.00)
SD	0.00	342.75	313.60	306.88
Min	1200.00	300.00	300.00	300.00
Max	1200.00	1200.00	1200.00	1200.00

[1] Median values are in parenthesis.

The overall median (mean) terminal period per subject is 1.00 (3.31) for ES treatment (base group) and they are 1.00 (3.52) and 2.00 (4.41) for ES and IA, respectively. The median (mean) terminal period for ES is lower than that of NS and it can be attributed to the differences in each subject's initial endowment (X) in the respective treatments (see table 4.2). The overall median (mean) RUP is 10.00 (17.47) for ES, while they are 1.00 (3.52) and 17.00 (39.47) for NS and IA, respectively, showing substantial differences by treatments. The differences are confirmed from figures 4.4(a) and 4.4(b) that compare medians of terminal periods and RUPs across treatments. We run the Mann-Whitney test to examine distributional differences in terminal period (or RUPs) across treatments, and apply it to every pair of scenarios. The null hypothesis is that the distributions of terminal periods (or RUPs) between two treatments are the same. Regarding terminal period, the results show that null hypotheses are rejected at 5 % and 10 % level only for the pairs of ES vs. IA and NS vs. ES, respectively. This implies that subjects' intertemporal choices for resource sustainability in NS and IA treatments are statistically different than those in the baseline treatment. Regarding the RUP, the null hypotheses are rejected at 1 % level for all pairs of treatments, meaning that subjects' intergenerational choices for resource sustainability are statistically different across treatments. Overall, the results suggest that subjects' intertemporal or intergenerational choices for resource sustainability are generally depend on treatments.

To quantitatively characterize the effects of the scenarios (or survival probabilities), treatments and other independent variables on subjects' terminal periods and RUPs, we employ the Poisson regression. We choose the Poisson regression because terminal period and RUP are the variables of the nonnegative integers with a relatively few observations for each count (Ramirez and Shultz, 2000; Cameron and Trivedi, 2005; Wooldridge, 2019). Since one subject provides 5 observations in our experiment, the data are considered to possess a panel-data structure, where panel unit is a subject and a time unit is a one scenario out of five. Since most independent variables are of time-invariant in nature, we apply random-effects panel Poisson regression (Angrist and Pischke, 2009; Wooldridge, 2019). Regarding RUP, we employ the Poisson regression. Since RUP is the aggregate number of decisions made by the sequences of user, i.e., intergenerational resource users (IRU)) who share the same initial resource (X)

until it is exhausted, we clustered or transformed all independent variables at IRU level by taking their averages.[6] For all treatments, we consider only the first subject per sequence in our analysis who starts SG with the initial endowment ($X = 1200$). Each estimated coefficient of a continuous (or a dummy) independent variable (x) is interpreted as a percentage change with $100 \times \hat{\beta}_x$ (or $\exp[(\hat{\beta}_x) - 1] \times 100$ in $\mathbb{E}$(terminal period$|x$) (or $\mathbb{E}$(RUP$|x$)) when one continuous (or dummy) independent variable increases by one unit (or from zero to one), holding other factors constant. We primarily focus on reporting the effects of treatments, survival scenarios and the interaction terms on terminal period and RUP, because they are the main interests of this study. Table 4.4 first reports the estimated coefficients of the main independent variables on terminal period, while table 4.5 reports for RUP.

The coefficients of NS on terminal period are not statistically significant through models 1 to 4 (table 4.4). However, it becomes statistically significant at 10 % level when we include interaction term between NS and survival probability. The results suggest that subjects' intertemporal choices for sustainability in NS treatment are not statistically different and consistent. Thus, the results do not support Hypothesis $4.1a$ that the subjects with no successors (i.e. NS) results in small terminal period than the subjects in ES treatment. The coefficients of the IA treatment on subjects' terminal period are statistically significant at 1 % level in general in models 1 to 2 with positive signs, holding other variables fixed. Model 1 also shows that the subjects in IA treatment have additional 46.07 % terminal periods than those of ES. The results suggest that IA induces subjects to have more intertemporal choices for sustainability than NS. The results also confirm Hypothesis $4.2a$ that the subjects with existence of successors along with intergenerational accountability results in greater terminal period than the subjects in ES treatment. Note that each subject in IA treatment is asked to write reasons & advice for each scenarios. This could be the reason that IA has positively influenced the subjects to maintain greater terminal period and improved intertemporal choices than ES.[7]

[6]IRU is the group of subjects in a sequence who share the same initial resource endowment (X) until it is exhausted.

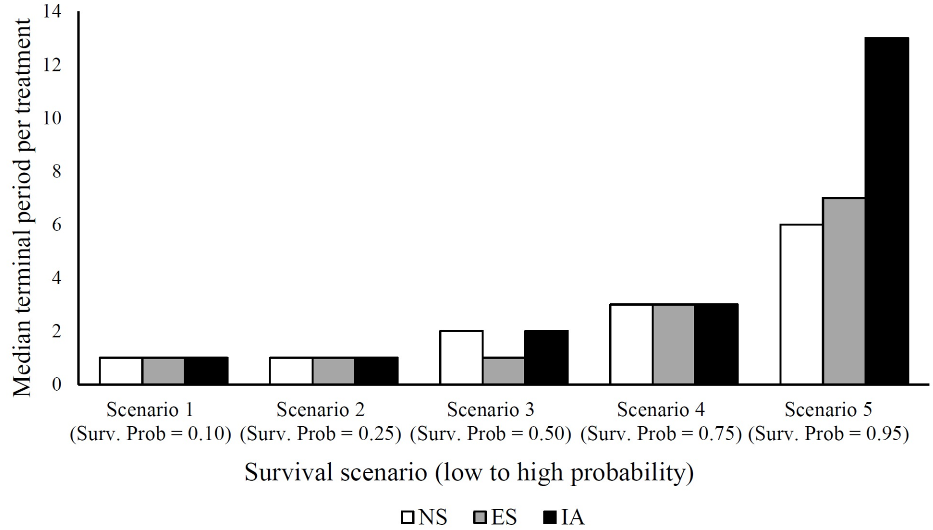
[7]The results of major variables remains consistent in additional models and regression specifications. The estimated coefficients and calculated marginal effects are reported in tables A4.1 to A4.3 in Appendix.

Table 4.3: Medians (means) of terminal periods per subject and resource utilization periods (RUPs) across scenarios in treatments.

Scenario (survival probability)	NS ($N = 95$)		ES ($N = 101$)		IA ($N = 115$)		Overall ($N = 311$)	
	Terminal period	RUP	Terminal period	RUP	Terminal period	RUP	Terminal period	RUP
Scenario 1 (0.10)	1.00 (1.15)	1.00 (1.15)	1.00 (1.10)	6.00 (6.60)	1.00 (1.12)	7.00 (7.48)	1.00 (1.12)	5.00 (5.26)
Scenario 2 (0.25)	1.00 (1.49)	1.00 (1.49)	1.00 (1.23)	6.00 (7.43)	1.00 (1.44)	11.00 (10.70)	1.00 (1.39)	6.00 (6.82)
Scenario 3 (0.50)	2.00 (2.09)	2.00 (2.09)	1.00 (1.84)	10.00 (11.13)	2.00 (1.90)	25.00 (20.59)	2.00 (1.94)	10.00 (11.87)
Scenario 4 (0.75)	3.00 (3.54)	3.00 (3.54)	3.00 (3.35)	20.00 (19.32)	3.00 (3.90)	28.00 (34.74)	3.00 (3.61)	14.00 (20.20)
Scenario 5 (0.95)	6.00 (9.33)	6.00 (9.33)	7.00 (9.02)	42.00 (42.87)	13.00 (12.35)	131.00 (123.85)	8.00 (10.34)	42.00 (62.57)
Overall	2.00 (3.52)	2.00 (3.52)	1.00 (3.31)	10.00 (17.47)	2.00 (4.14)	17.00 (39.47)	2.00 (3.68)	8.00 (21.34)
Observations	475	475	510	106	645	90	1630	671

Note: (1) Scenarios 1 to 5 represent subjects' life expectancy parameters (lower to higher) expressed in terms of survival probability; (2) Sustainable choice represents the median (mean) percentage of the subjects' choices of option B; (3) Mann-Whitney results for subject's sustainable choices: NS vs. ES ($Z = 12.64$, $p < 0.01$); for NS vs. IA ($Z = -13.53$, $p < 0.01$) and for ES vs. IA ($Z = -28.01$, $p < 0.01$) and (4) Mann-Whitney results for RUPs: NS vs. ES ($Z = -22.35$, $p < 0.01$); NS vs. IA ($Z = -24.57$, $p < 0.01$) and for ES vs. IA ($Z = -8.79$, $p < 0.01$).

(a) terminal period per subject



(b) resource utilization period (RUP)

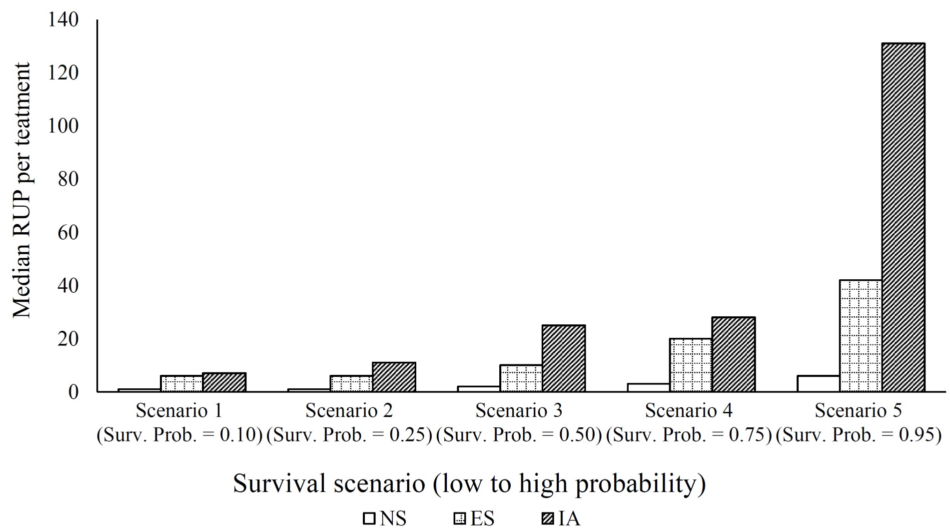


Figure 4.4: Bar graphs of median (a) the terminal period per subject and (b) the resource utilization period (RUP) across scenario (or survival probability) in treatments.

The coefficients of survival probability (or scenario dummies) on terminal period are statistically significant at 1 % level through models 1 to 3 with positive signs. Model 1 shows that the subjects are likely to have additional 2.97 % terminal period when survival probability increases by 10 %. This implies that an improvement in the subjects' life expectancy has a positive role in shaping their intertemporal choices for resource sustainability. Since the subjects in treatments may maintain different terminal periods depending upon the survival probabilities, we include interaction terms between treatments and survival probability (or scenario dummies) in models 3 and 4. The coefficients of the interaction terms between NS treatment and survival probability (or scenario dummies) are statistically insignificant in model 2 (or model 3). On the other hand, the coefficients of interaction term between IA treatment and survival probability (or scenario dummies) are statistically significant at 1 % to 10 % level with positive signs in general. The results demonstrate that the subjects in IA treatment tend to maintain greater terminal period in response to survival probability (or scenario dummies) than in ES. This implies that IA treatment has a positive influence on the subjects' intertemporal choices for resource sustainability when their life expectancy improved.

The coefficients of NS treatment on RUP is statistically significant at 1 % level with negative signs through models 1 to 4 (table 4.5). Model 1 shows that the subjects (or the users) in NS treatment are likely to reduce RUP by about 74 % as compared to ES. The results confirm Hypothesis $4.1b$ that the subjects with no successors (i.e. NS) results in small RUP than those of ES. The results imply that users' decisions to maintain RUP are substantially influenced by the fact of successors' existence. The effect of NS may largely reflect ongoing consequences of users' outmigration on their behaviors for maintaining resource sustainability. The coefficients of the IA generally are found to be statistically significant at 1 % level with positive signs in models 1 and 2, showing that the subjects (or the users) in IA tend to maintain additional 131 % RUP as compared to ES. The results confirm Hypothesis $4.2b$ that the subjects with existence of successors and intergenerational accountability (i.e. IA) results in greater resource utilization periods (i.e. RUP) than the subjects only with existence of successors (i.e. ES). The results could be due to the fact that IA induces intergenerational resource users to behave sustainably when they are asked to write reasons & advice and transfer them to the subsequent generations.

The coefficients of the survival probability (or scenario dummies) on RUP are statistically significant at 1 % level with positive signs in general through models 1 to 3 (or model 4), respectively. Model 3 show that the subjects tend to maintain additional 2.82 % RUP when the survival probability increases by 10 %. The results are consistent with our results in table 4.4, implying that an improvement in subjects' life expectancy positively contributes to intergenerational resource sustainability. The co-

Table 4.4: Estimated coefficients of the count variable of terminal period per subject as the dependent variable in the Panel Poisson regression models.

	Coefficients			
VARIABLES	Model-1	Model-2	Model-3	Model-4
Treatment dummies				
(base group = ES)				
NS	0.062	0.086	0.206*	0.081
	(0.604)	(0.071)	(0.118)	(0.062)
IA	0.225***	0.294***	−0.140	0.001
	(0.059)	(0.074)	(0.103)	(0.052)
Parameters				
Survival probability	2.965***	2.941***	2.794***	–
	(0.071)	(0.073)	(0.133)	
Treatments × Survival probability				
(base group = ES × survival probability)				
NS × survival probability	–	–	−0.156	–
			(0.197)	
IA × survival probability	–	–	0.475***	–
			(0.171)	
Scenario dummies				
(base group: surv. prob = 0.10)				
Survival probability = 0.25	–	–	–	0.211***
				(0.037)
Survival probability = 0.50	–	–	–	0.532***
				(0.041)
Survival probability = 0.75	–	–	–	1.158***
				(0.051)
Survival probability = 0.95	–	–	–	2.207***
				(0.042)
Treatments×survival probability				
(base group = ES × survival prob. = 0.10)				
NS × Survival probability = 0.25	–	–	–	0.148*
				(0.090)
NS × Survival probability = 0.50	–	–	–	0.067
				(0.108)
NS × Survival probability = 0.75	–	–	–	0.042
				(0.128)
NS × Survival probability = 0.95	–	–	–	−0.020
				(0.115)
IA × Survival probability = 0.25	–	–	–	0.149*
				(0.088)
IA × Survival probability = 0.50	–	–	–	0.013
				(0.095)
IA × Survival probability = 0.75	–	–	–	0.142
				(0.119)
IA × Survival probability = 0.95	–	–	–	0.325***
				(0.098)
Sociodemographic variables				
Rural	–	0.096*	0.097*	0.098*
		(0.057)	(0.057)	(0.057)
Prosociality	–	−0.027	−0.027	−0.027
		(0.125)	(0.123)	(0.118)
Other socioeconomic variables	No	Yes	Yes	Yes
Observations	1555	1500	1500	1500
Wald-χ^2	5055.21***	5207.44***	5342.73***	5573.5***

Note: (1) Standard errors clustered at IRU level are in parenthesis, (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$ and (3) Models $1, 2, 3$ & 4 are presented in models $3, 4, 5$ & 7 of table A3-2 in appendix.

efficients of the interaction terms between NS and survival probability (or scenario dummies) and ES are not statistically significant in model 3 (or model 4), meaning that the subjects in NS treatment do not behave differently in response to survival probability at maintaining RUP in comparison to ES. We find the coefficients of interaction terms between IA and survival probability (or scenario dummies) are statistically significant at 1 % level with positive signs. The results imply that the subjects in IA treatment tend to maintain higher RUP in response to survival probability than the subjects in ES.

The coefficients of NS treatment on RUP is statistically significant at 1 % level with negative signs through models 1 to 4 (table 4.5). Model 1 shows that the subjects (or the users) in NS treatment are likely to reduce RUP by about 74 % as compared to ES. The results confirm Hypothesis $4.1b$ that the subjects with no successors (i.e. NS) results in small RUP than those of ES. The results imply that users' decisions to maintain RUP are substantially influenced by the fact of successors' existence. The effect of NS may largely reflect ongoing consequences of users' outmigration on their behaviors for maintaining resource sustainability. The coefficients of the IA generally are found to be statistically significant at 1 % level with positive signs in models 1 and 2, showing that the subjects (or the users) in IA tend to maintain additional 131 % RUP as compared to ES. The results confirm Hypothesis $4.2b$ that the subjects with existence of successors and intergenerational accountability (i.e. IA) results in greater resource utilization periods (i.e. RUP) than the subjects only with existence of successors (i.e. ES). The results could be due to the fact that IA induces intergenerational resource users to behave sustainably when they are asked to write reasons & advice and transfer them to the subsequent generations.

The coefficients of the survival probability (or scenario dummies) on RUP are statistically significant at 1 % level with positive signs in general through models 1 to 3 (or model 4), respectively. Model 3 show that the subjects tend to maintain additional 2.82 % RUP when the survival probability increases by 10 %. The results are consistent with our results in table 4.4, implying that an improvement in subjects' life expectancy positively contributes to intergenerational resource sustainability. The coefficients of the interaction terms between NS and survival probability (or scenario dummies) and ES are not statistically significant in model 3 (or model 4), meaning that the subjects in NS treatment do not behave differently in response to survival probability at maintaining RUP in comparison to ES. We

Table 4.5: Estimated coefficients of the count variable of RUP as the dependent variable in the Poisson regression models.

	Coefficients			
VARIABLES	Model-1	Model-2	Model-3	Model-4
Treatment dummies				
(base group = ES)				
NS	−1.302***	−1.336***	−1.712***	−1.601***
	(0.104)	(0.107)	(0.166)	(0.127)
IA	0.792***	0.835***	−0.257	0.005
	(0.157)	(0.159)	(0.227)	(0.168)
Parameters				
Survival probability	2.817***	2.878***	2.149***	–
	(0.181)	(0.171)	(0.225)	
Treatments × Survival probability				
(base group = ES × survival probability)				
NS × survival probability	–	–	0.471	–
			(0.295)	
IA × survival probability	–	–	1.435***	–
			(0.398)	
Scenario dummies				
(base group: survival prob = 010)				
Survival probability = 0.25	–	–	–	0.085
				(0.150)
Survival probability = 0.50	–	–	–	0.554***
				(0.141)
Survival probability = 0.75	–	–	–	1.043***
				(0.152)
Survival probability = 0.95	–	–	–	1.657***
				(0.183)
Treatments×survival probability				
(base group = ES × survival prob. = 0.10)				
NS × Survival probability = 0.25	–	–	–	0.178
				(0.173)
NS × Survival probability = 0.50	–	–	–	0.037
				(0.171)
NS × Survival probability = 0.75	–	–	–	0.103
				(0.191)
NS × Survival probability = 0.95	–	–	–	0.399*
				(0.207)
IA × Survival probability = 0.25	–	–	–	0.354
				(0.229)
IA × Survival probability = 0.50	–	–	–	0.557**
				(0.225)
IA × Survival probability = 0.75	–	–	–	0.483*
				(0.243)
IA × Survival probability = 0.95	–	–	–	1.217***
				(0.256)
Sociodemographic variables				
% of prosocial subjects	–	−0.172	−0.161	−0.154
		(0.123)	(0.123)	(0.121)
Rural	–	0.516***	0.548***	0.576***
		(0.125)	(0.123)	(0.118)
Other socioeconomic variables	No	Yes	Yes	Yes
Observations	675	645	645	645
Wald-χ^2	419.48***	526.15***	1491.15***	2226.81***

Note: (1) Standard errors clustered at IRU level are in parenthesis, (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$ and (3) Models 1, 2, 3 & 4 are presented in models 3, 4, 5 & 7 of table A3-2 in appendix.

find the coefficients of interaction terms between IA and survival probability (or scenario dummies) are statistically significant at 1 % level with positive signs. The results imply that the subjects in IA treatment tend to maintain higher RUP in response to survival probability than the subjects in ES.

We find that the interaction terms between treatments and survival probability play crucial roles in characterizing terminal period and RUP. To quantitatively clarify the interactions, we calculate and plot terminal period per subject and RUP as predictions for different survival probabilities (holding other independent variables fixed at sample means) based on the estimated results in model 3 of tables 4.4 and 4.5, respectively, and we call them as "predicted terminal period" and "predicted RUP." Figure 4.5a shows the predicted number of terminal period per subject over survival probabilities for NS, ES and IA treatments, respectively, presenting the variations in intercepts and slopes. The intercepts for treatments are positive but there are no considerable differences among them. The slopes of all treatments are steep and positive, meaning that the subjects generally tend to maintain additional terminal period in response to survival probability. The slightly elevated slope of IA (dot lines) implies that subjects' intertemporal choices for resource sustainability, or subjects tend to have high sensitivity to their own survival probability as compared to the subjects in ES. The intercepts and slopes are distinct for the respective treatments in figure figure 4.5b that shows the predicted number of RUP over survival probabilities for treatments. In summary, the results graphically and quantitatively demonstrate that the long life expectancy, successors' existence are keys to improve the subjects' intertemporal as well as intergenerational choices for resource sustainability. In particular, provided with successors, "IA" is found to be more effective than others to induce the subjects not only for intertemporal but also for intergenerational sustainability.

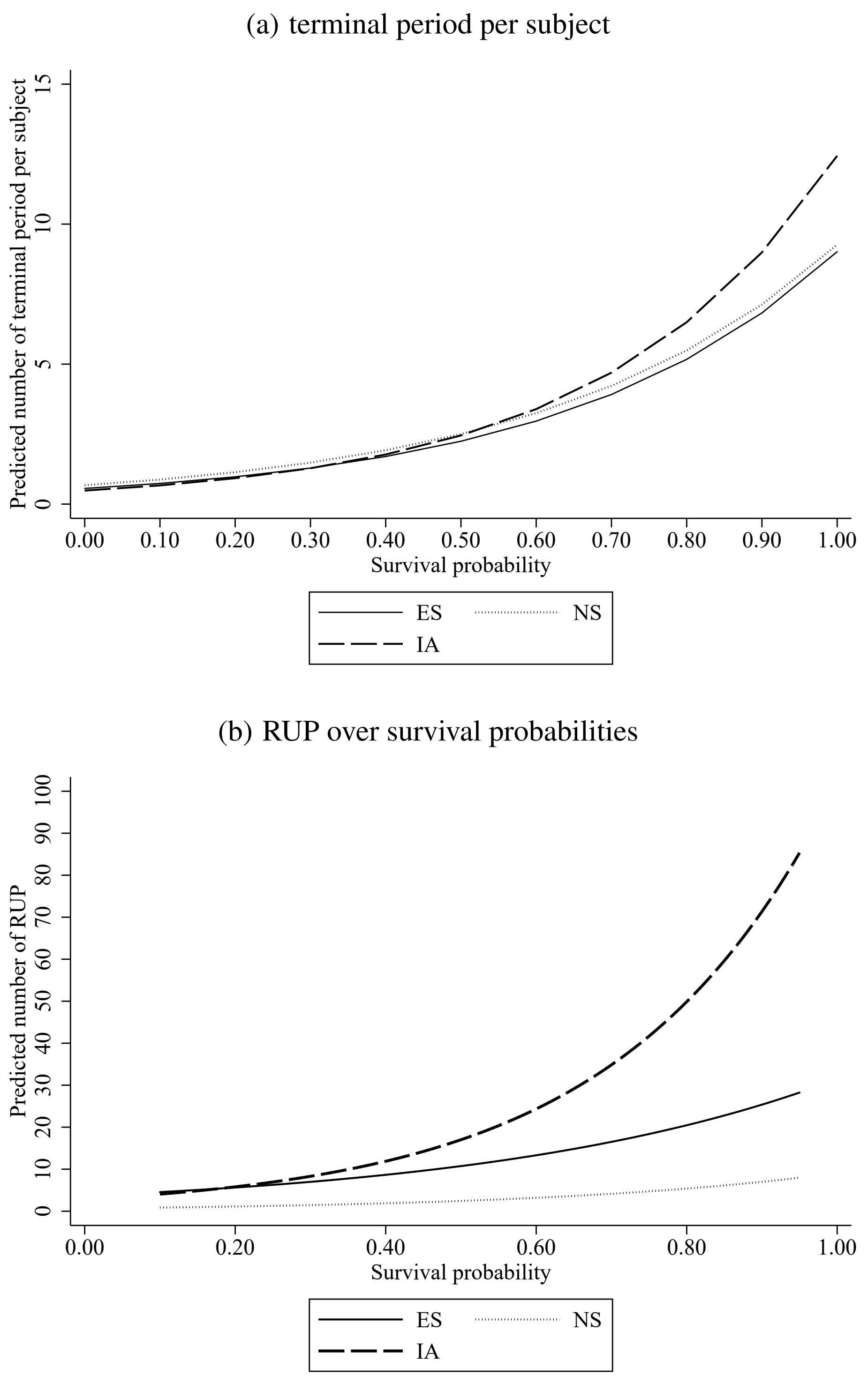


Figure 4.5: Predicted (a) the terminal period per subject and (b) the RUP over survival probabilities by treatments.

Behavioral scientists have identified several motives, such as generativity, legacy, altruistic, solidarity, generosity and reciprocity, that can induce users for social behaviors (Erikson, 2013; Kotre, 1996, 2011; Wade-Benzoni and Tost, 2009; Andreoni and Rao, 2011; Watanabe et al., 2014; Wade-Benzoni, 2019). They consider that these motives are responsible for carrying out the users' learning and life stories of handling and transferring resources to the future. However, these motives can only be carried out or function when a user perceives or realizes if he/she lives longer, or there are successors in the future to use and maintain the resources.[8] This could be the reasons for people's higher sustainable behaviors in ES than those of NS. Some economists, such as Bishop (1977) and Howarth (1991), argue that suitable environment is necessary for equitable distribution of resource across time, i.e., periods and generations. Thus, long life expectancy and existence of successors as reflected by our findings can be considered as a necessary condition for intertemporal and intergenerational sustainability.

Several resource economists attempt to address whether or not intertemporally efficient resource allocations lead for intergenerational equity (Solow, 1974; Dasgupta and Mitra, 1983; Pezzey, 1992, 1997; Horowitz, 1992; Mitra, 2002; Asheim and Mitra, 2020). They theoretically show that there exists a possible path (called as "amenity path") in which intertemporally efficient choice lead for intergenerational sustainability. Some studies argue that realizing such path is practically challenging in the light of uncertainty where people heavily discount futures (Yaari, 1965; Kreps and Poteus, 1978; Krysiak, 2008; Jacquet et al., 2013). Padilla (2002) argues that users need to take sustainability as an equity commitment to the future generations, and considers the need of some institutions or social devices to render sustainability as the rights of future generations. Our findings bring an empirical evidence that achieving the amenity path is possible when we introduce intergenerational accountability (IA) as a social device and induce users to be accountable for their decisions. By doing so, we argue that users' decisions not only be intertemporally efficient, but also become intergerationally sustainable (sustainable option, i.e., option B that represents for both intertemporally efficient as well as intergenerationally equitable choice for users in maintaining sustainability).

[8]For example, Levinson (1978) argue that anticipation of death triggers thoughts of "creating legacy" motivations as the postponement of user's death that enables to invest for his/her successors in the future.

In two possible ways, IA may induce users for sustainability. First, it might trigger users' motives of generativity, legacy, reciprocity, inducing them for maintaining sustainability by cognitively interconnecting them with successors. In the process of connecting with successors (future others), people might have automatically connected to their own future-selves, leading them for intertemporal sustainability. Past literature suggests that people tend to take future-others as if like future-selves when they plan for future (Bartels and Rips, 2010; Hershfield, 2011; Molouki and Bartels, 2020). Second, IA may function as a mechanism through which successors receive information from previous generations about their decisions, associated motives and lessons of resource management through the written reasons & advice (Koirala et al., 2021).[9,10] The effect of IA on users, however, may depend on several individual factors, such as life expectancy. Users with longer life expectancy accumulate greater decision-making (or life stories) experience in their life span than others.[11] We argue that such users may come up with long-term solutions along with reasons & advice due to the accumulative experience through their longer lives, and if they are asked to write the reasons & advice for their decisions and transfer them to successors, such asks may induce them for sustainability. It is because they may find it as an opportunity to pass their life stories to successors. The one-way transfers of reasons & advice may have induced successors to follow what the previous generations' did that ultimately results in enhanced sustainability.

Societies in several developing and developed countries have suffered from aging and/or depopulation either due to declined population growth rate, urbanization and/or outmigration (United Nations, 2019). Rural areas are often considered the sources of various resources as well as food basket for the rest of the population (Davis et al., 2013; Ojha et al., 2017). The areas also hold majority of the resources, the sources that generates livelihoods and foods for both the current and future genera-

[9]Several evidences from psychology, economics and ecology have shown that the ability of humans to learn and cooperate socially over generations is the key for their survival as a species (Sober and Wilson, 1999; Batki et al., 2000; Scharlemann et al., 2001; Haley and Fessler, 2005; Brewer and Caporael, 2006; Cimino and Delton, 2010; Henrich, 2015).

[10]Danku et al. (2019) argue that information flow from the past discourages defectors from exhausting resources and increases long-term benefits of cooperative behaviors.

[11]Fox et al. (2010) argue that legacy can function as a carrier of individual life meaning beyond her life, affecting other users in the future.

tions, i.e., successors. Our findings suggest that resource users may behave unsustainably and exhaust them untimely, leaving the irreversible consequences to the future if the ongoing trends of aging and out-migration continues. To resolve these adverse consequences, it shall be necessary to arrange the successors between the current users and successors and institutionalize accountability as a social device shall be necessary to drastically enhance not only intertemporal, but also intergenerational resource sustainability, even when societies suffer from aging and depopulation.

4.4 Conclusion

This research has addressed how people's intertemporal and intergenertaional choices for resource sustainability are affected by life expectancy, successors' existence and accountability to successors. We conduct field experiments by instituting sustainability game (SG) where a user is probabilistically determined to live up to the next period, and the probabilities are parametrized to represent different life expectancy by strategy method. Three treatments: (i) "no successors" (NS) – representing a societies without successors, (ii) "existence of successors" (ES) – representing societies with successors and (iii) "intergenerational accountability" (IA) – representing accountable societies with existence of successors. Results demonstrate that long life expectancy and successors' existence are keys to improve resource sustainability. In particular, provided with successors, "IA" is found to further contribute to sustainability, and the IA positive effect nonlinearly inflates with life expectancy. This implies that not only arranging a successor, but also institutionalizing accountability between current users and successors shall drastically enhance resource sustainability, even when societies suffer from aging and depopulation.

Chapter 5

Conclusion

In this thesis, we have addressed individual and group behaviors for sustainability and climate change under various institutional settings. First chapter presents issues and research gaps in understanding people's behaviors for sustainability and climate change as well as the motivations for the studies. The second chapter has analyzed whether or not deliberative forms of democracy with voting resolve ISD. In this chapter, we institute ISDG with three forms of decision-making models by experimentally manipulating prevoting components and examine how they maintain IS in laboratory experiments. Game theory predicts that generations choose an unsustainable option in ISDG, and our results in the base group (MV) are in line with the prediction. Other two models of deliberative decision making (i.e., DMV and MVDA) are found to be more effective than MV. We also find that a majority of generations still chooses an unsustainable option in all treatments. The results imply that maintaining IS shall be very challenging with majority voting, especially when generations are neither biologically nor socially connected, i.e., non-overlapping generation. However, when deliberation and one-way communication (IA) from the current generation to future generations are introduced along with majority voting, generations choose to be sustainable. Overall, the chapter suggests how people can be influenced for maintaining sustainability at the institutional level.

The third chapter has investigated what matters for farmers' adaptation responses to climate change, hypothesizing that farm size, climatic perceptions and the interplay are the key determinants for farmers' adaptation responses. We conduct questionnaire surveys with 1000 farmers in Nepal, collecting data on their adaptation responses, farm size, climatic perceptions and sociodemographic information in Nepal. The analyses reveal that farmers tend to take additional adaptation responses as farm size becomes small or as they have good climatic perceptions & social network with other farmers. They also show that small-sized farmers tend to adapt much more in response to their climatic perceptions than do large-sized ones, confirming insensitivity of large-sized farmers to climate change in Nepal. Overall, this research suggests that agriculture may be losing responsiveness to climate change, as large-sized farmers become dominant by holding a majority of land in developing countries. Thus, it is advisable to reconsider the tradeoff between productivity and responsiveness to climate change regarding farm size as well as how large-sized farmers can be induced to adapt through their cognition, policies, social networking and technology for food security. Overall, the chapter suggests how farmers can be induced for better adaptation responses at the household level.

The fourth chapter has addressed how individual intertemporal and intergenerational behaviors for resource in relation to uncertainty (or survival probability or life expectancy) and successors' existence. We conduct field experiments by instituting sustainability game (SG) where a user is probabilistically determined to live up to the next period, and the probabilities are parametrized to represent different degrees of uncertainty (or survival probability) by strategy method. Three treatments: (i) "no successors" (NS) – representing a societies without successors, (ii) "existence of successors" (ES) – representing societies with successors and (iii) "intergenerational accountability" (IA) – representing accountable societies with existence of successors. Results demonstrate that lower uncertainty and successors' existence are keys to improve resource sustainability. In particular, provided with successors, "IA" is found to further contribute to sustainability, and the IA positive effect nonlinearly inflates with life expectancy. This implies that not only arranging a successor but also institutionalizing accountability between current users and successors shall drastically enhance resource sustainability, even when societies suffer from aging and depopulation. Overall, the chapter suggests how people can be influenced for maintaining sustainability at the individual level.

Finally, we note some limitations and possible future studies. The second chapter only consider direct democracy as experimental treatments in this research. However, in the contemporary world, representative (or indirect) democracy is popular. It is important to examine IS under some forms of indirect democracy in the future. Third, as posited by Habermas, the deliberation in our experiment does not satisfy the "ideal speech" condition (Habermas, 1984, 1994), and the number of generation members is limited to be three. Future studies should be able to investigate IS by extending the deliberation conditions, such as the number of generation members. Fourth, this study includes only Japanese students from the student subject pool of KUT so that the effects of treatments can be under or overestimated. Future studies in this domain should examine IS by taking subjects from a general public pool for external validity. These caveats notwithstanding, we believe that this work is an essential step as experimental research, suggesting how two forms of deliberative democracy can enhance IS and represent potential interests of future generations.

The third chapter does not address the detailed processes of why different-sized farmers exhibit heterogeneous responses to climatic perceptions. Future studies should closely examine farmers' cognitive and motivational factors by farm size. Two approaches are suggested: (1) neuropsychological research and (2) qualitative and deliberative research. The former (latter) clarifies various cognitive scales and neuroimages (motivations) for farmers to adapt to climate change (Hobson and Niemeyer, 2011; Collins and Nerlich, 2014; Shahen et al., 2020; Sawe and Chawla, 2021; Timilsina et al., 2021a,b; Wang and van den Berg, 2021). Second, this study employs an area-based index to consider variations among farmers' adaptations, while some literature uses weights elicited from experts or stakeholders (Below et al., 2012; Khanal and Wilson, 2019). Because a developing country, such as Nepal, consists of heterogeneous geography and climate where wide range of agricultural practices are found, it is our view that experts or stakeholders might not be able to fully consider such heterogeneity. Rather, farmers may be the best candidates who can evaluate the differences among adaptations, and future research can consider weights by farmers for adaptations as well. These caveats notwithstanding, we believe that this is the first study to analyze the relationship between farm size and climatic perceptions to characterize farmers' adaptation responses to climate change, contributing to the economics literature and sustainability.

The fourth chapter only examines individual intertemporal and intergenerational choices for sustainability. In real life situations, people usually make choices not only considering intertemporal and intergenerational dimensions but also intra-generational dimension. Future studies can analyze how people make choices considering these three dimensions in a single framework. Second, we only incorporate five parameters of uncertainty in our field experiments; however, more point parameters should be included to provide a better explanation of individual behaviors. Third, our experiments did not explore the underlying mechanism that motivates people to sustain resources with ES and IA. Future study shall be able to fulfill these gaps by conducting qualitative study, such as in-depth interviews and identify individual motivations and perceptions of sustainable and unsustainable choices. These caveats notwithstanding, we believe that our field experiment takes an important step to characterize intertemporal and intergenerational choices for resource sustainability concerning uncertainty, an absence (or an existence) of successors and a social device, such as IA, considering non-overlapping generations, and hence contributes to the sustainability literature.

NOMENCLATURE

NS No Successors

ES An Existence of Successors

IA Intergenerational Accountability

VDC Village Development Committee

LSS Local Supporting Staff

RA Research Assistant

SVO Social Value Orientation

RUP Resource Utilization Period

IRU Intergenerational Resource Users

LRP Local Resource Person

NPR Nepalese Rupee

IS Intergenerational Sustainability

ISD Intergenerational Sustainability Dilemma

ISDG Intergenerational Sustainability Dilemma Game

MV Majority Voting

DMV Deliberative Majority Voting

MVDA Majority Voting with Deliberative Accountability

NE Nash Equilibrium

SVO Social Value Orientation

KUT Kochi University of Technology

RA Research Assistants

JPY Japanese Yen

WTP Willigness To Pay

VDC Village Development Commitee

HH Household

RA Research Assistant

AFU Agriculture and Forestry University

AdaptN Number of Adaptations

AI Adaptation Index

ha Hectares

CPI Climate Perception Index

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APPENDICES

Instructions

Introduction to AB game

Thank you for your participation in this experiment. Every subject shall be given 600 points as an **initial endowment** only for participation. **Additional points** will be given depending on how you perform in the AB game. In summary, the payoff you will receive from the AB game are as follows:

Your total payoff $=$ **Initial endowment of** 600 **points** $+$ **Your share of the additional points**.

In this AB game, you will go through the following procedures.

1. Group assignment: you are assigned to a group of three people.
2. Group decision: each group is asked to decide between options A and B through majority voting.

Group assignment

You shall be a part of a group which consists of three people. To determine your group, you are asked to pick one chip out of a bag where the chip indicates your group and ID (See example 1.1 below). Based on the information on the chip, experimenters instruct each of you to move to different rooms to conduct experiments.

Example 1.1 *The chip you picked from the bag indicates the following type of information:*

"A2-3"

where

- *The "2" is your group ID as the* $2nd$ *group of the sequence* A.
- *The "3" indicates your subject ID number* 3 *within the* $2nd$ *group.*

Group decision

Each member in a group is asked to cast an anonymous vote between options A and B independently of other members in the same group. You must mark your vote in a paper sheet and hand it over to the experimenters. Note that the majority of votes determines the group decision between options A and B. Specifically, the group decision will be "A" (or "B") if 2 or 3 (all) group members vote for option A (or B). By counting the votes of members in each group, experimenters will announce the group decision and the associated "additional points."

After the decision, the "additional points" are given to the group and equally divided among the three members. The division of the additional points by three will be **your share of the "additional points"** from the AB game. Recall that your total payoff in the AB game is the sum of the initial endowment ($= 600$ points) and your share from the group's "additional points" ($= \frac{\text{additional points}}{3}$). This is all about the rules concerning how your total payoff is determined. However, this is not the end of the story.

What your group does would affect other groups

What your group does may affect the additional points for other groups. In this experiment, the $1st$ group starts playing the AB game and is asked to choose between options A and B by majority voting with the following payoff structures:

- By choosing A, the $1st$ group receives 3600 points as the "additional points."
- By choosing B, the $1st$ group receives 2700 points as the "additional points."

Next, the $2nd$ group is asked to choose between options A and B with majority voting, based upon the $1st$ group's decision. Then, the $3rd, 4th, \ldots$ groups ensue sequentially in an ascending order of group IDs. Suppose that the $1st$ group makes the decision between options A and B, and next, the $2nd$ group shall be asked to play the AB game. Then, the subsequent group's payoff structures are affected by the $1st$ group's decision in the following way:

Table A2.1: How the decision of the $1st$ group affects the $2nd$ group

the $1st$ group	the $2nd$ group
A: 3600	A: 2700 B: 1800
B: 2700	A: 3600 B: 2700

- Suppose that the $1st$ group chooses option A and receives 3600 points. Then, subsequent groups' additional points decline uniformly by 900.
- Suppose that the $1st$ group chooses option B and receives 2700 points. Then, the next group $(= 2nd$ group) can have the same decision environment as the $1st$ group.

This rule could be better explained with numerical examples.

Example 1.2 *Assume as in table A2.1 that when the $1st$ group chooses option A, the group receives 3600 points. When the $1st$ group chooses option B, the group receives 2700 points.*

- *When the $1st$ group chooses option A, the additional points the $2nd$ group can receive by choosing options A and B uniformly decline by 900, and they are 2700 and 1800, respectively (Table A2.1).*
- *When the $1st$ group chooses option B, the additional points the $2nd$ group can receive by choosing options A and B remain the same, and which are 3600 points and 2700 points, respectively (Table A2.1).*

The same rule applies to any pair of other groups as well, say, between the $2nd$ and the $3rd$, the $4th$ and the $5th$ groups, . . . etc. To further illustrate the rule of the experiment, another example is provided below.

Example 1.3 *[Between the $2nd$ and the $3rd$ groups]Suppose the $1st$ group chooses option A. Then, in this case, the $2nd$ group can subsequently receive 2700 points or 1800 points depending on the*

Table A2.2: How the decision of the $2nd$ group affects the $3rd$ group

the $2nd$ group	the $3rd$ group
A: 2700	A: 1800 B: 900
B: 1800	A: 2700 B: 1800

decision between options A and B (see tables A2.1 & A2.2). The same rule as described in table A2.2 applies to the relation between the 2nd and the 3rd groups. Table A2.2 summarizes this example.

- *When the $2nd$ group chooses option A, the additional points the $3rd$ group can receive by choosing options A and B uniformly decline by* 900*, and they are* 1800 *points and* 900 *points, respectively (Table A2.2).*
- *When the $2nd$ group chooses option B, the additional points the $3rd$ group can receive by choosing options A and B remain the same, and they are* 2700 *points and* 1800 *points, respectively (Table A2.2).*

Note the possibility that your share of the additional points becomes even negative when you are assigned to be in the $5th, 6th, \ldots$ or the latter groups and when all previous groups choose option A. When the additional points your group receives becomes negative, each member in such a group needs to pay the individual negative share of the additional points from the initial endowment of 600 points.

Summary

You are a part of one group within a sequence consisting of the $1st, 2nd, \ldots$ groups. The group decision between options A and B is made by majority voting, affecting all of other subsequent groups that will play the game. Again, note that the aforementioned rule in the AB game applies to any pair of other groups as well, say, between the $3rd$ and the $4th$ and between the $4th$ and the $5th$ groups, …

etc. Finally, your total payoff in the AB game is the sum of the initial endowment ($= 600$ points) and your share from the group's "additional points" ($= \frac{\text{additional points}}{3}$).

Protocols for AB game

Experimenters let your group know the previous groups' decisions and the associated payoff structures your group faces before voting. If you are part of $2nd, 3rd, 4th \ldots$ groups other than $1st$ group, the payoff structures are affected by how previous groups have made decisions between options A and B. After voting, your group decision and the associated additional points shall be announced, and your total payoff are determined.

Exchange rate: 1 points you make from the AB game equals to 2 Japanese yen.

Table A2.3: Summary statistics of independent variables at generational level by treatments.

Variables	Treatments MV (N = 35)	DMV (N = 33)	MVDA (N= 36)	Overall (N = 104)
Prosocial subjects	31.43 % ($=\frac{33}{105}$)	30.30 % ($=\frac{30}{99}$)	49.07 % ($=\frac{53}{108}$)	37.18 % ($=\frac{116}{312}$)
Female subjects	51.43 % ($=\frac{54}{105}$)	43.43 % ($=\frac{43}{99}$)	44.44 % ($=\frac{48}{108}$)	46.47 % ($=\frac{145}{312}$)
# of prosocial members per generation				
Mean (Median)[1]	0.94 (1.00)	0.91 (1.00)	1.47 (1.00)	1.12 (1.00)
SD	0.90	0.80	0.99	0.93
Min	0.00	0.00	0.00	0.00
Max	3.00	3.00	3.00	3.00
Average empathic concern				
Mean (Median)	17.48 (17.33)	18.40 (18.33)	18.39 (18.50)	18.09 (18.17)
SD	2.59	1.92	2.99	2.58
Min	13.00	14.67	11.00	11.00
Max	23.33	22.00	24.67	24.67
Average personal distress				
Mean (Median)	15.92 (16.00)	15.67 (16.00)	15.91 (15.83)	15.84 (16.00)
SD	2.86	2.87	3.09	2.93
Min	10.00	9.33	6.67	6.67
Max	23.00	22.00	20.33	23.00
Average critical thinking disposition				
Mean (Median)	40.03 (40.67)	41.19 (41.00)	41.50 (41.83)	40.91 (41.17)
SD	3.37	3.18	2.91	3.21
Min	31.67	32.33	34.33	31.67
Max	48.33	46.67	47.33	48.33
# of female per generation				
Mean (Median)	1.54 (2.00)	1.30 (1.00)	1.33 (1.00)	1.39 (1.00)
SD	1.11	1.03	0.98	1.04
Min	0.00	0.00	0.00	0.00
Max	3.00	3.00	3.00	3.00

[1] Median values are in parenthesis.

Table A2.4: The frequencies and percentages of generation choices of option B with respect to the number of prosocial members per generation in treatments.

# of prosocial members	Percentage of option B choice			
	MV (N = 35)	DMV (N= 33)	MVDA (N = 36)	Overall (N= 104)
0	7.69 % $(=\frac{1}{13})$	0.00 % $(=\frac{0}{10})$	0.00 % $(=\frac{0}{6})$	3.45 % $(=\frac{1}{29})$
1	0.00 % $(=\frac{0}{13})$	11.11 % $(=\frac{2}{18})$	14.29 % $(=\frac{2}{14})$	8.89 % $(=\frac{4}{45})$
2	0.00 % $(=\frac{0}{7})$	0.00 % $(=\frac{0}{3})$	55.56 % $(=\frac{5}{9})$	26.32 % $(=\frac{5}{19})$
3	50.00 % $(=\frac{1}{2})$	100 % $(=\frac{2}{2})$	42.86 % $(=\frac{3}{7})$	54.55 % $(=\frac{6}{11})$
Subtotal	5.71 % $(=\frac{2}{35})$	12.12 % $(=\frac{4}{33})$	27.78 % $(=\frac{10}{36})$	15.38 % $(=\frac{16}{104})$

Table A2.5: Marginal effects of independent variables on the probability of option B choice in logit regressions (base group $=$ option A choice).

	Option B choice		
	Model 1	Model 2	Model 3
Independent variables			
Treatment dummies (base group = DMV)			
MVDA	0.159***	0.047	0.050***
	(0.049)	(0.043)	(0.041)
Sociodemographic and psychometric variables			
Prosocial		0.154***	0.152***
		(0.018)	(0.019)
Gender			−0.011
			(0.020)
Empathic concern			0.018***
			(0.007)
Personal distress			−0.020*
			(0.010)
Critical thinking disposition			−0.001
			(0.010)
Observations (generations)	69	69	69

Note: (1) Standard errors clustered at the sequence level are in parenthesis, (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$ and (3) Marginal effects are calculated at the same means of independent variables.

Table A3.1: Number of sampled households by region, district, administrative unit, ward and locality.

Province (or Development Region)	District	Administrative unit	Ward number	Locality	# of HHs
Province 1 (Eastern)	Dhankuta	Dhankuta Municipality	2,3	Bhirgaun	35
Province 1 (Eastern)	Dhankuta	Dhankuta Municipality	9,10	Belhara	35
Province 1 (Eastern)	Dhankuta	Pakhribas Municipality	9,10	Chumbang	30
Province 1 (Eastern)	Morang	Dhanapatan Rural Municipality	1	Nocha	25
Province 1 (Eastern)	Morang	Katahari Rural Municipality	7	Thalaha	25
Province 1 (Eastern)	Morang	Gramthan Rural Municipality	5	Tetariya	25
Province 1 (Eastern)	Morang	Belbari Municipality	5	Kaseni	25
Province 2 (Eastern)	Saptari	Chinnamasta Rural Municipality	6	Kochawakhari	55
Province 2 (Eastern)	Saptari	Rupni Rural Municipality	1	Raipur	45
Bagmati (Central)	Bhaktapur	Suryabinayak Municipality	2,3	Balkot	34
Bagmati (Central)	Bhaktapur	Suryabinayak Municipality	1,4	Dadhikot	30
Bagmati (Central)	Bhaktapur	Suryabinayak Municipality	5,6	Katunje	36
Bagmati (Central)	Chitwan	Rapti Municipality	7	Birendranagar	30
Bagmati (Central)	Chitwan	Bharatpur Metropolitan City	15	Phulbari	30
Bagmati (Central)	Chitwan	Bharatpur Metropolitan City	20	Gunjanagar	40
Gandaki (Western)	Kaski	Pokhara Municipality	23	Chapakot	25
Gandaki (Western)	Kaski	Annapurna Rural Municipality	4	Bhadaure	25
Gandaki (Western)	Kaski	Annapurna Rural Municipality	2	Dhikurpokhari	25
Gandaki (Western)	Kaski	Annapurna Rural Municipality	7	Lumle	25
Lumbini (Western)	Rupendehi	Mayadevi Rural Municipality	7,8	Hattibangai	38
Lumbini (Western)	Rupendehi	Tilottama Municipality	9	Anandaban	27
Lumbini (Western)	Rupendehi	Tilottama Municipality	5,6	Managalpur	35
Lumbini (Mid-western)	Dang	Ghorahi Municipality	10	Narayanpur	36
Lumbini (Mid-western)	Dang	Tulsipur Municipality	16	Manpur	34
Lumbini (Mid-western)	Dang	Tulsipur Municipality	18,19	Bijauri	30
Lumbini (Mid-western)	Bardiya	Bardiyataal Rural Municipality	5	Sorhawa	32
Lumbini (Mid-western)	Bardiya	Bardiaytaal Rural Municipality	8,9	Kalika	30
Lumbini (Mid-western)	Bardiya	Gulariya Municipality	11	Mohammadpur	38
Sudurpaschim (Far-western)	Baitadi	Patan Municipality	8	Khodpe	52
Sudurpaschim (Far-western)	Baitadi	Dilashaini Rural Municipality	6	Gokuleshowar	48

Table A4.1: Logit models with dummy variable of the binary choice between options A and B as the dependent variable, with the choice of option A as the base group. (Table continues to the next page.)

	Model-1		Model-2		Model-3		Model-4		Model-5		Model-6	
Variables	Coeff.[a]	ME[b]	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME
Treatment dummies												
(base group = ES)												
NS	−0.718***	−0.129***	−0.730***	−0.123***	−0.738***	−0.124***	−0.634***	−0.102***	−0.720**	−0.101***	−0.225	−0.101***
	(0.084)	(0.015)	(0.088)	(0.015)	(0.088)	(0.015)	(0.110)	(0.018)	(0.325)	(0.018)	(0.233)	(0.018)
IA	0.805***	0.105***	0.875***	0.108***	0.891***	0.108***	0.970***	0.116***	−0.086	0.115***	0.073	0.115***
	(0.092)	(0.012)	(0.093)	(0.012)	(0.094)	(0.012)	(0.102)	(0.013)	(0.287)	(0.013)	(0.225)	(0.013)
Parameters												
Survival probability	–	–	2.22***	0.308***	–	–	–	–	–	–	2.14***	0.303***
			(0.149)	(0.019)							(0.241)	(0.020)
Treatments × Survival probability												
(base group = ES)												
NS × Survival probability	–	–	–	–	–	–	–	–	–	–	−0.546*	–
											(0.305)	
IA × Survival probability	–	–	–	–	–	–	–	–	–	–	1.529***	–
											(0.338)	
Scenario dummies												
(base group: Survival probability = 0.10)												
Survival probability = 0.25	–	–	–	–	0.692***	0.137***	0.672***	0.128***	0.159***	0.131***	–	–
					(0.164)	(0.032)	(0.177)	(0.033)	(0.177)	(0.033)		
Survival probability = 0.50	–	–	–	–	1.568***	0.293***	1.630***	0.291***	0.955	0.296***	–	–
					(0.160)	(0.030)	(0.173)	(0.033)	(0.268)	(0.030)		
Survival probability = 0.75	–	–	–	–	1.870***	0.337***	0.199***	0.342***	1.596***	0.347***	–	–
					(0.155)	(0.029)	(0.169)	(0.033)	(0.177)	(0.033)		
Survival probability = 0.95	–	–	–	–	2.099***	0.366***	2.217***	0.369***	1.710***	0.375***	–	–
					(0.154)	(0.029)	(0.166)	(0.030)	(0.244)	(0.030)		
Treatments × Survival scenarios												
(base group: ES & survival probability = 0.10)												
NS × Survival probability = 0.25	–	–	–	–	–	–	–	–	0.496	–	–	–
									(0.422)			
NS × Survival probability = 0.50	–	–	–	–	–	–	–	–	0.533	–	–	–
									(0.392)			
NS × Survival probability = 0.75	–	–	–	–	–	–	–	–	−0.035	–	–	–
									(0.372)			
NS × Survival probability = 0.95	–	–	–	–	–	–	–	–	−0.020	–	–	–
									(0.346)			
IA × Survival probability = 0.25	–	–	–	–	–	–	–	–	0.850**	–	–	–
									(0.383)			
IA × Survival probability = 0.50	–	–	–	–	–	–	–	–	1.218***	–	–	–
									(0.380)			
IA × Survival probability = 0.75	–	–	–	–	–	–	–	–	1.029***	–	–	–
									(0.362)			
IA × Survival probability = 0.95	–	–	–	–	–	–	–	–	1.603***	–	–	–
									(0.337)			
Decision period dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Initial resource endowment (X)	–	–	–	–	–	–	−0.045	−0.006	−0.086	−0.011	−0.075	−0.010
							(0.152)	(0.020)	(0.156)	(0.020)	(0.153)	(0.020)

Note: (1) Models 1 to 6 include decision period dummies, (2) Standard errors are in parenthesis and (3) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$.

[a] Coeff. indicates coefficients.

[b] ME indicates marginal effects calculated at the same means of the independent variables.

Table A4.1: (Continued from the previous page.) Logit models with dummy variable of the binary choice between options A and B as the dependent variable, with the choice of option A as the base group.

	Model-1		Model-2		Model-3		Model-4		Model-5		Model-6	
Variables	Coeff.[a]	ME[b]	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME
Sociodemographic variables												
Prosociality	–	–	–	–	–	–	−0.140*	−0.018*	−0.141*	−0.018*	−0.133*	−0.018*
							(0.078)	(0.013)	(0.078)	(0.013)	(0.078)	(0.012)
Rural	–	–	–	–	–	–	1.028***	0.134***	1.029***	0.134***	1.020***	0.134***
							(0.103)	(0.013)	(0.104)	(0.013)	(0.103)	(0.013)
Age	–	–	–	–	–	–	−0.014***	−0.002***	−0.015***	−0.002***	−0.014***	−0.002***
							(0.004)	(0.001)	(0.004)	(0.001)	(0.004)	(0.001)
Education	–	–	–	–	–	–	0.041***	0.005***	0.041***	0.005***	0.040***	0.005***
							(0.009)	(0.001)	(0.009)	(0.001)	(0.009)	(0.001)
Family structure	–	–	–	–	–	–	0.212**	0.028**	0.212**	0.028**	0.209**	0.028**
							(0.086)	(0.011)	(0.087)	(0.011)	(0.086)	(0.011)
Family size	–	–	–	–	–	–	0.078***	0.010***	0.078***	0.010***	0.079***	0.010***
							(0.024)	(0.003)	(0.025)	(0.003)	(0.025)	(0.003)
Gender	–	–	–	–	–	–	−0.153*	−0.020*	−0.153*	−0.020*	−0.140*	−0.018*
							(0.079)	(0.010)	(0.079)	(0.010)	(0.079)	(0.010)
Agricultural engagement	–	–	–	–	–	–	−0.048	−0.006	−0.048	−0.006	−0.039	−0.005
							(0.105)	(0.014)	(0.106)	(0.015)	(0.106)	(0.015)
Marital status	–	–	–	–	–	–	−0.057	−0.008	−0.054	−0.007	−0.076	−0.010
							(0.110)	(0.014)	(0.112)	(0.015)	(0.112)	(0.015)
Observations	5417		5417		5417		5206		5206		5206	
Wald-$\chi 2$	619.61***		805.82***		782.04***		869.98***		867.85***		841.97***	

Note: Note: (1) Models 1 to 6 include decision period dummies, (2) Standard errors are in parenthesis and (3) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$.

[a] Coeff. indicates coefficients.

[b] ME indicates marginal effects calculated at the same means of the independent variables.

Table A4.2: Poisson models with count variable of RUP as the dependent variable (Table continues to the next page.).

	Coefficients						
VARIABLES	Model-1	Model-2	Model-3	Model-4	Model-5	Model-6	Model-7
Treatment dummies							
(Base group = ES)							
NS	−1.464***	−1.302***	−1.336***	−1.712***	−1.276***	−1.313***	−1.601***
	(0.125)	(0.104)	(0.107)	(0.166)	(0.105)	(0.108)	(0.127)
IA	0.570***	0.792***	0.835***	−0.257	0.818***	0.872***	0.005
	(0.197)	(0.157)	(0.159)	(0.227)	(0.155)	(0.149)	(0.168)
Parameters							
Survival probability	–	2.817***	2.878***	2.149***	–	–	–
		(0.181)	(0.171)	(0.225)			
Treatments × survival probability							
(base group = ES)							
NS × Survival probability	–	–	–	0.471	–	–	–
				(0.295)			
IA × Survival probability	–	–	–	1.435***	–	–	–
				(0.398)			
Scenario dummies							
(base group: survival probability = 0.10)							
Survival prob = 0.25	–	–	–	–	0.295***	0.314***	0.085
					(0.097)	(0.101)	(0.150)
Survival prob = 0.50	–	–	–	–	0.811***	0.833***	0.554***
					(0.096)	(0.100)	(0.141)
Survival prob = 0.75	–	–	–	–	1.268***	1.302***	1.043***
					(0.112)	(0.112)	(0.152)
Survival prob = 0.95	–	–	–	–	2.251***	2.309***	1.657***
					(0.126)	(0.120)	(0.183)
Treatments × survival probability							
(base group: ES & survival probability = 0.10)							
NS × Survival probability = 0.25	–	–	–	–	–	–	0.178
							(0.173)
NS × Survival probability = 0.50	–	–	–	–	–	–	0.037
							(0.171)
NS × Survival probability = 0.75	–	–	–	–	–	–	0.103
							(0.191)
NS × Survival probability = 0.95	–	–	–	–	–	–	0.399*
							(0.207)

Note: (1) Standard errors clustered at IRU level are in parenthesis and (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$.

Table A4.2: (Continued from the previous page.) Panel (unbalanced) logit models with dummy variable of the binary choice between options A and B as the dependent variable, with the choice of option A as the base group.

	Model-1		Model-2		Model-3		Model-4		Model-5		Model-6	
Variables	Coeff. [a]	MEb	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME	Coeff.	ME
Sociodemographic variables												
Prosociality	–	–	–	–	–	–	−0.239	−0.020	−0.250	0.021	−0.247	−0.021
							(0.187)	(0.016)	(0.184)	(0.015)	(0.184)	(0.015)
Rural	–	–	–	–	–	–	1.729***	0.149***	1.735***	0.149***	1.721***	0.147***
							(0.239)	(0.019)	(0.237)	(0.019)	(0.237)	(0.019)
Age	–	–	–	–	–	–	−0.024**	−0.002***	−0.024**	−0.002**	−0.023***	−0.002***
							(0.009)	(0.001)	(0.009)	(0.001)	(0.009)	(0.001)
Education	–	–	–	–	–	–	0.051**	0.004**	0.050**	0.004**	0.050***	0.004***
							(0.022)	(0.002)	(0.022)	(0.002)	(0.022)	(0.002)
Family structure	–	–	–	–	–	–	0.287	0.024	0.285	0.024	0.287	0.024**
							(0.207)	(0.017)	(0.204)	(0.017)	(0.204)	(0.017)
Family size	–	–	–	–	–	–	0.112**	0.010**	0.109**	0.110**	0.110**	0.009**
							(0.054)	(0.004)	(0.053)	(0.004)	(0.054)	(0.004)
Gender	–	–	–	–	–	–	−0.254	−0.022	−0.253	−0.021	−0.248	−0.021
							(0.191)	(0.016)	(0.188)	(0.016)	(0.187)	(0.015)
Agricultural engagement	–	–	–	–	–	–	−0.035	−0.003	−0.047	−0.004	−0.039	−0.003
							(0.234)	(0.020)	(0.232)	(0.020)	(0.233)	(0.019)
Marital status	–	–	–	–	–	–	−0.014	−0.001	−0.016	−0.001	−0.031	−0.003
							(0.270)	(0.023)	(0.269)	(0.023)	(0.269)	(0.023)
Observations	5417		5417		5417		5206		5206		5206	
Wald-$\chi 2$	199.82***		305.21***		307.37***		337.70***		353.94***		341.18***	

Note: (1) Models 1 to 6 include decision period dummies, (2) Standard errors are in parenthesis and (3) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$.

[a] Coeff. indicates coefficients.

[b] ME indicates marginal effects calculated at the same means of the independent variables.

Table A4.3: Poisson models with count variable of RUP as the dependent variable (Table continues to the next page.).

	Coefficients						
VARIABLES	Model-1	Model-2	Model-3	Model-4	Model-5	Model-6	Model-7
Treatment dummies							
(Base group = ES)							
NS	−1.464***	−1.302***	−1.336***	−1.712***	−1.276***	−1.313***	−1.601***
	(0.125)	(0.104)	(0.107)	(0.166)	(0.105)	(0.108)	(0.127)
IA	0.570***	0.792***	0.835***	−0.257	0.818***	0.872***	0.005
	(0.197)	(0.157)	(0.159)	(0.227)	(0.155)	(0.149)	(0.168)
Parameters							
Survival probability	–	2.817***	2.878***	2.149***	–	–	–
		(0.181)	(0.171)	(0.225)			
Treatments × survival probability							
(base group = ES)							
NS × Survival probability	–	–	–	0.471	–	–	–
				(0.295)			
IA × Survival probability	–	–	–	1.435***	–	–	–
				(0.398)			
Scenario dummies							
(base group: survival probability = 0.10)							
Survival prob = 0.25	–	–	–	–	0.295***	0.314***	0.085
					(0.097)	(0.101)	(0.150)
Survival prob = 0.50	–	–	–	–	0.811***	0.833***	0.554***
					(0.096)	(0.100)	(0.141)
Survival prob = 0.75	–	–	–	–	1.268***	1.302***	1.043***
					(0.112)	(0.112)	(0.152)
Survival prob = 0.95	–	–	–	–	2.251***	2.309***	1.657***
					(0.126)	(0.120)	(0.183)
Treatments × survival probability							
(base group: ES & survival probability = 0.10)							
NS × Survival probability = 0.25	–	–	–	–	–	–	0.178
							(0.173)
NS × Survival probability = 0.50	–	–	–	–	–	–	0.037
							(0.171)
NS × Survival probability = 0.75	–	–	–	–	–	–	0.103
							(0.191)
NS × Survival probability = 0.95	–	–	–	–	–	–	0.399*
							(0.207)

Note: (1) Standard errors clustered at IRU level are in parenthesis and (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$.

Table A4.3: (Continued from the previous page.) Poisson models with count variable of RUP as the dependent variable.

	Coefficients						
VARIABLES	Model-1	Model-2	Model-3	Model-4	Model-5	Model-6	Model-7
IA × Survival probability = 0.25	–	–	–	–	–	–	0.354
							(0.229)
IA × Survival probability = 0.50	–	–	–	–	–	–	0.557**
							(0.225)
IA × Survival probability = 0.75	–	–	–		–	–	0.483*
							(0.253)
IA × Survival probability = 0.95	–	–	–	–	–	–	1.217***
							(0.256)
Sociodemographic variables							
% of prosocial subjects	–	–	−0.172	−0.161	–	−0.173	−0.154
			(0.123)	(0.123)		(0.121)	(0.121)
Rural	–	–	0.516***	0.548***	–	0.535***	0.576***
			(0.125)	(0.123)		(0.120)	(0.118)
Average education	–	–	0.032**	0.032**	–	0.035**	0.036**
			(0.014)	(0.014)		(0.014)	(0.014)
Average age	–	–	−0.004	−0.003	–	−0.003	−0.002
			(0.006)	(0.006)		(0.006)	(0.006)
% of subjects with joint family	–	–	0.034	0.034	–	0.036	0.035
			(0.124)	(0.121)		(0.121)	(0.115)
Average family size	–	–	0.059*	0.056	–	0.060*	0.053
			(0.035)	(0.034)		(0.035)	(0.034)
% of female subjects	–	–	−0.051	−0.045	–	−0.061	−0.052
			(0.113)	(0.113)		(0.114)	(0.114)
% of subjects with agricultural engagement	–	–	−0.262*	−0.317**	–	−0.284*	−0.357*
			(0.152)	(0.155)		(0.153)	(0.153)
% of married subjects	–	–	−0.146	−0.149	–	−0.135	−0.134
			(0.158)	(0.161)		(0.159)	(0.164)
Observations	675	675	645	645	675	645	645
Wald-χ^2	235.71***	419.48***	526.15***	1491.15***	550.27***	705.98***	2226.81***

Note: (1) Standard errors clustered at IRU level are in parenthesis; (2) *** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$; and (3) Models 3, 4, 6 & 7 include socioeconomic variables.

[a] Coeff. indicates coefficients.

[b] ME indicates marginal effects that is calculated at the same means of the coefficients.

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