Realized and Elicited Cooperation Under Water Scarcity: Evidence from a Field Experiment in Tanzania

Charlotte Aubrac

Department of Agricultural Economics

Faculty of Agricultural and Environmental Sciences

McGill University, Montreal

July 2023

A thesis submitted to McGill University in partial fulfillment

of the requirements of the degree of

Master of Science

Table of Contents

Abstract

Improving the provision of water to farmers in a sustainable way, e.g., through irrigation schemes, is a key strategy for climate change adaptation and agricultural development. As more frequent droughts will increasingly affect farmers in countries like Tanzania, farmers need to cooperate to ensure the functioning of their irrigation scheme. Yet, it is unclear whether drought risk will induce a shift towards more cooperation or, instead, more defection. Previous research shows that risk and social preferences influence the decision to cooperate, but how that dynamic unfolds in an irrigation system is unclear. We conduct a public goods, dictator, and lottery game with 470 irrigated rice farmers in a farmer-managed irrigation scheme in Morogoro, Tanzania. Our results show that farmers, particularly extremely risk-averse and socially inefficient individuals, become less cooperative when facing a risk to a public resource. We test the external validity of the public goods game contributions by seeing if in-game cooperation matches realized in cash and in-kind contributions. We find that the public goods game correlates with social cooperation but not financial cooperation. Our results have important policy implications - farmers are expected to cooperate less to maintain the irrigation scheme as water becomes scarcer. This suggests that irrigation systems facing water scarcity must also support and promote cooperative behaviour and/or attenuate the adverse effects of shocks like drought.

Resumé

Améliorer l'approvisionnement en eau pour les agriculteurs de façon durable, par exemple à travers des systèmes d'irrigation, est une stratégie clé pour l'adaptation au changement climatique et le développement agricole. Étant donné que des sécheresses plus fréquentes affecteront de plus en plus les agriculteurs dans des pays comme la Tanzanie, ces derniers doivent coopérer pour assurer le fonctionnement de leur système d'irrigation. Cependant, il n'est pas certain que le risque de sécheresse induise une hausse de la coopération ou, au contraire, une hausse de la défection. Des recherches précédentes montrent que les préférences face au risque et les préférences sociales influencent la décision de coopérer, mais la façon dont cette dynamique se déroule dans un système d'irrigation n'est pas claire. Nous avons joué à un jeu des biens publics, de dictateur et de loterie avec 470 riziculteurs dans un système d'irrigation géré par les agriculteurs à Morogoro, en Tanzanie. Nos résultats montrent que les agriculteurs, en particulier les individus extrêmement averses au risque et socialement inefficaces, deviennent moins coopératifs lorsqu'ils sont confrontés à un risque touchant les ressources publiques. Nous avons aussi testé la validité externe du jeu des biens publics en vérifiant si la contribution dans le jeu correspond aux contributions en espèces et en biens. Nous constatons que le jeu des biens publics explique la coopération sociale, mais pas à la coopération financière. Nos résultats ont d'importantes implications politiques : à mesure que l'eau se raréfie, on s'attend à ce que les agriculteurs coopèrent de moins en moins pour maintenir le système d'irrigation. Cela suggère que les systèmes d'irrigation qui sont confrontés à une pénurie d'eau doivent soutenir et promouvoir les comportements coopératifs de ses members et/ou atténuer les effets défavorables de chocs telle que des sécheresse.

Acknowledgements

First and foremost, I want to thank Aurélie Harou, because I learned the most from her during this entire research process. Thank you for all your support and feedback in creating and improving this project, for encouraging me and pushing me to challenge myself, and for working with me so regularly even when we were in vastly different time zones. I appreciate all the energy and time you invested in this project.

Next, I would like to profoundly thank Christopher Magomba, the team of enumerators, and Sokoine University of Agriculture for making the data collection possible. More precisely, many thanks to Christopher Magomba for organizing all the logistics of fieldwork but also for welcoming me in Morogoro for the weeks that I was there, during which he always made sure that I was well. My thanks are extended to all eleven enumerators who not only provided essential feedback on the survey but also collected the survey and played the game with more than 470 participants. Without their precious time, mental and physical efforts, this project would not have been possible. Thank you to Pascal Mumelo, Gideon Boniface, Anna Lulale, Saidi Mhina, Winfrida Mihambo, Happy Kilave, Habib Lupato, particular thanks to Michael Paul who also arranged my accommodations and transportation in Tanzania, and extra special thanks to the enumerator leaders Revocatus Ntengo, Ambonisye Haule, and Anna Muffui, for leading the team and on-site data collection, and for welcoming me so warmly. Thanks to Damas for driving the team everywhere.

This project would not have been possible without my co-authors Soumya Balasubramanya and Katya Vasilaky. Their passion for research inspired me deeply. Thank you, Soumya, for sharing your knowledge with me and for the time you poured into this research project. Thank you, Katya, for sharing your expertise with me, especially for the more technical details of the games and coding, and for all your effort to continuously improve this project. I would like to thank Vidhi Chellani who generously spent her summer holidays helping me code the survey.

My graduate education was fulfilling thanks to Paul Thomassin, who led the agricultural economics seminar and manages the department, and to Mary Doidge, who kindly answered any academic questions I had. All the action would not have been possible without funding to make it happen. Thank you to the McGill Sustainability Systems Initiative for funding the project and to the Office of Graduate and Postdoctoral Studies for financing my fieldwork travels and expenses.

On top of the academic support, I want to extend my gratitude to Mariève Isabel and the Graphos team for supporting me throughout the writing process. Honorary mention to all my friends for always making me laugh. Finally, allow me to share a small poem of mine.

On their wings, my dreams take flight,
Their unwavering support is my guiding light.
In their arms, I find strength and courage,
My family's love, an eternal heritage.

Contribution of Authors

As the main author of this study, I wrote all the chapters in this thesis, including appendices, figures, and tables, and as such all views and opinions expressed in this thesis are my own. I was the main author of the survey questionnaire and the main person to code it in XLS forms. I trained the team of eleven enumerators in Tanzania with the protocol and training material I created. I oversaw the data collection in the field and ensured the data was uploaded correctly. I led the data analyses, which included cleaning the data and developing all the models in Stata.

Aurélie Harou is my co-author and supervisor. She continuously supported and guided me throughout every step of this research project. She helped with the research framing and design, with writing and reviewing the survey modules, developing estimation strategies, with data analyses, any troubleshooting, and finally, she provided feedback on every chapter of this thesis.

Christopher Magomba is also a co-author of this study. In addition to assisting in framing the research question and contextualizing it to Morogoro, he managed all the logistics and details for the field collection, from selecting the Mkindo irrigation scheme to hiring the team of enumerators, managing the data collection with me on the field, communicating with the team and the scheme's administrators, obtaining local ethics approval, etc.

Soumya Balasubramanya is also a co-author of this study. Her insights into applied agricultural/water economics were essential to develop and frame the research questions and to design the research study. She also helped with creating the survey modules and questions. Katya

Vasilaky is also a co-author of this study. Thanks to her experience with economic games, she helped tremendously to design the games for this study, along with framing the research questions and designing the study. Katya also connected me with Vidhi Chellani, who helped me code the survey in XLS form.

List of Figures

List of Tables

1. Chapter 1: Introduction

1.1. Problem Statement

Global food production has increased over the past decades due to extensive advances in agriculture. Yet, advances in technologies like agrochemicals, improved crop varieties, modern farming practices, and irrigation, which have allowed this increased productivity, have, unfortunately, largely bypassed sub-Saharan Africa (SSA) (Pittock et al., 2014). Though the adoption of these technologies has been proven to increase agricultural productivity, the adoption rate of these has remained low in SSA due to numerous, complex constraints such as market failures (Jones et al., 2022), limited credit access (Nakano & Magezi, 2020) to financial constraints and lack of information (Harou et al., 2022). In light of a changing climate that is expected to disrupt weather patterns around the world, particularly affecting SSA (Serdeczny et al., 2017), agricultural development needs to be secure and resilient. The adoption and use of agricultural technologies, such as irrigation and improved seed varieties, can help farmers and agri-businesses secure agricultural productivity by creating a more resilient agricultural system.

Many regions in SSA will face more water scarcity and disrupted rain patterns (Lema & Majule, 2009; Serdeczny et al., 2017) with climate change, which is concerning for countries that rely primarily on rainfed agriculture (Mancosu et al., 2015; Serdeczny et al., 2017). One efficient way to manage and provide water for agriculture is through irrigation. Irrigation can provide a more constant water supply and allow farmers to cultivate year-round (Oladimeji & Abdulsalam, 2014).

Irrigation can be done from a very small, plot-level scale to a very large scale, covering thousands of hectares and serving hundreds of farmers.

However, irrigation is challenging to implement and adopt due to the high associated development, operation, and maintenance costs that come with it. The challenges of irrigation go beyond being technical, as there are also social challenges behind these systems, especially the larger they become. Water needs to be distributed, fees must be paid and collected, infrastructure needs regular maintenance, and conflicts between members must be resolved. As such, cooperation between farmers is also necessary to have a successful irrigation system. One key question that remains is how farmers will cooperate in the face of water scarcity. It is unclear from the literature if farmers become more cooperative or more competitive as water becomes scarcer (Araral, 2009; Nie et al., 2020; Prediger et al., 2014). In this study, we aim to study how farmers' willingness to cooperate changes when there is a risk to a public resource, such as water, versus a private resource. Furthermore, we wish to examine how individual characteristics, including risk and social preferences, affect cooperation. Finally, as we explain further below, we wish to study whether public goods games are a valid metric of cooperation between members of an irrigation scheme.

How farmers make decisions in the face of uncertainty is complex, but risk preferences play a crucial role. In sub-Saharan Africa, risk preferences have been shown to affect which water management technology farmers adopt (Katic & Ellis, 2018; Koundouri et al., 2006), the adoption rate of weather-index insurance (Hill et al., 2013), the adoption of drought-resistant crops (Holden & Quiggin, 2016; Magnan et al., 2020) as well as fertilizer (Adong et al., 2020; Kebede, 2022). Overall, risk aversion seems to inhibit farmers from making choices that could increase their income and resilience to climate change effects. Previous authors found that risk-averse individuals tend to cooperate less, but they conducted these studies in general contexts, and none sampled rural farmers (de Heus et al., 2010; Fung et al., 2012; Levati et al., 2009). Given how important cooperation is to maintain an irrigation scheme, particularly farmer-managed schemes, the question of how risk preferences impact the willingness to cooperate between irrigation scheme members still needs to be answered.

Social preferences, meaning how an agent considers others' payoffs (negatively or positively) (Balliet et al., 2009), have also been shown to influence willingness to cooperate. Individuals can be classified as "pro-social" if they try to maximize other people's outcomes or "pro-self/anti-social" if they prioritize only their own outcome or actively minimize others' outcomes (Fehr & Fischbacher, 2002). To the best of our knowledge, studies have looked at how external conditions impact antisocial behaviour but not vice versa. For example, there is evidence that resource scarcity and higher market competition lead to more antisocial behaviour (Carpenter & Seki, 2005; Prediger et al., 2014). But overall, little research has been done on how social preferences influence farmers' decisions, particularly around water.

To study cooperation, we run experimental games, which is a method that has become increasingly popular in agricultural economics over the past decade (Hernandez-Aguilera et al., 2020), due to their usefulness in measuring social behaviours. Games provide a controlled environment where researchers can design and manipulate variables to study specific phenomena. In this study, we play the public goods game (PGG) to measure cooperation. Assuming people follow decision-making heuristics that are influenced by one's existing preferences and norms (Rand et al., 2014), i.e., assuming people do not behave entirely irrationally in the game, contributions in a PGG can be used to measure an individual's willingness to cooperate. Though the game is stripped away of any context, players' behaviour can reveal how cooperative they are outside of the game if we assume insights gained in field experiments can be extrapolated to the real world. For research in the physical sciences, this assumption is valid; but in the field of social sciences, this assumption loosens because humans are the object of study and are influenced by many factors.

Given the numerous assumptions that need to be made to interpret behaviour in the PGG, researchers have recently questioned the external validity of this approach (Galizzi & Navarro-Martinez, 2019; Hernandez-Aguilera et al., 2020; Levitt & List, 2007a, 2008). Games can be practical for research, but we need to know if they measure actual social behaviour or if they simply measure how individuals play the game. A recent systematic review of all previous research that tests the external validity of games revealed mixed results (Galizzi & Navarro-Martinez, 2019), further questioning whether insights from games can be extrapolated.

Although some studies have tested the external validity of the public goods game to measure cooperation around a natural resource, none that we are aware of have focused on water or agriculture. A study done in Sierra Leone by Voors et al. (2012) found no correlation between in-game contribution and real-life financial contribution of their endowment to fund a shared well. Another study in Nepal by Bluffstone et al. (2020) found a mixed correlation between in-game contribution and cooperation in caring for a community forest. Moreover, in a community of shrimp fishermen in Brazil, in-game behaviour correlated with real-life cooperative behaviour (Fehr & Leibbrandt, 2011; Leibbrandt, 2012). As aforementioned, in this study, we seek to determine whether the public goods game is a valid measure of cooperation between members of an irrigation scheme.

To study farmers' cooperation under uncertainty and how elicited cooperation compares to real cooperation, we survey rice farmers in an irrigation scheme, the Mkindo Irrigation scheme, in the rural region of Morogoro, Tanzania. Agriculture in Tanzania is still mostly rainfed and small-scale, as is the case in much of sub-Saharan Africa (*The State of Food and Agriculture 2020*, 2020). Concurrently, the region of Morogoro is expected to experience more sporadic and shorter rains due to climate change, increasing the risk of droughts (Adhikari et al., 2015, 2017; Paavola, 2008; Sweya et al., 2018). Such risks ultimately threaten the agricultural production and livelihood of Morogoro's rainfed farmers. Irrigation can provide a step towards resiliency. The country currently has around 0.18 million hectares (ha) of irrigated land, yet approximately one million ha of land has the potential for irrigation (You et al., 2011). Of these, it is estimated that 0.7 million ha are suitable for large-scale, dam-based irrigation, while 0.3 million ha would be appropriate for small-scale irrigation (You et al., 2011). Currently, irrigated areas account for 3.6% of the total cultivated area in Tanzania, yet represent 10% of the total agricultural output (Pittock et al., 2014), highlighting the potential of irrigation on agricultural productivity.

Though irrigation systems are an effective way to provide and manage water for agriculture, there are only a few of them in Tanzania and maintaining them has proven challenging (Inocencio et al., 2007; Kadigi et al., 2019; Mdemu et al., 2017; Pittock et al., 2014). In the 1960s, the Tanzanian government made significant efforts to build large irrigation systems all over the country, but many of them failed by the 1990s due to poor infrastructure and management, rendering them unprofitable (Inocencio et al., 2007; Kadigi et al., 2019). Many of these government-run schemes were subsequently either privatized or farmer-managed (Pittock et al., 2014). Still today, the main obstacles faced by farmer-managed irrigation schemes are poor infrastructure, poor management, and a lack of adequate finances (Mdemu et al., 2017).

1.2. Study Objectives

This study has two objectives. First, we want to understand how cooperation among members of an irrigation scheme changes in the face of resource scarcity and how that change differs by social and risk preferences. To do so, we elicit cooperation using a public goods game (here onward, "PGG") where the amount contributed is a proxy for cooperativeness. Participants also play a lottery game to elicit risk preferences and a binary dictator game to measure social preferences.

We begin by examining the determinants of cooperation and the relationships between risk preferences, social preferences, and contributions in the PGG. We hypothesize and test that factors such as land tenure, gender, risk aversion and social preferences affect contributions. Additionally, we expect and test whether risk-loving or pro-social farmers are more willing to cooperate, based on the literature (de Heus et al., 2010; Fung et al., 2012; Levati et al., 2009). We then explore whether farmers become more cooperative or competitive as public and/or private resources in the game are at risk of being lost. To do so, we modify the rules of the PGG in separate rounds to simulate different types of scarcity. More specifically, in one round, the public resource becomes at risk of being lost for all players; in another round, the private resource becomes at risk of being lost. We hypothesize and test whether cooperation decreases when there is a risk to a public resource and increases when there is a risk to a private resource.

The second objective of this study is to test the external validity of the PGG. To do so, we test the lab-field association by comparing cooperation in the game with how cooperative a player is in real-life to maintain the irrigation scheme. We hypothesize that elicited, in-game cooperation will match realized cooperation, measured by survey answers.

1.3. Summary of Results

When examining the determinants of cooperation, we find that farmers with more dependents and those who are extremely risk-averse tend to contribute more in the PGG. Meanwhile, farmers in the poorest quartile and those who are socially inefficient tend to contribute significantly less than others.

Next, we study how cooperation changes under uncertainty by comparing contributions across four rounds of the PGG with differing risks. We find that in the round where public resources are at risk of becoming lost, farmers decrease their contributions the most and significantly compared to other rounds. In the same round, extremely risk-averse people decrease their contribution the most even though they have the highest average contribution throughout the game, revealing that extremely risk-averse people are quite sensitive to shocks. Again, in the same round, socially inefficient respondents decrease their contributions the most. In other rounds, a risk to the private resource does not significantly affect contributions. The key takeaway is that public risk leads to significantly fewer contributions, while private risk has little influence on farmers' contributions or cooperation.

Finally, we test the external validity of the PGG by analyzing the statistical relationship between elicited, in-game contributions and real-life, realized cooperation revealed through survey answers. We ask participants questions that reveal how *financially* cooperative they are by asking if they paid all their fees in the past seasons and how much cash and labour (hired or self) they contributed to maintaining the canal adjacent to their most important plot. We also asked questions about how *socially* cooperative they are, with questions on the number of water-related disputes they have had, whether they voted in the recent block elections, etc. We find that the PGG explains social-based cooperation well, i.e., having water-related disputes or interacting with scheme administrators, but does not correlate with financial cooperation, i.e., paying fees, contributing cash or labour to maintain irrigation canals.

1.4. Contribution to the Literature

This study contributes to two streams of literature. The first one is the literature on cooperation under water scarcity. Other studies have investigated how irrigated farmers change their willingness to cooperate under water scarcity, though they have different results and measures. Studies in China by Nie et al. (2020) and

find a positive, linear relationship between water scarcity and cooperation inside irrigation schemes. Meanwhile, in the Philippines, Araral (2009) finds a curvilinear relationship, where cooperation increases as water becomes scarcer until a turning point where cooperation collapses.

Compared to these other studies, we have a more precise measure of cooperation here. Namely, we measure financial (e.g., probability of paying fees and contributing labour) and social cooperation (e.g., probability of having disputes with members, of voting in local water group elections). In contrast, past studies only have metrics on financial cooperation. We find, more specifically, that water scarcity leads to less social cooperation between members of irrigation schemes.

The second stream of literature we contribute is the literature on experimental games. Our main contribution is that we elucidate the use and validity of the PGG for economic research. The validity of games for economic research has been debated (Levitt & List, 2007b, 2008) yet research on the validity of games has been scarce (Galizzi & Navarro-Martinez, 2019). A very limited number of studies look at whether the game can capture cooperation around a natural resource. We are the first study to test the validity of the game to measure cooperation around water and, more particularly, to measure cooperation between members of an irrigation scheme. Our results show that the external validity of the PGG is mixed. We find that the behaviour in the game explains how socially cooperative a member of an irrigation scheme is in real-life (e.g., resolving conflicts related to water, interacting with administrators, etc.) but does not correlate with how financially cooperative they are (e.g., paying fees due to the administrators, contributing cash or labour to the maintenance of canals, etc.).

2. Chapter 2: Literature Review and Theoretical Framework

2.1. Literature Review

This literature review is divided into three sections. The first section examines the nexus between personal preferences, including risk and social preferences, and the general decision to cooperate. The second section discusses the determinants of cooperation around a resource. In particular, it examines the effects of external factors, such as group and resource characteristics, on the decision to cooperate. Finally, the third section looks at the utility and external validity of the public goods game to measure cooperation. Following this review of different literatures, we provide a theoretical framework to explain the decision to cooperate in a public goods dilemma.

2.1.1. Literature on risk preferences, social preferences, and cooperation

In this section, we review studies on risk preferences across smallholder farmers in SSA and the interaction between risk preferences, social preferences, and the decision to cooperate.

Risk Preferences in sub-Saharan African Farmers

While the topic of risk-aversion among smallholder farmers in SSA has been an important area of research, there is high spatial heterogeneity in risk preferences across and within countries (Ambali & Begho, 2022; de Brauw & Eozenou, 2014; Doss et al., 2008; Katic & Ellis, 2018; Yesuf & Bluffstone, 2009). As such, it is important to study the interactions between risk preferences and agricultural decision-making locally. Yesuf & Bluffstone (2009) study extremely poor, subsistence farmers in Ethiopia (n=262) and find that 66% of their sample show extreme risk aversion in games. Most importantly, they find that the constraints of low income and lack of market access largely explain this behaviour. Lifting those constraints allows farmers to build up assets, allowing them to take on more risks. As variables for wealth and age increase, such as land size, number of oxen, cash liquidity, etc., risk aversion decreases. They also find that as expected payoffs in the game increase, risk aversion increases. Furthermore, they find that farmers are less risk-averse in hypothetical games than in non-hypothetical games.

In contrast, Katic & Ellis (2018) (n=137) are the first to find that rural farmers in Ghana show moderate risk-aversion towards adopting agricultural water management technologies, i.e., runoff collection using hand-dug wells, lined wells, or buckets, motorized pump, etc. Only a third of the farmers in their small sample are severe to extremely risk averse. They find that higher literacy, age and expected payoff increase risk-taking behaviour, suggesting that farmers do not aim to reduce risk variance but rather increase expected payoffs. This has worrying implications for farmers at the margin of poverty traps, who are more likely to take riskier gambles, edging closer to the trap.

Risk Preferences and Cooperation

When deciding to cooperate, agents balance the satisfaction of receiving a public good with the personal cost of cooperating and the social cost of free-riding, given that there is peer pressure from the group to cooperate. This balance can be represented in a utility function. Furthermore, following Expected Utility Theory (Von Neumann & Morgenstern, 1944), an agent's preference towards risk shapes the curve of their utility function. As such, authors have theorized that risk preferences influence the probability that an agent will cooperate or defect; more specifically, Daido (2004) and Kandel & Lazear (1992) built economic models where risk aversion changes the weight of peer pressure on the cost of defecting or free-riding. Theoretical findings are that risk aversion favours cooperation as risk-averse agents weigh the social cost of peer pressure higher than risk-loving agents (Parks, 2004; Raub & Snijders, 1997).

Empirically, most studies find that risk-lovers are more likely to cooperate than risk-averse individuals (de Heus et al., 2010; Fung et al., 2012; Levati et al., 2009), though one study finds, instead, that risk-averse people cooperate more in games than others (Van Assen & Snijders, 2004). The differences in these results might stem from discrepancies in methodologies or contexts between studies. When thinking about context, one can imagine many confounding factors impacting cooperation. In fact, risk preferences are not the only internal factor influencing cooperation; another factor appears to be social preferences.

Social Preferences and Cooperation

The field of economics has long relied on the assumption that agents behave solely on self-interest. But in the early 2000s, as the field of experimental economics grew, it became apparent that agents exhibit social preferences (Fehr & Fischbacher, 2002). Social preferences define the degree to which an agent considers not only their but also others' payoffs (negatively or positively) (Balliet et al., 2009). This preference fundamentally affects an agent's behaviour around competition, cooperation, and incentives. In a meta-analysis of 82 studies in the field of psychology, Balliet et al. (2009) reveal that social preferences explained 9% of the variance of cooperative behaviours in social dilemmas.

There exist many classifications of social preferences. Broadly speaking, people can be classified as pro-socials or anti-socials: pro-socials try to maximize the payoffs of the collective or others, while anti-socials are concerned with maximizing only their own payoffs. In a more complex classification developed by Fehr et al. (2008) and Fehr & Fischbacher (2002), we can identify five types of social preferences: reciprocity, inequity aversion, pure altruism, enviousness, and selfishness. We briefly review these here to provide the necessary background to understand our simplified classification.

i. *Reciprocal* individuals respond to others' kind actions with kindness and to hostile actions with hostility. They judge an action based on its fairness — on how equitable the payoffs are. Unlike other preferences, reciprocal individuals are not driven by material benefits. In other words, they will reciprocate kind or hostile actions regardless of how much they lose or win. Rabin (1993) first examined the existence of fairness equilibria, which are the outcomes when all players in a dilemma are reciprocal, such that they maximize (mutual-max) or minimize (mutual-min) the other's payoff. Other models of reciprocity have been explored by Falk & Fischbacher (2006) and Levine (1998).

ii. On the other hand, *inequity averse* individuals are concerned with reaching an equal payoff for all. As Fehr & Schmidt (1999) describe, these individuals are altruistic to people that have less than an equitable level of payoff yet act in spitefulness to people who exceed that same equitable level. Reciprocal and inequity averse people can often behave similarly, but the motivation behind their decision differs (Fehr & Fischbacher, 2002). In both preferences, individuals care about fairness but seem to disregard social efficiency. Social efficiency is defined as the optimization of all resources and costs to ensure that payoffs are maximized. Similar to the definition of Pareto efficiency, in a socially efficient system the better outcome must improve at least one person's payoff but cannot decrease any other payoff, meaning outcomes need to increase or maintain the current sum of payoffs. Reciprocal people do not consider gains and losses and do not aim to maximize all resources. Meanwhile, inequity averse people will choose the allocation where everyone is equal, even if, in other cases, both people could be getting more but in unequal ways. It is apparent, then, how these two preferences are socially inefficient, i.e., their actions do not aim to maximize the sum of payoffs for the group or their own payoff.

iii. *Purely altruistic* individuals will value another agent's material resources more or as much as their own, to the point where they are even willing to lose resources if it means the other will gain or the group will reach a beneficial allocation of resources. Andreoni (1989) and Levine (1998) theorized that a motivation behind such generosity, other than simple altruism, is that agents feel a "warm glow", an emotional reward from doing good actions. Altruistic people are considered pro-social because they aim to maximize others' payoffs instead of just their own.

iv. Altruism is very different from *enviousness*, the fourth class of social preference. Envious people always value the resources of others negatively, willing to decrease others' payoff even if it means they will also lose. Their decisions do not take fairness into consideration, and they are considered anti-social since they purposefully want to lower the payoffs of others. Experiments and models exploring enviousness are developed by Falk et al. (2005) and Kirchsteiger (1994).

v. Finally, *selfish* individuals do not exhibit any social preferences. They focus solely on increasing their own material resources, no matter if the allocation increases or decreases the resources of others (Fehr & Fischbacher, 2002). Like inequity averse people, they are not interested in reaching social efficiency and are often considered pro-self or anti-social.

We use these five established types of social preferences to group farmers into three classifications: pro-socials, anti-socials, and we add a third type —socially inefficient, where socially inefficient people do not aim to maximize either the group or their own payoff. We review our classification used in this study more thoroughly later in the methodology chapter. We regroup farmers in this way in part because of our smaller sample size.

The study of social preferences sits between the fields of psychology and economics. In both fields it was found that people with different social preferences are more or less influenced by their risk preferences when deciding to cooperate (Biel & Gärling, 1995; Fung et al., 2012; Weber et al., 2004). However, it is unclear how social preferences mediate this. On the one hand, Biel & Gärling (1995) use economic theory to explain that pro-selves are more affected by their risk preferences in resource dilemmas compared to pro-socials. A risk-loving pro-self is more likely to cooperate than a risk-averse pro-self, given that cooperating is a riskier decision compared to defecting, where one is sure to incur no personal costs. Meanwhile, pro-socials are more concerned about the group's outcome than their personal risk, so their decision to cooperate is generally less influenced by their preference towards risk.

On the other hand, psychologists Fung et al. (2012) find the opposite. In their sample of university students, pro-socials were, in fact, more influenced than pro-selves by their risk preferences in their decision to cooperate in a public goods game. They find that risk-loving pro-socials are more cooperative than risk-averse pro-socials in a public good game, while pro-selves are not influenced by their risk orientation, consistent with Weber et al. (2004). The mechanism at play is that risk-averse pro-socials are more worried about losing their endowments by cooperating than risk-loving pro-socials. For a pro-self agent, defection remains the dominant choice, regardless of their risk preference.

2.1.2. Literature on the collective action problem in irrigation schemes: Drivers of cooperation

In the previous section, we covered the internal drivers of cooperation. In this section, we review some external factors that influence the decision to cooperate in an irrigation scheme. Given how climate change is bringing forth more risks and uncertainties around water availability, it is important to understand better what prompts farmers to cooperate in an irrigation scheme. Factors that influence cooperation can be generalized into two categories: resource characteristics and group characteristics. The first category includes factors such as the scarcity of the resource, its size and proximity to markets. The second category involves wealth distribution, salience, and group size. Finally, we review why local institutions also matter in prompting farmers to cooperate or defect. Many of the mechanisms at play in this nexus of factors remain unclear to researchers. In this study, we aim to shed light on this topic by both studying the characteristics of irrigated rice farmers who cooperate (or defect) and also studying how cooperation changes in the face of different risks and uncertainties.

A collective action problem, as defined by Ostrom (2000), arises when individuals make interdependent decisions (e.g., users of a common resource pool). Individuals can decide to maximize their own short-term material benefits even though the sum of all individual actions will generate lower joint outcomes than what could have been achieved had they maximized the group payoff instead. Deriving and maintaining the sustainable level of use of a natural resource is both scientifically and politically challenging. Here we briefly review the literature on the economics of common pool resources.

Physical characteristics

The physical characteristics of a natural resource determine the conditions needed for collective actions (Ostrom et al., 1994). Different natural resources, e.g., water, forests, fisheries, etc., all need different management strategies. Three important physical characteristics affecting cooperation include the scarcity of the resource, its size and proximity to markets. In the case of water, water scarcity in an irrigation scheme can lead to either more cooperative or more competitive behaviour (Bardhan, 1993; Uphoff et al., 1990). This mixed conclusion is echoed in the empirical literature on the subject. For example, Ito (2012) studies irrigation schemes (n=104) in Yunnan, China, and finds a positive relationship between moderate scarcity and cooperation between farmers. A more recent study by Nie et al. (2020) looks at farmers (n=312) in large irrigation schemes in Gansu District, China, and also finds that water scarcity leads to more cooperation between farmers. Scarcity can make the boundaries of the resource clearer, thus strengthening the need for cooperation and institutions to manage the resource. It is also interesting to note that if the relationship between water scarcity and cooperation is U-shaped, these two studies above might have captured only the upwards part of this curve before the turning point where extreme scarcity leads to a lack of cooperation.

However, a study looking at 1958 irrigation associations in the Philippines by Araral (2009) finds a curvilinear relationship between water scarcity and cooperation. They find that cooperation between farmers is challenging when water is either abundant or extremely scarce, suggesting a U-shaped relationship. When water is abundant, there is little incentive to cooperate, and when water is scarce conflicts arise more easily. Though these studies account for endogeneity concerns, there are many confounding factors, besides scarcity, that these studies might not account for that impact cooperation in an irrigated system, e.g., historical background or policies.

Water scarcity is of particular interest to our research since climate change is expected to impact the availability of water in the Mkindo irrigation scheme. Studies predict that the water supply in this region will increase during the wet seasons but decrease during the dry season, increasing the risk of drought (Adhikari et al., 2017; Paavola, 2008). Furthermore, Tanzanian farmers are expected to intensify agriculture to adapt to climate change and food insecurity, adding additional stress on water resources (Paavola, 2008). Another challenge of climate change is the uncertainty it brings. A few studies have played games to understand how uncertainty hinders cooperation. Barrett & Dannenberg (2012) play a modified public goods game, framing it as a game between climate change mitigation versus adaptation. They find that coordination is almost guaranteed when the group impact and threshold needed to avoid disaster are known; however, cooperation collapses when the threshold is uncertain, and so is the group impact. The changes in water scarcity in Morogoro are hard to know, so this study aims to understand how farmers' cooperation will react in an unknown future.

As aforementioned, the size of the resource also affects cooperation. Small resource pools with clear boundaries are generally more successfully managed (Wade & Feeny, 1989). The small size of the resource means its use can be monitored more easily. For irrigation, some scholars argue that it is not solely the size of the water resource that explains successful cooperation but its size relative to the size of the user group (Meinzen-Dick et al., 2002), as discussed below.

Finally, the proximity to markets is also a physical characteristic thought to impact cooperation, although its net effect needs to be clarified. Increasing interactions with commercial markets can increase the anonymity of users, thus reducing the power of group monitoring and social ties that ensure that everyone cooperates (Ostrom & Gardner, 1993). However, markets can also increase the returns to irrigated farming, thus encouraging farmers to maintain a successful irrigation scheme (Meinzen-Dick et al., 2002).

Group characteristics

Besides the physical characteristics of the resource, the characteristics of the group are also important factors of cooperation in an irrigation scheme. These characteristics include wealth distribution, salience, and group size. The literature suggests that wealth inequality leads to less cooperation due to the decrease in willingness to cooperate as income both increases or decreases (Cherry et al., 2005; Hargreaves Heap et al., 2016; Tavoni et al., 2011). In an irrigation scheme, it is a system where users have a private input that makes up their wealth (e.g., land), and they want to extract a collective good (e.g., water), to then produce a private good (e.g., rice) while causing negative externalities (e.g., less water available for other scheme members). As Bardhan et al. (2007) theoretically suggest, in the case where extracting a common resource has no externality, perfect wealth equality within the groups of contributing and non-contributing players leads to an optimal extraction of the resource. However, when extracting it causes a negative externality, perfect equality is not optimal. Indeed, on the extremity where everyone has equal wealth, the average contribution remains low, but the number of contributors would be high. On the other extremity, where one person holds all the wealth, the average contribution would be driven up, but only the wealthy would be willing and able to contribute. As such, the optimal distribution of wealth for using a common resource lies between equality within the group and between two groups of contributors and non-contributors (Bardhan et al., 2007).

Salience is the degree to which users depend on the public resource for their livelihood. It has been found that the more salient the resource, the more users commit time and capital to build a strong institution to manage the resource and incentivize farmers to be cooperative (Dietz et al., 2003; Wade, 1988).

Furthermore, cooperation tends to become more challenging as the group size increases (Araral, 2009; Janssen et al., 2011). In irrigated systems, when the group increases, the economies of scale for the scheme's maintenance decrease. Each individual contribution to the maintenance decreases as the group size increases. However, as group size increases, so do transaction costs of monitoring because individual action becomes less observable (Meinzen-Dick et al., 1994). As group size increases, authors argue as well that members perceive their contribution as a negligible step to reaching the group optimum (Araral, 2009; Olson, 1965). When members understand that their contribution will not affect the chances of success of a public goods dilemma, the likelihood that they will cooperate and incur the costs of cooperating diminishes. As group size increases, the private gain of a successful irrigation scheme needs to remain high enough to encourage farmers not to defect.

Institutions

Finally, in the context of an irrigation scheme, institutions and governing structures also play an important role in inciting cooperation. The autonomy of its governance, how and whether leaders are elected, and whether the institution is more punitive or rewarding are all factors that impact cooperation (Abernethy, 2010; Grossman & Baldassarri, 2014). It has been generally found that farmer-managed irrigation schemes, even when large (over 1000 ha), experience more cooperation than government-controlled ones, though they can be more challenging to operate (Araral, 2009).

2.1.3. Literature on the external validity of economic games

The public goods game (PGG) is a game used in psychology and, more recently, in experimental economics. The purpose of the PGG game is to measure players' willingness to cooperate by mimicking the conditions of a public goods dilemma through the game's rules. In the basic form of the game, participants privately decide how many tokens to allocate to a public pool/account that is later multiplied and shared among all group members. There are several forms of public goods games that serve different purposes. There are one-shot games where participants play once (Bluffstone et al., 2020; Torres-Guevara & Schlüter, 2016). There are iterative games where participants play several rounds and can learn (Balliet et al., 2009; Nie et al. 2020). Certain variations include punishment for free riders or a reward for cooperators (Fehr & Gächter 2000; Yang et al. 2020). Finally, these games can also be played transparently, where everyone sees the payoffs and actions of each other (Fischbacher et al., 2001). Rules, such as risks to accounts, can also be added to mimic a real-life scenario (Barrett & Dannenberg, 2012).

Games, especially social preference games involving trust and altruism, have become increasingly popular in the field of agriculture and sustainability over the past decade (Hernandez-Aguilera et al., 2020). They allow us to see how people react in a scenario that is not real, allowing researchers to speculate future behaviour. For example, in the public goods game, giving to the public pool can be used as a proxy for the decision to mitigate climate change effects. On the other hand, keeping tokens privately can serve as a proxy for autonomous adaptation, opening a window to examine decisions to mitigate versus adapt to climate change (Barrett & Dannenberg, 2012; Hasson et al., 2010).

Some economists have warned about and discussed whether social preference games, in general, are internally and externally valid (Levitt & List, 2007b, 2008). Amidst these concerns, Galizzi & Navarro-Martinez (2019) conduct a meta-analysis of 18 studies testing the external validity of the PGG. They find mixed results: certain studies find that in-game behaviour matches real-life behaviour, some find no such correlation, while others find mixed results depending on the variables they examine. Only a few of those studies have a relatively large sample size (n>100). Additionally, the context of these 18 studies varies from examining general cooperative behaviour among university students (e.g., if cooperative students bring back borrowed books from the library) to examining cooperation in a fishermen community or a community forest. None of these studies survey crop farmers, and none focus on irrigation or water for agriculture. Our research project is the first to study the external validity of the public goods game when looking at cooperation between farmers in an irrigation scheme.

The one study that resembles ours most closely is one by Voors et al. (2012), who compare in-game cooperation and willingness to fund a community well in forest edge communities in Sierra Leone (n=500). They find no meaningful correlation between elicited and realized cooperation (Voors et al., 2012). Carpenter & Seki (2005) also find no correlation between in-game cooperation and kilograms of shrimp caught per trip with Japanese shrimp fishermen. Similarly, Torres-Guevara & Schlüter (2016) use a fishing impact index as a proxy for real cooperation among Columbian artisanal fishermen and find no lab-field association between their measure of real-life cooperation and in-game contribution.

On the other hand, a recent study with community forest user groups done in Nepal by Bluffstone et al. (2020) finds that some variables of realized cooperation match with elicited measures. For example, planting trees is positively correlated with in-game cooperation, while attending group meetings and spending time monitoring the forest is not. Likewise, Lamba & Mace (2011) look at central Indian villages taking salt from a common salt pool and find mixed evidence that the public goods game is externally valid. Finally, Fehr & Leibbrandt (2011) find positive and significant lab-field associations when studying small shrimp farmers in northeastern Brazil.

From these mixed results, one question arises: Why do people behave differently in experimental games than they do in real-life situations? Why is it complex to extrapolate game results to realized scenarios? Levitt & List (2007, 2008) study these questions extensively. The choices we make in a game depend not just on financial but also on moral implications. Depending on the problem we face, we juggle between maximizing our wealth or maximizing our moral costs and benefits. The conditions of lab experiments affect how we make choices. Levitt & List suggest that five main factors influence results in lab experiments: (1) the ethics behind the decision (i.e., if the action is socially bad or good), (2) the nature and degree of scrutiny by others, (3) the context of the game (i.e., the context of how the game is played, coupled with the fact that in the game, time and choice sets are bounded), (4) self-selection to participate in a study and, (5) the stakes of the game (i.e., if and how much a player loses or gains). Amidst these drawbacks, Levitt & List (2007) do not dismiss the use and practicality of experimental games. On the contrary, they suggest combining lab-in-the-field data with data from natural settings to have both an elicited and realized measure, which we aim to do in this research project.

In conclusion, games have become increasingly popular in economic research over the past decade, as have the critiques of them (Galizzi & Navarro-Martinez, 2019; Levitt & List, 2007b, 2008). Games can be interesting, but questions remain about their validity in real contexts. As we have reviewed, there is mixed evidence of the external validity of the public goods game when used to measure cooperation around a natural resource. Games can help researchers gain insights into behaviours that are not observable, so more research is needed to study the validity of games and how they can be improved.

2.2. Theoretical Framework

We next present a theoretical framework to understand the dynamics of group cooperation. The following theoretical framework is inspired by Kandel & Lazear (1992) and Aggarwal (2000). Suppose we have a group G of N individuals all working together to provide enough of a public good, a goal that requires effort and costs but benefits all community members regardless of how much effort they put in. This is what we call a public goods dilemma, and the setting of the public goods game mimics this scenario. Let $e = (e_1, e_2, \ldots, e_N)$ be the vector of contributions or effort. Let $f(e)$ be a concave production function of the public good. Provision and agreement among members are associated with personal costs and transaction costs (negotiation, implementation, monitoring costs), so let $C(e_1)$ be the convex cost function of providing the public good for individual n=1. At the individual level[1], the maximization problem for *i* becomes:

$$\underset{e_i}{\text{Max}} \frac{f(e)}{N} - C(e_i) \qquad (1)$$

The individual maximizes their share of the good minus their personal effort. Now the optimal individual contribution is the solution to the following first-order condition, which is the partial derivative of (1) with respect to e_i:

$$\frac{1}{N}\left(\frac{\partial f(e)}{\partial e_i}\right) - \left(\frac{\partial C(e_i)}{\partial\, e_i}\right) = 0 \qquad (2)$$

[1] Note that we assume to have Nashian agents here. Unlike Nashian agents, Kantians will only deviate (i.e., contribute less), if they know everyone else will deviate in the same way (Laffont, 1975). Kantians will have a different maximization problem, which Long (2017, 2020) elaborates on.

Suppose e_0 is the solution to this problem, representing the optimal individual contribution. This is the optimal level of contribution that will maximize only the *individual* welfare. Let us now change our perspective and look at the public goods dilemma from the *social planner's* perspective. At the group level, the maximization problem becomes:

$$\max_{e_1, e_2, \ldots, e_N} f(e) - \sum_{i=1}^{N} C(e_i) \qquad (3)$$

The group-level problem is to maximize total output minus the sum of all costs. The solution to this maximization problem is the optimal level of cooperation of each individual to maximize the *group welfare*. It satisfies the following first-order condition:

$$\left(\frac{\partial f(e)}{\partial e_i}\right) - \frac{\partial C(e_i)}{\partial e_i} = 0 \quad \forall i \qquad (4)$$

Suppose e^* is the solution, the Pareto optimal level of contribution, also called the group norm. When comparing e_0 to e^*, it is clear that if N>1, then $e^* > e_0$. This means that the level of effort required by each individual to reach the optimal group output is higher than the optimal individual contribution. In other words, the individual is not incentivized to contribute more than what is optimal for themselves only. In fact, the optimal strategy in this public goods dilemma is $e_0 = 0$, to bear no costs and still benefit from the public good, or to *freeride*.

Yet we know that some individuals will cooperate, and some more than others. The framework above omits the important fact that there exist motivations to cooperate. For example, *peer pressure* adds a social cost to not cooperating or a moral benefit for "doing the right thing"[2]. When

[2]Another example could be whether agents are Nashians or Kantians, as mentioned in a previous footnote. Kantian agents will behave the way they want other people to behave, as in, they will behave in a way they believe should be a universal law (Laffont, 1975). Here, Kantians can put a stronger weight on morality and/or peer pressure in their decision, compared to Nashians.

we consider the cost of peer pressure in the scenario above, the individual maximization problem becomes the following:

$$\underset{e_i}{\text{Max}} \frac{f(e)}{N} - C(e_i) - P_i\big(e_i, e_{j\neq i}, \gamma\big) \qquad (5)$$

With the peer pressure function, $P_i(\,.\,)$, the individual i now needs to consider the cost of peer pressure when solving for their optimal contribution level, e_i. Notice that, if $P_i(\,.\,) \neq 0$ pressure steers us away from the free rider equilibrium, e_0, and brings us closer to the group norm, $e*$. In other words, peer pressure encourages cooperation. There exist many formulations of the peer pressure function, as it will be shaped differently for all individuals, depending on their social preferences and the context (Daido, 2004; Kandel & Lazear, 1992).

Generally, the peer pressure function is defined as:

$$P_i = \gamma_i(e^* - e_i)\left(\frac{\bar{e}_j}{e*}\right), \qquad \text{where } \bar{e}_j = \frac{1}{N-1}\sum_{j\neq i} e_j \qquad (6)$$

Here, $e*$ is the group norm or the expectation of what all individuals in the group should be contributing to reach the best outcome for the group; e_i is the actual contribution of the individual i, and γ_i represents the intensity of peer pressure perceived by i. This means that $(e * - e_i)$ is the gap between what i is expected to contribute by the group and what i is actually contributing. $\bar{e}_j$ represents the contribution of other group members in relation to the norm. Note that as the contribution of others in the group increases, $\frac{\bar{e}_j}{e*}$ increases, applying more pressure in P_i. The more other people in the group contribute, the more individual i is pressured to increase contributions as well.

The effect of this pressure, P_i, on the actions of the individual i will depend on how sensitive they are to external pressure. We can characterize this sensitivity with γ_i. This is where the social preferences of an individual play a role. In the case of a pro-social individual who cares about the opinion of others and reaching the group optimum, γ_i will take on a positive value, such that $\gamma_i > 0$. On the other hand, individuals that can be described as pro-self or anti-social only want what is best for them and are not concerned with peer pressure. At the extreme, when the individual is not concerned with peer pressure at all, then $\gamma_i = 0$, resulting in $P_i = 0$. Finally, individuals who are neither pro-social nor anti-social do not aim to maximize any outcome. Their peer pressure function might have $\gamma_i < 0$, meaning that peer pressure makes them collapse back to the free rider equilibrium instead of encouraging them to contribute.

There are also other formulations of the peer pressure function that might be considered, for example:

$$P_i = \gamma_i(e * -e_i)^2 \left(\frac{\bar{e}_j}{e*}\right) \qquad (7)$$

In this case, falling short or exceeding the group norm represents a cost, such that the only optimal strategy for this individual is to provide exactly $e*$, not more nor less. This form of peer pressure allows individuals to maximize both their own payoff and the group payoff simultaneously since it imposes a cap on cooperative behaviour. Following the theoretical view that we just laid out in the above paragraphs, we expect pro-socials to contribute the most and anti-socials to free-ride, i.e., to contribute nothing.

How does the mechanism to contribute unfold in a public goods game (PGG)? For every player, there are two strategies: Cooperate (C) or Defect (D). Following the theory written by Van Assen & Snijders (2004), in a PGG with only two players, we have only 4 possible outcomes:

- {C, C} called Reward
- {C, D} called Sucker
- {D, C} called Freeride
- {D, D} called Punishment

A rational individual with a continuous utility function would have the following preference: Freeride ≻ Reward ≻ Sucker ≻ Punishment. In the best-case scenario, Freeride, the player does not contribute, and so incurs no costs, yet still receives their share of the public account sum since the other player contributed. The worst-case scenario is Punishment, where neither player contributed so that the public account is empty, every player is as well-off as they were before the start of the game. As we can see here, the likelihood to cooperate or to defect depends on the utility function of the individual.

Risk preferences and the shape of the utility functions are directly related if we assume that actors are rational as explained by the Expected Utility Theory (Von Neumann & Morgenstern, 1944). A risk-averse individual has an increasing concave utility function with respect to the utility of a public good, where the utility of a public good is higher than its expected utility. A risk-loving individual has an increasing convex utility function, where the utility of a public good is lower than its expected utility of a public good. A risk-neutral individual has an increasing linear utility function, where the level of utility equals the expected utility. Accordingly, risk-loving individuals are expected to be more likely to cooperate than risk-averse and risk-neutral individuals because their expected utility is higher than the actual utility of the good itself. In other words, risk lovers are ready to bear the costs and potential risks of contributing in a public goods dilemma because they value the use of that public good more than they value the risk of being the only one to bear the costs. Conversely, following the abovementioned theory, risk-averse people are less likely to cooperate than risk-loving and risk-neutral individuals. Since the utility of the good is higher than the expected utility of it, they value the potential risk of bearing all the costs more or as much as the benefit of the public goods alone. In other words, the risk of being the only one to bear the costs makes them reluctant to cooperate, as it is a risky decision. This substantiates our hypothesis that risk-loving farmers are more willing to cooperate than risk-averse farmers.

3. Chapter 3: Methodology and Experimental Design

3.1. Data

The data for this study were collected in August 2022 through a survey questionnaire and a series of field experiments, including a public goods game (PGG), a modified one-shot dictator game (DG), and a lottery game (LG). Data was collected in collaboration with the Sokoine University of Agriculture in Morogoro and a team of 11 enumerators who conducted the questionnaire and experiments in Swahili. The study included 470 participants who operate land served by the Mkindo irrigation scheme. The selection criteria were that first, the participant had to be actively farming (or fallowing) on a plot inside the irrigation scheme during the past 12 months (i.e., they could not be a distant owner); next, they had to make decisions regarding irrigation on the plot. Note that properties in the scheme are only used for rice cultivation. The region of Morogoro has a few large irrigated systems, but the Mkindo irrigation scheme was chosen because it is farmer-managed, relying more on cooperation between members than private or government-run schemes, making it more appealing to the study. Mkindo is also a gravity scheme, meaning that the water comes from a nearby river and is distributed by gravity, unlike pump irrigation.

Since all scheme members were intended to be surveyed, there was no need to stratify the sample and randomly select farmers. Nonetheless, statistical power was estimated to detect significant effects in parameters. No other study in Tanzania conducted a PGG similar to this study, and thus, prior estimates of contributions to a public account were not available for power calculations. Instead, we use the average rice yields of rice farmers in Tanzania, taken from the 2019 Living

Standards Measurement Study - Integrated Surveys on Agriculture (LSMS-ISA), which provides representative agricultural data for all Tanzania by sampling from all regions in a balanced manner. The 2019 national average annual rice yield is 0.835 tonnes/acre and, in 2016, around 90% of farmers in Tanzania were rainfed (Food and Agriculture Organization of the United Nations, 2016; World Bank, n.d.).

Farmers in the scheme follow the System of Rice Intensification (SRI) method (Kahimba et al., 2013), which is found to significantly increase rice yields in Tanzania, though not many Tanzanian farmers have adopted it (Alavaisha et al., 2022; Gowele et al., 2020; Kangile et al., 2018; Katambara et al., 2013; Reuben et al., 2016). Since our farmers follow SRI and irrigate, we expect them to have higher yields than the national average.

The estimated power for a one-sample mean test is shown in Figure 1. If we want to detect a 20% higher difference in rice yield (in tonnes/acre) compared to the national average of 0.835 in this sample, meaning if we want to detect an average rice yield of 0.996 tons/acres, a sample of 470 farmers will have a power of 0.9855[3]. Alternatively, suppose we expect a mean contribution of 50 Tanzanian Shillings (TZS) to the public account in the PGG, across all four rounds, with 30 TZS standard deviation, a power of 80% and a 5% statistical significance. Then, the minimal detectable difference (MDE) in a sample of 500 farmers is a contribution of 53.7 TZS, as shown in Figure 2.

[3] Power is the probability of rejecting the null hypothesis when it is, in fact, false. In other words, it is the probability that a test of significance will pick up on an effect that is present. In economics, researchers should aim to have a power of 0.8.

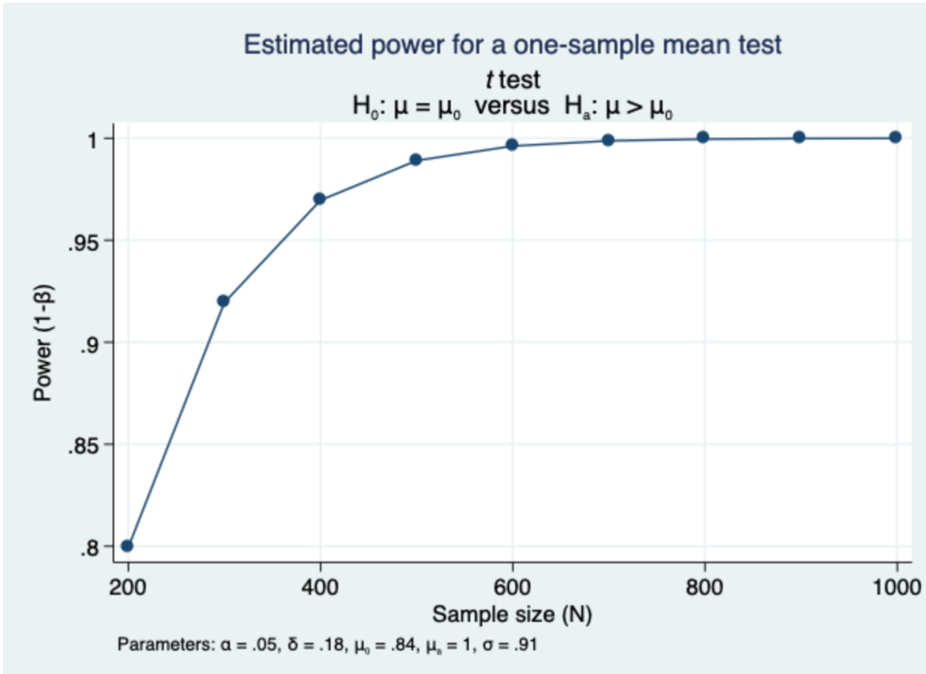


Figure 1. Estimated power for a one-sample mean test of rice yield (in tonnes/acre).

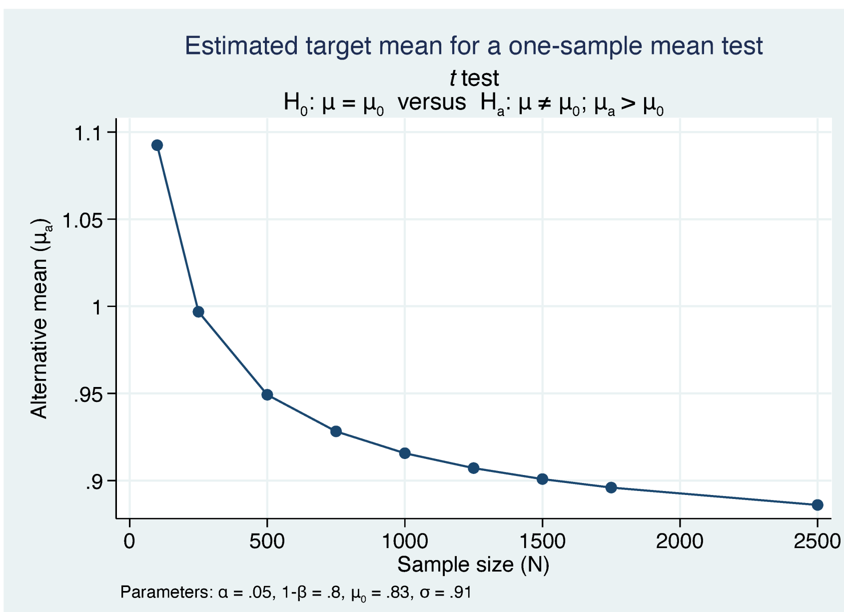


Figure 2. Estimated target mean of rice yield (in tonnes/acre) for a one-sample mean test with varying sample sizes.

3.2. Games and Survey

3.2.1. Experimental Design and Procedure

In this section, we first elaborate on the experimental design and procedure of the study, and then we explain each of the four components of the study in detail. We conducted a survey and three economic games, in the following order: (1) a survey with components on household demographics, education, assets, water insecurity index, farm management (land tenure, water management), participation in the irrigation scheme (charges, repairs, disputes, governance), household water consumption; (2) a public goods game (PGG) to measure farmers' cooperation under different risks and uncertainties; (3) a dictator game (DG) to elicit social preferences; and (4) a lottery game (LG) to measure risk preferences. The survey was completed first using the Kobo Toolbox application on a tablet, followed by the games done with pen and paper.

The PGG had a practice round and four rounds: A, B, C and D. The practice round and round A were played first, but the order of the subsequent rounds (B to D) and the dictator game was randomized for each participant using a phone application, to avoid any bias stemming from the order of rounds. Randomizing the rounds for each participant removes any learning or order bias in the final coefficients since farmers may learn the game as they play and behave differently.

The call for participation was made before and during the week of data collection. Scheme members met the researchers at the Mkindo irrigation scheme headquarters, where many members already gather regularly because of the large rice storage facility available for scheme members.

At the start of the survey, enumerators explained the purpose of the study, followed by an ethics speech and "cheap talk", where they emphasized the importance of truthful answers for accurate results with real-life consequences. Enumerators then asked for participants' consent and informed them they could refuse to answer or leave at any time but still receive the participation fee. The survey took 45 minutes to complete, and the games 30 minutes. Participants received 2,000 TZS (≈1.16 CAD), equivalent to roughly a quarter day's wage of an off-farm worker[4].

3.2.2. Public Goods Game

In the PGG, participants had to decide how much resources (money) to allocate between their private and publicly shared accounts. This simulates scenarios where people need to cooperate for a public good to be efficient but can free-ride instead. It is important to note that the money and payouts in the games were hypothetical, meaning the money that players won or dealt with in the games was not real. The game was initially designed to be played with real money, however, the first round of participants raised concerns about equity and fairness because players would receive different amounts, yet all invested the same time. The unequal chance of winning money was also deemed to resemble gambling. Thus, payouts became hypothetical, and all participants received 2,000 TZS at the end. Consequently, participants did not experience real, monetary consequences from their choices in the game, while in real-life scenarios, their choices do have consequences. This creates a disparity between in-game and real-life behaviour, where players are now less inclined to behave how they would if the games were real. This disparity introduces a hypothetical bias in the answers. To minimize this bias, we did two things. First, we used the method of "cheap

[4] Tanzania's GDP per capita in 2021 was 1,535 CAD, which is roughly 4.21 CAD/day.

talk", reminding participants to answer as truthfully as possible. Though it is a simple method, cheap talk has been proven to reduce hypothetical bias (Bosworth & Taylor, 2012; Cummings & Taylor, 1999).

Participants were paired with a hypothetical second player and given 500 TZS (≈ 0.21 USD). Due to physical constraints, making members play with each other in real time while remaining anonymous was not possible. Anonymity is essential in this game because if players know whom they are playing with, that will likely impact their decisions. The PGG is an interesting game because players need to consider what the other player(s) will do, but since we could not make players play with each other at the same time due to anonymity and physical constraints, we made the second player hypothetical. To reduce hypothetical bias and to keep the game's strategic nature, we used answers from the previous day. To do so, we had current participants play with the answers from participants of the previous day. We told current players they were playing with other study participants, but they could not know who it was. For example, answers from Day 1 became the answers of the hypothetical player for participants on Day 2. So, players on Day 2 were playing with the numbers of participants on Day 1. This chain continued until the end of the field collection, i.e., Day 2 players' answers were used for Day 3, etc. On Day 1, the answers of the second participant were randomly generated using a phone application with the options of [0, 100, 200, 300, 400, 500]. Doing this reduces hypothetical bias because players are dealing with real decisions from past players. The numbers and choices of the hypothetical second player were recorded on paper, but they were not visible to the current player.

The player then had to decide how much from the 500 TZS they wanted to allocate to their private or public accounts. The money in their private account is kept for themselves, while contributions to the public account are multiplied by 1.5 and then shared equally among the two players at the end of the round. The payoff function for player i is such that:

$$\pi_i = g_i + 1.5 \sum_{j=i}^{2} g_j \qquad i = 1,2 \qquad (8)$$

Where π_i is the payoff of player i, g_i is the amount player i put in their private account, and the sum of g_j is the sum of all the contributions by both players to the public account. After the current player makes their decisions, they are informed of the total of the public account.

The game consisted of four rounds (A, B, C, and D) with different rules. Round A was a classic PGG with no risks, as explained above. In Round B, we introduced a risk that the public account could become null. Here, a coin flip determined a 50/50 chance of the public account becoming null, which meant that all money in the public account would be lost for all players. Participants were only informed about the loss after making their allocation decisions.

In Round C, the private account was at risk of being lost following a coin flip. If lost, participants lost the money in their private account; if safe, they kept the money. In Round D, participants picked a ball from an opaque bag to determine which account (public or private) was lost. One colour signalled that the public account was lost, while the other colour signalled that the private account was lost. Participants did not know how many balls of each colour were in the bag. In reality, the bag had a uniform distribution of ten white and ten red balls. For all these rounds, participants only knew which account was lost after they made their decisions.

3.2.3. Dictator Game

Next, participants played a modified dictator game, making three binary choices to elicit their social preferences, i.e., how they consider others in their decision. The choices are represented in Figure 3. For each choice, the participant decided how much to give to themselves (amount on the left) and how much to give to the second hypothetical participant (amount on the right), following a design inspired by previous studies (Bauer et al., 2014; d'Adda & Levely, 2016; Fehr et al., 2008). All participants played this game in the same order, from choice A to C. They were told that the hypothetical player was another member of the irrigation scheme. Based on the combination of choices made, participants were classified as "Pro-Social," "Anti-Social," or "Socially Inefficient," as explained in Table *1*. Players who always chose the options that benefited the other player more, even if it meant they got a lower amount, were classified as "Pro-Social"; players whose choices put the other players in a worse situation than themselves or did not seem to take into consideration the other player and only maximized their own payoff were labelled as "Anti-Social"; finally, players whose choices did not aim to maximize either their own or the other's payoff were considered to have a "Socially Inefficient" preference.

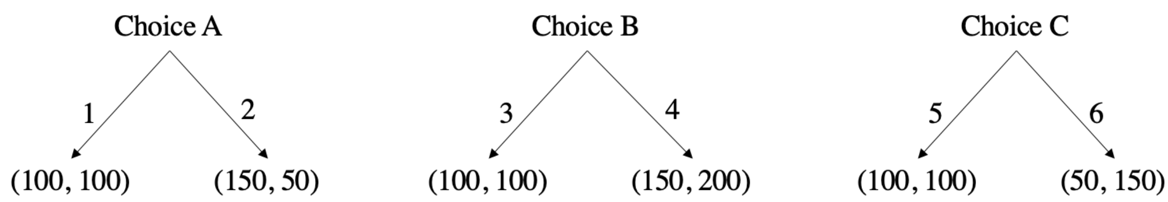


Figure 3. Binary-choice dictator game to elicit social preferences.

Table 1. Groups of social preferences.

Preference Profile	***Choice Combination***
Pro-Social	(1, 4, 5) or (1, 4, 6)
Anti-Social	(2, 4, 5) or (2, 4, 6)
Socially Inefficient	(1, 3, 6) or (2, 3, 5) or (2, 3, 6) or (1, 3, 5)

3.2.4. Lottery Game

The third game was a lottery game, inspired by Eckel & Grossman (2002), where participants had to choose from four lotteries with varying payoffs and risks. Table *2*. summarizes the lotteries, starting with a safe option and increasing in both expected pay-off and risk. A coin toss done in front of participants determined whether they won the high or low payoff. Lottery A ensured a win of 500 TZS, making it the safest choice, while lottery D meant participants were risk-loving. If they chose lottery B or C, participants were classified as simply risk-averse. Lottery C and D had the same expected payoff, but the standard deviation was higher for lottery D, making it more appealing to risk lovers.

Recall that the money in the game is hypothetical. Past research has found that players tend to show less risk aversion and more risk-taking behaviour in hypothetical games compared to real games (Yesuf & Bluffstone, 2009). Hence, we suspect the actual number of extremely risk-averse individuals to be higher than observed, and the number of risk-lovers to be lower.

Table 2. Payoff table for the lottery game.

Choice	***Low Payoff (TSh)***	***High Payoff (TSh)***	***Risk Aversion Class***	***E[X]***	***SD***
A	500	500	Extreme Risk Averse	500	0
B	400	850	Risk Averse (more)	625	225
C	300	1200	Risk Averse (less)	750	450
D	0	1500	Risk Loving	750	750

4. Chapter 4: Results and Empirical Strategies

4.1. Summary Statistics

4.1.1. Descriptive Statistics of the Farmers

This study includes 470 rice farmers who were members of the Mkindo irrigation scheme in the region of Morogoro, Tanzania, in August 2022. The Mkindo irrigation scheme is located approximately 60km north of the city of Morogoro, in the district of Mvomero, which is one of the six wilayas (districts) of the Morogoro region. As explained in Chapter 3 (Methodology), the selection criteria for our study were the following: first, the participant had to be actively farming (or fallowing) a plot inside of the irrigation scheme during the 2022 long rain or 2021 short rain season (i.e., it cannot be a distant owner); next, they had to make some decisions regarding irrigation on the plot.

Table *3* presents some descriptive statistics of the respondents. 67% of participants were the household head, with a mean age of 46. There is an almost even split by gender, with 47% of the sample being male. We have a significant disparity in plot size, where two participants owned no plots (i.e., they rented one or more plots in the Mkindo irrigation scheme), and one person owned 14 plots for a total sum of 180 acres. We winsorize these outliers so that values above the 99th percentile were replaced by the value at the 99th percentile, while values under the 1st percentile were replaced by the value at the 1st percentile. After this procedure, we find that individuals in our sample owned, on average, 3.46 acres over 2.16 plots. About 22% of the sample rented in a plot over the past twelve months. 75% of the sample completed primary education, which is seven years in Tanzania, while 10% received education beyond primary school.

The average household has 4.74 members, excluding the participant, with an average annual income of 2,216,356 TZ Shillings (CAD 1,285 at the time of the study). Again, we winsorize income, replacing values above (below) the 99th (1st) percentile with the value at the 99th (1st) percentile. Even after removing outliers, there is still a wide range in income, with a minimum of 120,000 TZ Shillings (CAD 69) and a maximum of 16 million TZ Shillings (CAD 9,280). The proportion of dependents is measured by taking the total number of dependents over the total household size. We considered any person below the age of 18 and over 65 to be a dependent, i.e., generally a person who depends on another for care and income. The higher the proportion of dependents, the higher the pressure there is on the household to provide. Here, the average proportion of dependents in a household is 0.56, meaning that, on average, just over half of the household is comprised of dependents.

Finally, to gauge the level of water insecurity in this sample, we measure the 4-level Household Water Insecurity Index (HWISE), developed by Young et al. (2021). This index measures universal experiences of household water insecurity across low-income and middle-income countries. Water insecurity is not limited to just the physical lack of water but also the emotional and social distress that comes with it, and the HWISE encompasses all those dimensions through only four questions. The scale goes from 0 (extremely water *secure*) to 12 (extremely water *insecure*). Responses where participants were unsure were removed from the calculations. The average HWISE is 1.07 and is largely skewed to the left, indicating that the sample is largely water secure – though a handful of participants are extremely water insecure.

Table 3. Descriptive statistics of participants.

Variable Name	Mean	SD	Min	Max	N
Individual Characteristics					
Household Head dummy	0.67	0.47	0	1	470
Age	46.18	14.88	20	85	470
Male dummy	0.47	0.50	0	1	470
Plots owned in total[5]	2.16	1.12	1	6	470
Total land owned (acres)[6]	3.46	4.14	0.25	27	470
Renter dummy (=1 if rent in a plot over the last 12 months)	0.22	0.41	0	1	470
Dummy if completed primary education (7 years)	0.75	0.43	0	1	470
Dummy if completed more than primary education	0.1	0.3	0	1	470
Household characteristics					
Household size (person)	4.74	3.90	1	65	470
Household gross income (TZS)[7]	2,216,356	2,296,623	120,000	16,000,000	462
Proportion of Dependents	0.56	0.26	0	1	470
Water insecurity index[8]	1.07	1.84	0	12	466

4.1.2. Summary Statistics of the Games

We played three games: a public goods game, a modified dictator game, and a lottery game. Sample sizes are slightly smaller than 470 because some participants did not want to play certain

[5] Outliers above the 99th percentile were replaced by the value at the 99th percentile, while values under the 1st percentile were replaced by the value at the 1st percentile. This was done using the Stata command *winsor2.*
[6] Again, we used *winsor2,* similar to the footnote above.
[7] Again, we used *winsor2,* similar to the footnote above.
[8] Created by Young et al. (2021). The index goes from 0 to 12, increasing from water secure (0) to extremely water insecure (12).

rounds or games. Table *4* presents summary statistics of the public goods game (PGG). In each round of the PGG, players received 500 TZS. We are interested to know how much players contribute to the common pool. The group's average contribution was 231.15 TZS, with a standard deviation of 84. Note that the minimum average contribution of a participant was zero, yet the maximum average contribution of another player was below 500, meaning some people unconditionally refused to contribute (i.e., have an average contribution of 0) while no one unconditionally accepted to contribute (i.e., have an average contribution of 500). Round A was risk-free, with a mean contribution of 240.09 TZS. We introduced risk to the public account in Round B, where the mean contribution was 204.63 TSZ. In Round C, where the private account was at risk, the average contribution was 249.14 TZS. Finally, in Round D, both accounts were at risk, and the average contribution was 231.53 TZS.

Table 4. Summary statistics of contributions in the Public Goods Game.

Public Goods Game	Mean	SD	Min	Max	N
Average Contribution	231.15	84.0	0	462.5	465
Contribution in Round A	240.09	121.78	0	500	459
Contribution in Round B	204.63	126.4	0	500	464
Contribution in Round C	249.14	127.62	0	500	463
Contribution in Round D	231.53	114.19	0	500	463

Table 5. Risk preference of participants, measured by the lottery game.

Risk preference	Frequency	Percentage
Extreme Risk-Averse	162	35.21%
Risk-Averse	224	48.7%
Risk-Loving	74	16.09%
Total	*460*	*100%*

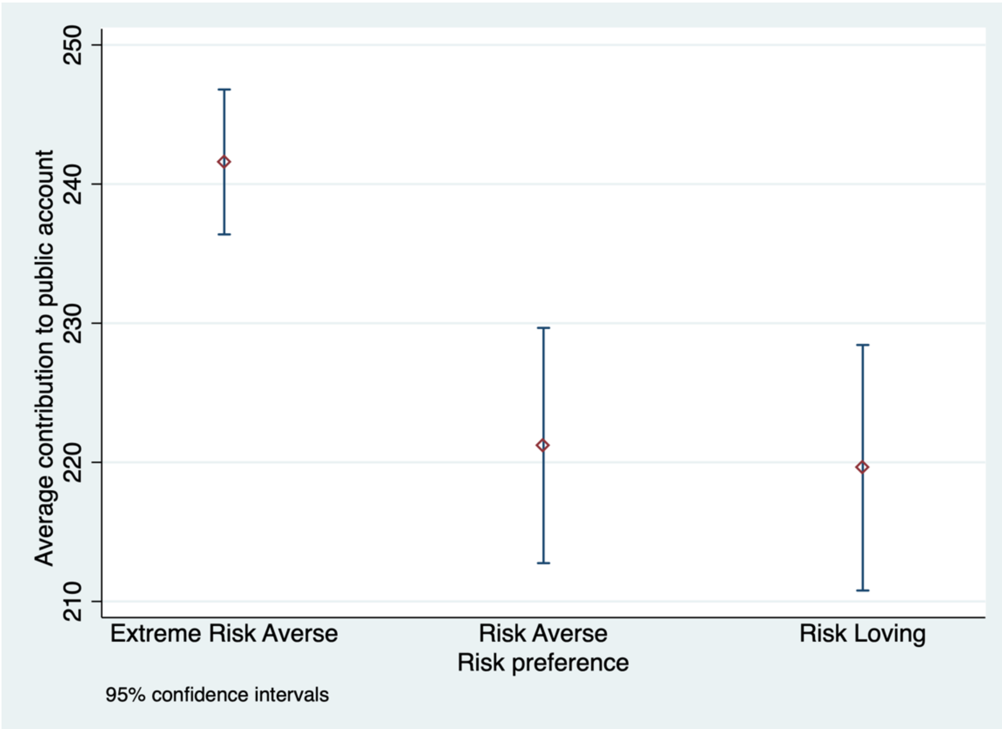


Figure 4. Average contribution to public account of each risk preference class.

In the lottery game, participants revealed their risk preferences. The methodology chapter offers a detailed description of the classification. In the sample, 49% of respondents are risk-averse, 35% are extremely risk-averse, and 16% are risk-loving. Because the payouts are hypothetical, the results suffer from a hypothetical bias; however, past research on this type of bias in risk games has shown that rural farmers were less risk-averse in hypothetical games compared to non-hypothetical games (Yesuf & Bluffstone, 2009). Thus, there are probably fewer actual risk-loving individuals in this sample but more farmers that are extremely risk-averse. Overall, we find that the rice farmers of the Mkindo irrigation scheme are moderately to highly risk-averse.

Table 6. Social preferences of participants.

Social Preference Class	Frequency	Percentage
Anti-Social	142	30.6%
Pro-Social	85	18.32%
Socially Inefficient	237	51.08%
Total	*464*	100%

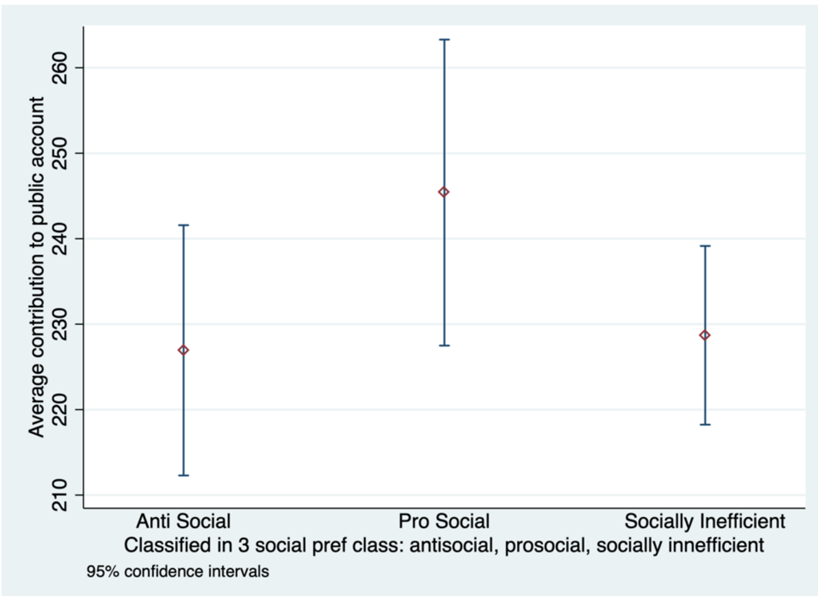


Figure 5. Average contribution to public account by social preference class.

We classify respondents into three social preference classes based on their choices in the dictator game: anti-social, pro-social, or socially inefficient. A more detailed description of the classes is provided in the methodology chapter. About 30% of participants are anti-social, meaning they maximize only their own payoff or actively minimize their partner's payoff. Next, 18% are pro-socials, i.e., they prioritize their partner's profit. Finally, around half of the sample has socially inefficient preferences, i.e., they do not maximize their own or their partner's payoff.

4.2. Regression Estimations and Results

4.2.1. Outcome 1: Determinants of Cooperation

To understand the determinants of cooperation, we estimate the following ordinary least squares (OLS) model with robust standard errors and block fixed effects:

$$AverageContribution_i = \alpha_0 + \beta_1 LandTenure_i + \beta_2 Male_i + \sum_{k=3} \theta_k \, RiskAversion_i + \sum_{k=4} \delta_k \, SocialPreferenceClass_i + \sum_{j=3} \sigma_j \, Location_i + \Gamma' X + \varepsilon_i \quad (9)$$

Where $AverageContribution_i$, the dependent variable of interest, is the average contribution across the four rounds of the PGG of individual i. $LandTenure_i$ is an indicator variable equal to 1 if individual i owns only plots inside of the Mkindo irrigation scheme. $Male$ is a dummy variable equal to 1 if individual i is a male. $RiskAversion_i$ is a vector of indicator variables that identify the risk preference of individual i. $SocialPreferenceClass_i$ is a vector of indicator variables that identify the social preference class of the player. $Location_i$ refers to the location of their plot(s) along the scheme's canal, i.e., whether their plot(s) is (are) situated in Block A, B, C or D[9]. Finally, X is a matrix of individual controls, such as age, education, and wealth; ε is the idiosyncratic error term. The parameters of interests are β_1, β_2, θ_k and δ_k which show the effects of land ownership,

[9] We control for block membership to account for varying socio-economic and farming conditions among farmers in different blocks. For instance, farmers in Block A, the oldest block with cement canals, receive water year-round, while those in Block D, the newest block with surface hand-dug canals, only receive water during the long rains season. Farmers in Block A are found to have a higher income than in Block D. Moreover, Block A is also reported to be the least well-maintained, while Block B is the most well-maintained.

gender, risk aversion, and social preference, respectively, on the average cooperation level of participant i in the public goods game. Results are shown in *Table 7*, column (1).

To gain further insights into player behaviour, we conducted the same analysis as equation (9) using different dependent variables. Namely, contributions in rounds A, B, C, D, and the average spread of contributions shown in *Table 7*, columns (2), (3), (4), (5) and (6), respectively. The spread of contributions is the difference between an individual's maximum and minimum contribution; it shows how much an individual varied their contribution in the game, thus revealing how sensitive to shocks or conditions that individual is. For example, a person not affected by shocks to resources in the game always contributed the same amount and had a spread of zero. On the other hand, a person with a spread of 500, for example, means that in one round, they contributed all their Shillings, but in another, they kept them all for themselves, so this individual significantly responded to shocks and conditions in the game.

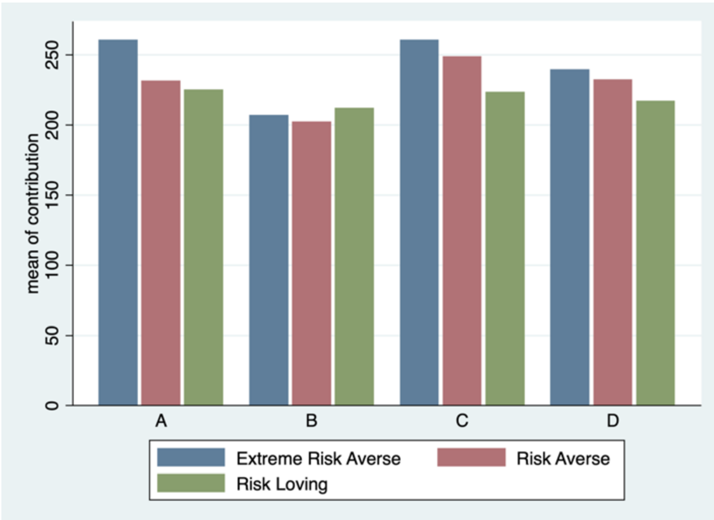


Figure 6. Contribution in each round by risk preference.

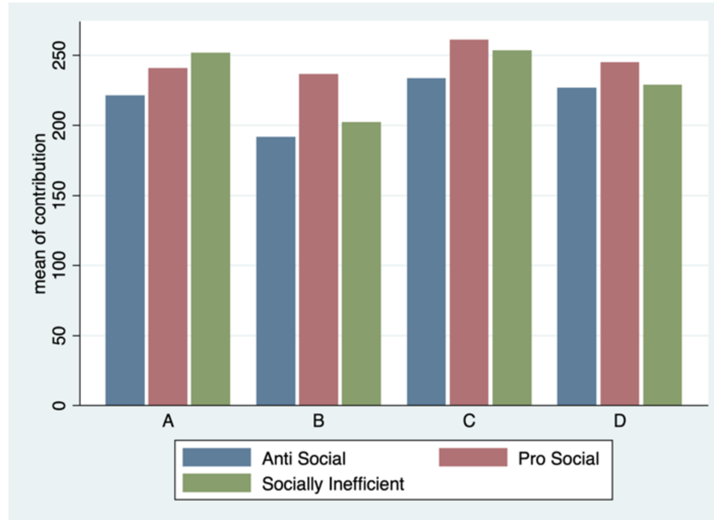


Figure 7. Contribution in each round by social preference.

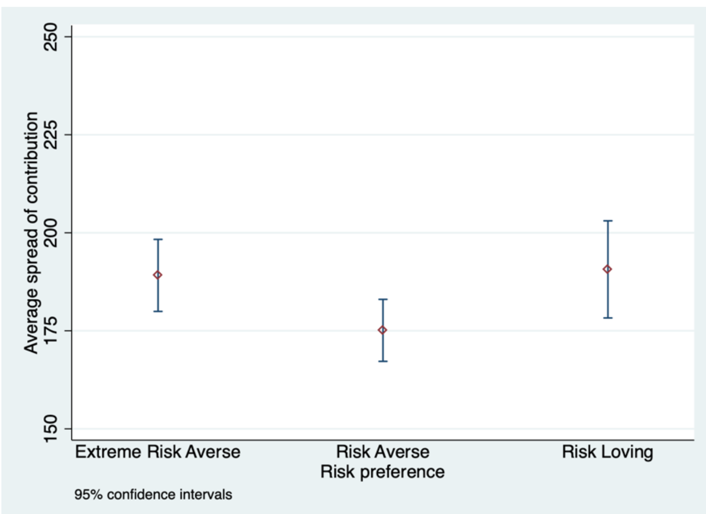


Figure 8. Spread of contribution by risk preference.

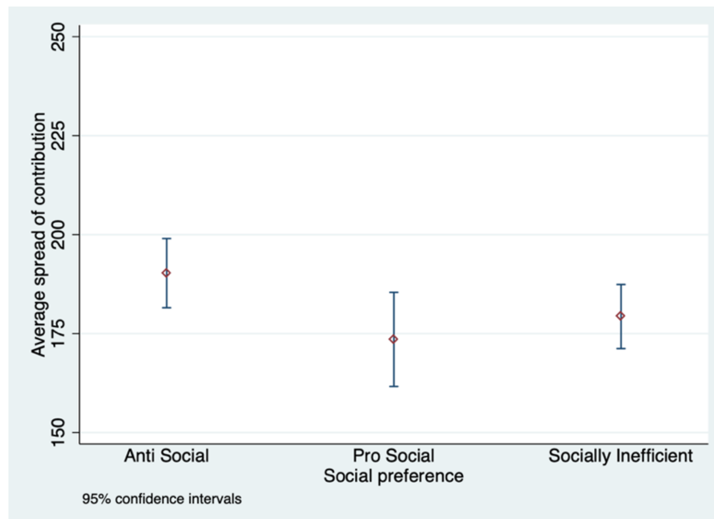


Figure 9. Spread of contribution by social preference.

Table 7. Average contribution and contribution in each round, regressed on individual characteristics and preferences.

VARIABLES	(1) Average contribution	(2) Contribution Round A	(3) Contribution Round B	(4) Contribution Round C	(5) Contribution Round D	(6) Average spread of contribution
=1, owns plots only inside scheme	4.875	15.93	-3.517	-1.977	8.918	16.51
	(9.013)	(12.91)	(13.03)	(13.10)	(12.21)	(13.29)
Male	-7.292	-3.306	-6.782	-10.27	-9.075	16.70
	(8.014)	(12.42)	(12.70)	(12.52)	(10.80)	(13.33)
Risk-Lover	-6.043	-5.768	13.27	-22.05	-9.792	12.43
	(11.66)	(17.02)	(17.79)	(18.19)	(16.16)	(17.84)
Extremely Risk Averse	15.85*	31.80**	3.629	19.26	10.47	23.05
	(8.800)	(13.20)	(13.63)	(13.59)	(12.01)	(14.12)
Socially Inefficient Preferences	-19.01*	1.691	-47.49***	-11.05	-21.39	1.690
	(10.83)	(15.64)	(17.05)	(16.86)	(13.46)	(16.57)
Anti-Social Preferences	-16.22	-0.670	-42.22**	-13.19	-9.737	23.70
	(11.91)	(17.78)	(18.71)	(18.71)	(15.17)	(18.10)
Age	-0.104	0.410	-1.101**	0.434	-0.134	0.417
	(0.337)	(0.476)	(0.509)	(0.500)	(0.486)	(0.510)
Proportion dependents	36.07*	4.433	64.88**	43.36	31.20	32.91
	(19.11)	(27.43)	(26.89)	(27.70)	(25.76)	(25.79)
=1 if in richest quartile	-7.440	-10.93	21.26	-29.40*	-11.02	-10.34
	(10.46)	(15.21)	(15.13)	(15.24)	(13.80)	(15.55)
=1 if in poorest quartile	-20.55*	-17.56	-25.41	-22.67	-15.55	27.86
	(10.69)	(15.92)	(16.37)	(16.93)	(15.36)	(17.64)
=1 if got any education	7.325	17.72	8.806	3.499	4.393	-20.98
	(18.05)	(26.11)	(26.39)	(27.05)	(26.11)	(27.84)
=1 if completed primary school	-1.628	22.21	-27.24	5.903	-11.12	17.96
	(14.18)	(21.54)	(20.21)	(21.86)	(19.46)	(22.01)
Constant	239.0***	190.7***	271.6***	234.8***	257.7***	136.9***
	(23.78)	(34.90)	(37.63)	(38.06)	(32.03)	(37.55)
Blocks FE?	Yes	Yes	Yes	Yes	Yes	Yes
Observations	457	451	457	456	456	457
R-squared	0.062	0.051	0.066	0.075	0.048	0.088

Robust standard errors in parentheses. Risk-averse is the base variable for risk preference classes. Pro-social is the base variable for social preference classes. Proportion dependents is the total number of dependents over the total household size. A dependent in this case is a person under the age of 18 and above the age of 65.
*** p<0.01, ** p<0.05, * p<0.1

Of the three risk preferences, Figure 6. Contribution in each round by risk preference.Figure 6 shows that extremely risk-averse individuals tend to contribute the most. There is no round with a higher contribution from all players, but Round B is where all three groups contributed the least. In Figure 7, anti-socials always contributed the least in each round out of all social preferences, while pro-socials always contributed the most. This is because anti-socials prioritize their own payoff while pro-socials consider the group's outcome.

Figure 8 and Figure 9 present the spread of contributions between Round A to Round D by risk and social preference. The spread of contribution is the difference between an individual's maximum and minimum contribution. The higher the spread, the more sensitive a person is to risk, and the more volatile their contribution to the group is. A spread closer to zero shows that the player has a fixed contribution to the group regardless of risks, meaning they are unresponsive to risk. From Figure 8 and Figure 9 and Table *7* we cannot decipher any differences in the spread of contributions.

The lack of significance in land ownership, gender, age, and education in *Table 7*, column (1) indicates that these variables do not help explain the contribution of a player to the public account. However, *extremely* risk-averse individuals had an average contribution that is 15.85 TZS higher than risk-averse ones ($p<0.1$). This increase in the average contribution is driven by Round A, as we can see in column (2), extremely risk-averse people contributed 31.80 TZS more than risk-averse players ($p<0.05$). Since Round A has no risk, players who are not sensitive to risk won't be prompted to contribute. Risk-lovers and risk-averse individuals did not have an average contribution that is different from each other. When computing an F-test of joint significance, we find a modest explanatory power of risk preferences as a group (p=0.09). From columns (2) to (5) and Figure 4 it is apparent that no significant behaviour divides risk-lovers from risk-averse individuals. Although we find modest power of risk preferences when we study the *average* contribution, this power is absent when we dissect the game by rounds, suggesting a potential need for more robustness.

For social preferences, an F-test of joint significance reveals that social preferences do not have joint significance (p=0.21). But *Table 7*, column (1), and Figure 5 show that socially inefficient players contributed, on average, 19 TZS less than pro-socials, with 10% significance. Interestingly, this dip in the average contribution is driven by these players' significant decrease of 47.49 TZS in contribution in Round B, compared to pro-socials (p<0.01), as we see in column (3). Meanwhile, anti-social farmers contributed 44.22 TZS less in Round B than pro-socials (p<0.05). Again, although social preferences have modest power when we study the average contribution in the game, this power is gone when we dissect the game by rounds.

The higher the proportion of dependents, the more participants contributed on average, with 10% significance. In Round B, the average contribution increased with the proportion of dependents, significant at the 5% level. Overall, having more dependents in a household increases cooperation in the game, particularly when there is a risk to a public resource.

We constructed an asset index to separate participants into wealth quartiles using principle component analysis (PCA); see Appendix A.1 Construction of Asset Indexfor details. The index includes productive assets such as farm tools and equipment, household assets such as cell phones and furniture, and livestock assets. In *Table 7*, column (1), the wealthiest individuals did not contribute differently than others. However, in Round C, column (4), when private resources were at risk, they contributed 29.40 TZS less than individuals in the 2nd and 3rd quartile ($p<0.1$). Meanwhile, on average, the poorest individuals contributed 20.55 TZS less than individuals in the 2nd and 3rd quartile ($p<0.1$), as apparent in column (1).

4.2.2. Outcome 2: Cooperation Under risk

The second, and main, aim of this study was to see how farmers change their cooperation level when facing different risks. For this, we ran the following model OLS model with robust standard errors:

$$Contribution_i = \beta_0 + \beta_1 RoundB_i + \beta_2 RoundC_i + \beta_3\ RoundD_i + \varepsilon \quad (10)$$

$Contribution_i$ is the amount that individual i contributed to the public account, while parameters β_1, β_2, and β_3 are indicator variables for Rounds B, C, and D, respectively, and ε is the idiosyncratic error term. The results of this regression estimation are shown in Table *8*.

Results in Table *8* show that when there was a risk to the public account in Round B, farmers decreased their contribution by 34.76 TZS compared to Round A, where there was no risk, statistically significant at the 1% level. This means that players reduced their cooperation significantly when there was a shock to common resources in the game. Yet, we do not see statistically significant behaviour in Rounds C or D compared to the risk-free Round A. This story is visually apparent in Figure 10, which shows that the average contribution in rounds A, C, and

D is around 240 TZS, but dips to 204.63 (± 11.53) TZS in Round B. Though we do not find statistical significance, the signs of coefficients for Round C and D are telling. Indeed, we would expect farmers to increase their contribution in Round C, and here we see that in Round D farmers tend to decrease their contribution. Note that contributions in each round follow a normal distribution, apparent in Figure 11, which justifies our use of an OLS model.

Table 8. Changes in contribution to the public account when introducing different risks.

VARIABLES	(1) Contribution to public account
Round B: risk to public account	-34.76***
	(8.142)
Round C: risk to private account	8.690
	(8.201)
Round D: risk to both accounts	-8.730
	(7.762)
Constant	239.8***
	(5.664)
A≠B (p-value)	0.00
A≠C (p-value)	0.24
A≠D (p-value)	0.17
B≠C (p-value)	0.00
C≠D (p-value)	0.00
Observations	1,857
Number of players	465
R-squared	0.017

Robust standard errors in parentheses. The risk-less and standard Round A is the base indicator variable in this model. We do a paired t-test of equality of means of rounds and report the two-tailed p-values.
*** p<0.01, ** p<0.05, * p<0.1

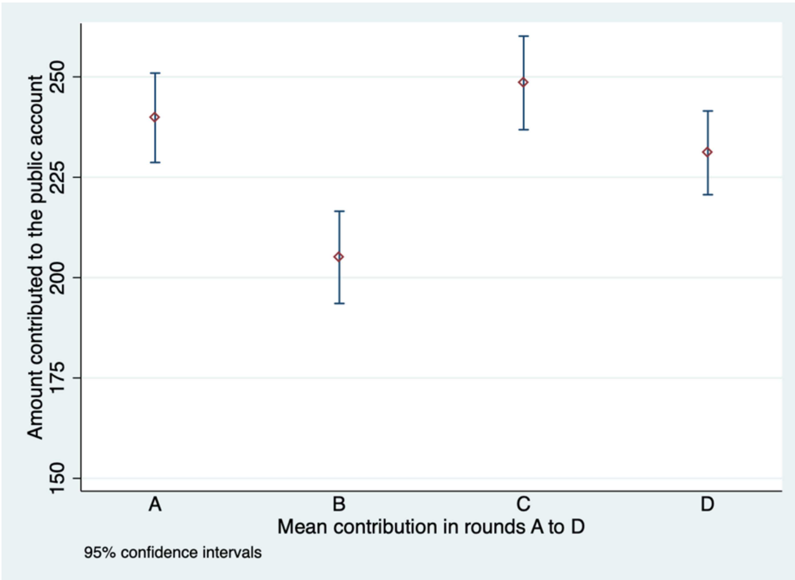


Figure 10. Mean contribution in each round (in TZS).

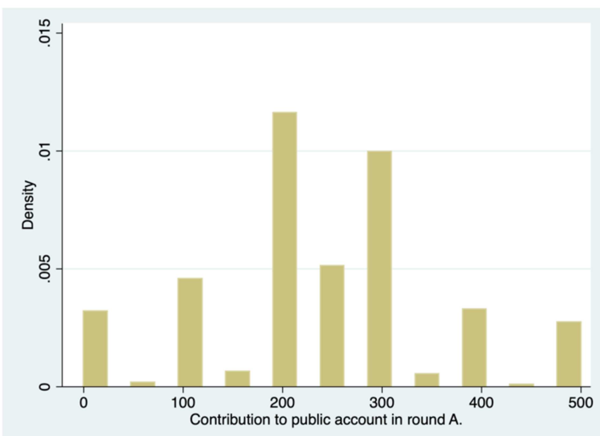


Figure 11a. Round A.

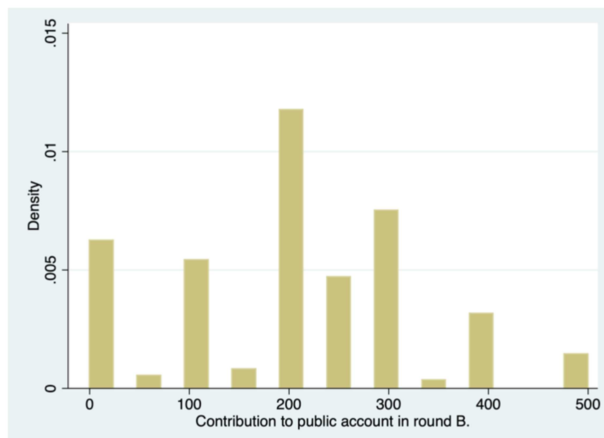
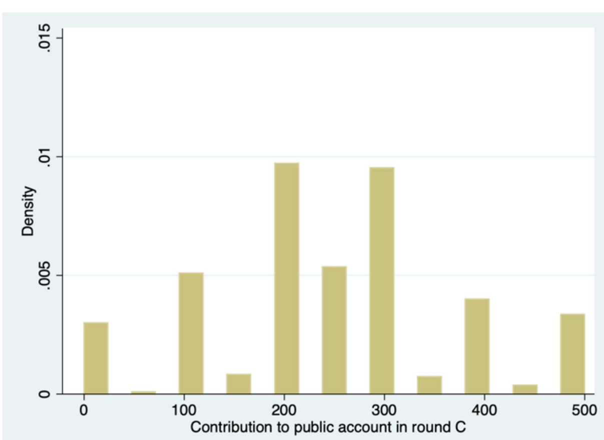


Figure 11b. Round B.



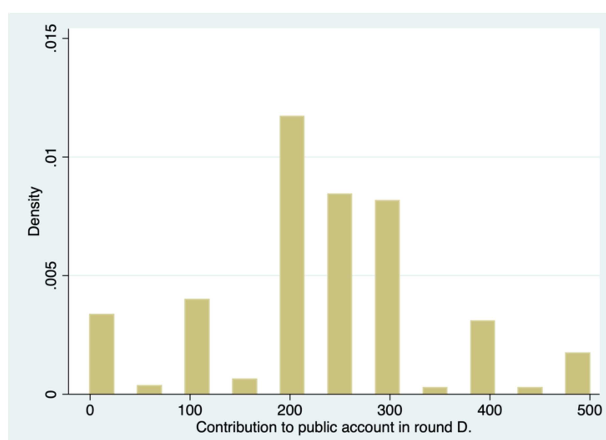


Figure 11c. Round C. Figure 11d. Round D.

Figure 11. Distribution of contribution (in TZS) to public account in each round.

To further analyze cooperation in the PGG, we examine how different risk and social profiles behaved in the rounds. First, we study how the three risk preference types acted. Recall that the three types are extremely risk-averse, risk-averse, and risk-loving. Also, recall that in Round A, there was no risk; in Round B, there was a risk to the public account; in Round C, there was a risk to private accounts; and in Round D, there was a risk to both public and private accounts.

Table *9* shows the results of equation (10) when isolating each risk preference to observe how their contribution changed throughout the game. In column (1), extremely risk-averse individuals contributed, on average, 260.8 TZS in Round A. Their contribution decreased by 53.62 TZS, on average, in Round B and 21.38 TZS in Round D, compared to Round A, with 1% and 10% significance, respectively. In column (2), risk-averse farmers contributed, on average, 231.6 TZS in Round A. These risk-averse farmers contributed, on average 29.39 TZS less in Round B, compared to Round A, statistically significant at the 5% level. They did not behave differently in Rounds C and D. Finally, the coefficients in column (3) show that risk-lovers contributed 225 TZS in Round A, on average, but did not behave differently across the rounds.

Of these three classes, extremely risk-averse farmers lowered their contribution the most when facing a common risk in Round B (Table *9*), though they had the highest average contribution (Figure 4). This suggests that extremely risk-averse farmers are more sensitive to risk and shocks than risk-averse and risk-loving farmers. On the other hand, risk-lovers do not seem affected by changes in risk, be it common or private risk. These results make sense since we expect extremely or normally risk-averse players to be sensitive to risks in the game but risk-loving players to not change their behaviour because of it. Note that the lower number of observations for risk-lovers in column (3) might explain the absence of significant coefficients.

Table 9. Difference in contribution in each round, per risk preference class.

VARIABLES	(1) Contribution of extreme risk-averse farmers	(2) Contribution of risk-averse farmers	(3) Contribution of risk-loving farmers
Round B: risk to public account	-53.62***	-29.39**	-13.00
	(13.25)	(12.14)	(20.13)
Round C: risk to private account	0.110	17.05	-1.351
	(13.48)	(12.04)	(20.60)
Round D: risk to both accounts	-21.38*	0.608	-7.667
	(12.31)	(11.73)	(18.90)
Constant	260.8***	231.6***	225***
	(9.094)	(8.691)	(12.74)
Observations	640	898	298
Number of Players	160	225	74
R-squared	0.034	0.018	0.002

Robust standard errors in parentheses. Round A is the base variable (no risk).
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Next, we examine how each social preference classes changed their contribution in the rounds of the PGG. Similar to what we did above, *Table 10* presents the results of equation (10) when isolating each social preference class. In column (1), pro-socials had an average contribution in Round A of 240.7 TZS, but we do not capture any significant changes in contributions across rounds. On the other hand, anti-socials, in column (2), had a mean contribution of 221.1 TZS in Round A but contributed 29.53 TZS less in Round B compared to Round A ($p<0.05$). Finally, socially inefficient individuals in column (3) have a mean contribution in Round A of 251.7 TZS and contributed 49.58 TZS less in Round B and 22.73 TZS less in Round D compared to Round A, with 1% and 5% statistical significance, respectively.

Of the three classes, socially inefficient farmers reacted the strongest to the public risk in Round B, which is consistent with Table *7*. On the other hand, pro-socials do not seem affected by shared or private risks. The higher number of observations for socially inefficient players helps capture more significant coefficients; the opposite can be said for pro-socials, where the lower observations might prevent the model from grasping significant coefficients. These results make sense because pro-social farmers are inherently more altruistic and so risks would not change their willingness to contribute. On the other hand, anti-social and socially inefficient farmers are less altruistic and so it makes sense that they decreased their contribution when anti-socials faced risks in Round B, and socially inefficient farmers faced risk in Round D. Note that we still find a significant decrease in contribution in Round B, which is consistent with Table *8*.

Table 10. Regression of contribution in each round, per social preference class.

VARIABLES	(1) Contribution of pro-social farmers	(2) Contribution of anti-social farmers	(3) Contribution of socially inefficient farmers
Round B: risk to public account	-4.270	-29.53**	-49.58***
	(19.36)	(14.30)	(11.43)
Round C: risk to private account	20.44	12.31	1.709
	(19.04)	(14.35)	(11.69)
Round D: risk to both accounts	3.965	5.369	-22.73**
	(16.74)	(13.68)	(11.30)
Constant	240.7***	221.1***	251.7***

	(12.91)	(9.761)	(8.192)
Observations	336	595	925
Number of Players	85	148	231
R-squared	0.006	0.017	0.028

Robust standard errors in parentheses. Round A (no risk) is the base variable.
*** p<0.01, ** p<0.05, * p<0.1

4.2.3. Outcome 3: Validity of the Public Goods Game (PGG)

Finally, the third aim of this study was to test the external validity of the PGG by comparing cooperation in the game with real-life cooperation. To capture cooperation in real life, we asked a series of questions to gauge participants' engagement in maintaining the scheme. Our original hypothesis was that elicited (in-game) and realized (real-life) behaviour would not differ statistically significantly. We compare in-game cooperation with nine real-life cooperation variables:

i. *Paid bills (LR)*: a binary variable equal to 1 if the participant paid the water bills in full for the long rain (LR) season, 0 otherwise. Members owe water bills at the end of every harvest season to the Water User Association (WUA; also named UWAMKI), the irrigation scheme management association. There are two seasons: short and long rain.

ii. *Paid bills (SR)*: a binary variable equal to 1 if the participant paid their water bills in full for the short rain (SR) season, 0 otherwise.

iii. *Contributed any cash or labour*: a binary variable equal to 1 if the participant gave any cash or provided any labour to help maintain the canal adjacent to their most important plot in the past 12 months, 0 otherwise. This reveals if the participant helped with maintenance in any way.

iv. *Days of labour contributed*: a continuous variable of the number of hours the participant spent maintaining the canal adjacent to their most important plot in the past 12 months, excluding hired labour.

v. *Cash contributed*: a continuous variable of how much cash the participant spent to help maintain the canal adjacent to their most important plot in the past 12 months, including hired labour, measured in TZS.

vi. *Voted in past election*: a binary variable equal to 1 if the participant voted in the last election of their block, 0 otherwise. Each block has a Water User Group (WUG) that holds elections every three years to elect its board of administrators, including a chair, secretary, and treasurer.

vii. *Interactions with the block leadership:* a categorical variable of the number of interactions the participant had with the block administrators/WUA in the past 12 months. If they had plots in more than one block, they answered for the block with their most important field. Answers were in intervals of [never; 1-3; 4-6; 7-9;10 or more].

viii. *Interactions with UWAMKI:* a categorical variable of the number of interactions the participant had with UWAMKI, the board of directors of the scheme, in the past 12 months. The answers were offered in intervals of [never; 1-3; 4-6; 7-9;10 or more].

ix. *Disputes:* a count variable of the number of water-related disputes the participant reported having with another scheme member in the past 12 months. These may be related to irrigation (timing, quantity), water infrastructure, maintenance, payments, or other water-related issues. Many actors may be involved: neighbour farms, households from the village, administrators of the irrigation scheme, etc.

First, to compare in-game and real-life behaviour, we run the following model:

$$Y_i = \beta_0 + \beta_1 PGG_i + \Gamma' X + \upsilon + \varepsilon \qquad (11)$$

Where Y_i is one of the nine cooperation variables from the list above (*Paid Bills*, *Contributed*, etc.). If the dependent variable is binary, we run a probit model; if it is a count variable, we run a Poisson model; if it is a continuous variable, we run an OLS model; and if it is an interval variable, we run an interval regression[10]. β_0 is the constant, PGG_i is the average contribution of i to the public account over the four rounds of the PGG, X is a vector of individual controls (social and risk preferences, age, wealth, etc.). Finally, υ are blocks fixed effects, and ε is the error term. *Table 11* shows the results.

The main variable of interest in these models is the average contribution to the public account in the game, which we use as a proxy for the player's level of cooperation. In *Table 11*, the following variables show no significant relationship with average contribution: whether the participant paid their water bills in full in either season, whether they contributed any cash or labour, the total amount of cash contributed over the past 12 months, and whether they voted in the last election.

The variables statistically significantly related to in-game contribution are: labour contributed (negative), interactions with the block leadership and UWAMKI (both positive), and the number of disputes (positive). In column (4), we see that when farmers increase their average contribution by 100 TZS (=CAD$ 0.06), they decrease, on average, labour contributed by 0.3 days of labour,

[10] Interval regressions are done using the *intreg* command on Stata.

statistically significant at the 1% level. The more players contribute monetarily in the game, the less labour they contribute in real-life. This negative relationship might reflect the substitutability between labour and monetary contributions. Farmers might perceive these two forms of contributions as substitutes for each other, meaning that monetary contributions can replace labour contributions or vice versa. In the game, players are restricted to contributing money for the group's interest, so players that value money over labour will contribute a lot in the game but not provide labour in real-life. Similarly, players that value labour contributions more than monetary assistance might not give monetarily in the game; but in real life, they are willing to provide labour for the group's interest.

Interactions with the block leadership (also called WUA) and UWAMKI (also called WUG) have a significant positive relationship with average contribution, as shown in columns (7) and (8). An increase of 100 TZS in average contribution leads to an average increase of 1.1 interactions with the block leadership and 1.2 interactions with UWAMKI in the past 12 months, both significant at the 1% level. We assume that the higher the number of interactions, the more cooperative the participant, as they show a willingness to communicate and interact with administrators. A person who did not interact with administrators might be unproblematic but might also not communicate regularly, leading us to think they are less cooperative.

Finally, in column (9), as farmers increase their average contribution by 100 TZS, they have, on average, 0.1 fewer water-related disputes ($p<0.05$). The more disputes a person has, the less cooperative (or, instead, more competitive) we assume they are. This coefficient suggests that farmers who are more cooperative in the game are also more cooperative in real life because they had fewer disputes.

We can split the nine cooperation variables into two groups: cash-based and social cooperation variables. The first group includes five variables that reveal monetary or cash-based cooperation, in columns (1) to (5), e.g., if they paid their bills (for the long rain or short rainy season), if they contributed cash or labour, and how many days of labour and cash they contributed to canal maintenance. The second group includes four variables that reveal social-based cooperation or cooperation not based on money, in columns (6) to (9), e.g., if they voted, their number of interactions with the WUA and WUG, and disputes.

In Table *11*, we see that most social cooperation variables have a statistically significant relationship with average contribution, while most cash-based cooperation variables do not. Due to the large number of outcome variables we examine in Table *11*, we correct for multiple hypothesis testing by measuring the sharpened False Discovery Rate (FDR) q-values (Anderson, 2008). The FDR is the expected proportion of false rejections (type I errors). The sharpened q-values do not differ greatly from the p-values, as seen in Table *11*, meaning the results are robust: social cooperation variables have more significant relationships with average contribution than cash-based cooperation ones.

Table 11. Explaining real-life cooperation with cooperation displayed in a game.

VARIABLES	(1) Paid bills (LR)	(2) Paid bills (SR)	(3) Contributed any cash or labour	(4) Days of labour contributed	(5) Total cash given	(6) Voted in past election	(7) Interactions with block leadership	(8) Interactions with UWAMKI	(9) Number of disputes
Average Contribution	-0.000442	-3.40e-05	0.000515	-0.00323***	-48.41	-0.000512	0.0113***	0.0125***	-0.00150**
	(0.000767)	(0.000757)	(0.00133)	(0.000903)	(38.26)	(0.000768)	(0.00237)	(0.00220)	(0.000687)
P-value	*0.564*	*0.964*	*0.699*	*0.00*	*0.207*	*0.505*	*0.00*	*0.00*	*0.029*
Sharpened q-value	*0.594*	*0.75*	*0.594*	*0.001*	*0.262*	*0.594*	*0.001*	*0.001*	*0.046*
Risk Loving	-0.377**	-0.282	-0.102	0.0264	2,035	0.306	0.259	0.907*	-0.131
	(0.184)	(0.179)	(0.351)	(0.214)	(10,241)	(0.190)	(0.511)	(0.474)	(0.173)
Extreme Risk Averse	-0.120	-0.115	-0.216	0.00496	-13,163**	0.0674	0.910**	1.259***	0.0381
	(0.144)	(0.140)	(0.234)	(0.184)	(5,132)	(0.144)	(0.420)	(0.386)	(0.133)
Socially Inefficient	-0.0182	-0.161	0.0540	0.234	2,286	-0.0556	0.0802	-0.418	0.113
	(0.177)	(0.174)	(0.266)	(0.151)	(5,129)	(0.175)	(0.518)	(0.470)	(0.174)
Anti-Social	0.0448	-0.0891	0.393	0.283	6,541	0.371*	-0.272	-0.606	0.130
	(0.199)	(0.193)	(0.332)	(0.208)	(7,698)	(0.197)	(0.576)	(0.528)	(0.194)
Male Dummy	-0.356***	-0.174	0.425*	-0.00203	-4,218	0.0530	1.376***	1.353***	0.0885
	(0.138)	(0.133)	(0.243)	(0.139)	(5,513)	(0.138)	(0.376)	(0.346)	(0.128)
Age	-0.00759	-0.00798	-0.0286***	0.000372	90.67	0.00379	-0.0191	-0.00827	-0.00837
	(0.00529)	(0.00510)	(0.00951)	(0.00539)	(227.3)	(0.00543)	(0.0143)	(0.0135)	(0.00512)
Proportion of dependents	0.393	0.173	0.334	-0.0395	-6,881	0.0918	-0.220	0.281	0.645**
	(0.287)	(0.274)	(0.476)	(0.273)	(12,990)	(0.291)	(0.773)	(0.712)	(0.285)
=1, in richest quartile	-0.167	-0.0439	-0.284	0.162	11,324*	0.228	0.304	0.209	0.199
	(0.160)	(0.157)	(0.247)	(0.180)	(6,619)	(0.163)	(0.479)	(0.445)	(0.137)
=1, in poorest quartile	0.00593	-0.0628	-0.346	-0.309	-4,504	-0.560***	-0.250	0.0755	-0.0530
	(0.170)	(0.164)	(0.295)	(0.193)	(4,807)	(0.172)	(0.458)	(0.437)	(0.164)
=1, if any education	-0.0311	0.0748	-0.372	0.447	-6,683	0.188	0.0761	0.573	-0.137
	(0.282)	(0.270)	(0.420)	(0.358)	(6,767)	(0.266)	(0.712)	(0.697)	(0.279)
=1, if completed primary education	0.00969	-0.0104	0.0664	-0.223	10,496*	0.149	-0.0325	-0.300	0.105
	(0.238)	(0.232)	(0.376)	(0.332)	(6,117)	(0.225)	(0.618)	(0.600)	(0.215)
Constant	1.172***	1.133***	2.694***	1.564***	13,440	-0.617	1.194	-0.789	-0.176

	(0.418)	(0.414)	(0.727)	(0.350)	(17,151)	(0.421)	(1.143)	(1.037)	(0.397)
Ln(Sigma)							1.279***	1.200***	
							(0.0437)	(0.0472)	
Blocks FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	447	453	291	402	355	433	446	446	407
adj. R^2/ Pseudo R^2	0.0487	0.0292	0.1207	0.1607	0.131	0.1137	/	/	0.0342

Robust standard errors in parentheses. Models (1), (2), (3) and (6) are probit models. Models (4) and (9) Poisson models. Models (7) and (8) are interval regression models. Model (5) is an OLS model. For the risk preferences variables of risk loving and risk-averse, the coefficients are relative to the base variable of risk-averse. For the social preference variables of socially inefficient and anti-social, the coefficients are relative to the base variable of pro-social. Anderson's sharpened q-values are computed to control for False Discovery Rate when testing multiple hypotheses (Anderson, 2008).
*** p<0.01, ** p<0.05, * p<0.1

Index of cooperation

To get a better sense of cooperation, we created a few cooperation indices. First, we created a general cooperation index including all nine cooperation variables shown separately above in each column of Table *11*. This index ranges from 0 (not cooperative at all) to 8 (very cooperative). Next, we created a cash-based cooperation index that takes a value between 0 and 5. Finally, we created a social cooperation index that takes a value between 0 to 4. Appendix A.2: Construction of cooperation indices includes more details on how these indices were made.

We regress the three cooperation indices on average contribution, with the previous control variables (i.e., risk preferences, social preferences, gender, age, wealth, etc.), blocks fixed effects and robust standard errors. *Table 12* shows the results of this regression. In column (1), the average contribution has no explanatory power for the general cooperation index. But farmers in the poorest (fourth) quartile have an index of general cooperation that scores, on average, 0.43 points lower than farmers in the second and third quartiles ($p<0.05$).

In column (2), we find no correlation between *cash-based* cooperation and average contribution. However, risk-lovers and extremely risk-averse players have an index score for cash-based cooperation that is, respectively and on average, 0.28 and 0.20 points lower than normal risk-averse individuals, albeit only statistically significant at the 10% level. Males tend to score 0.28 points lower than females ($p<0.05$), and age has a negative effect on the score, decreasing by 0.009 points per year ($p<0.05$). We find that people in the poorest (fourth) quartile have a cash-based cooperation score that is 0.22 points lower than people in the second and third wealth quartiles (p<0.1). These results suggest that poorer households, older respondents, and male respondents contributed less financially than their counterparts.

In column (3), we regress the *social* cooperation index on average contribution. Here, as a player increases their average contribution by 100 TZS, their social cooperation score increase, on average, by 0.25 points (p<0.01). Risk lovers score 0.24 points higher than risk-averse people (p<0.1). Males tend to have a higher social cooperation score than females by 0.32 points (p<0.01). Men tend to be more socially collaborative (p<0.05) but less financially cooperative (p<0.1) than women. The results in Table *12* suggest that the PGG is better at explaining and measuring social cooperation than cash-based cooperation.

Table 12. Explaining cash-based and social cooperation through the public goods game.

VARIABLES	(1) General Cooperation Index	(2) Cash-based Cooperation Index	(3) Social Cooperation Index
Average contribution	0.00151	-0.00102	0.00253***
	(0.000946)	(0.000634)	(0.000624)
Risk-Loving	-0.0412	-0.283*	0.242*
	(0.199)	(0.157)	(0.141)
Extremely Risk-Averse	-0.0286	-0.203*	0.174
	(0.172)	(0.117)	(0.115)
Socially Inefficient	-0.0946	0.111	-0.206
	(0.214)	(0.144)	(0.143)
Anti-Social	-0.0953	0.0471	-0.142
	(0.223)	(0.156)	(0.154)
Male	0.0510	-0.276**	0.327***
	(0.160)	(0.114)	(0.104)
Age	-0.00953	-0.00912**	-0.000411
	(0.00603)	(0.00415)	(0.00399)
Proportion of dependents	-0.0715	0.128	-0.199
	(0.309)	(0.212)	(0.200)

=1, in richest quartile	0.125	0.0152	0.110
	(0.198)	(0.136)	(0.127)
=1, in poorest quartile	-0.434**	-0.223*	-0.210
	(0.186)	(0.126)	(0.133)
=1, had any education	0.329	0.0896	0.239
	(0.301)	(0.226)	(0.207)
=1, completed primary education	-0.166	-0.0977	-0.0686
	(0.245)	(0.187)	(0.171)
Constant	4.167***	3.327***	0.840***
	(0.484)	(0.342)	(0.316)
Blocks FE?	Yes	Yes	Yes
Observations	457	457	457
R-squared	0.078	0.076	0.160

Robust standard errors in parentheses. For the risk preferences variables of risk loving and risk-averse, the coefficients are relative to the base variable of risk-averse. For the social preference variables of socially inefficient and anti-social, the coefficients are relative to the base variable of pro-social.
*** p<0.01, ** p<0.05, * p<0.1

4.2.4. Robustness of Results

To check the robustness of the results in *Table 11*, we run the model in equation (11) with every cooperation variable again (*Paid Bills*, *Contributed*, etc.), but this time using OLS models only; except for the categorical variables in columns (7) and (8) where we run an interval regression[11]. The model has robust standard errors and blocks fixed effects. *Table 13* shows the results. We find similar coefficients and statistical significance as in *Table 11*, though they are different regression models, thus showing that the coefficients are robust. To test for multiple hypotheses, we again ran sharpened q-values following Anderson (2008). The q-values are similar to the original p-values, showing the robustness of the results. For another test of robustness, we run the same model as above in equation (11) to compare in-game and real-life cooperation, but this time without block

[11] Interval regressions are done using the *intreg* command on Stata. Interval regression is used again here, because an OLS model cannot be used with interval variables.

fixed effects. The results are in *Table 14*. We find similar statistically significant coefficients of interest, which shows that the coefficients are robust.

Table 13. Comparing real-life and in-game cooperation using mainly OLS models.

VARIABLES	(1) Paid bills (LR)	(2) Paid bills (SR)	(3) Contributed any cash or labour	(4) Days of labour contributed	(5) Total cash given	(6) Voted in past election	(7) Interactions with block leadership	(8) Interactions with UWAMKI	(9) Number of disputes
Average Contribution	-0.000147	-2.02e-05	0.000123	-0.0141***	-48.41	-0.000162	0.0113***	0.0125***	-0.00112**
	(0.000262)	(0.000278)	(0.000234)	(0.00531)	(38.26)	(0.000276)	(0.00237)	(0.00220)	(0.000534)
P-value	*0.577*	*0.942*	*0.598*	*0.008*	*0.207*	*0.557*	*0.00*	*0.00*	*0.036*
Sharpened q-value	*0.594*	*0.721*	*0.594*	*0.02*	*0.262*	*0.594*	*0.001*	*0.001*	*0.058*
Risk Loving	-0.126*	-0.102	-0.0166	0.0545	2,035	0.106	0.259	0.907*	-0.0917
	(0.0668)	(0.0680)	(0.0514)	(0.996)	(10,241)	(0.0668)	(0.511)	(0.474)	(0.117)
Extreme Risk Averse	-0.0379	-0.0393	-0.0376	0.104	-13,163**	0.0240	0.910**	1.259***	0.0306
	(0.0482)	(0.0501)	(0.0389)	(0.830)	(5,132)	(0.0525)	(0.420)	(0.386)	(0.102)
Socially Inefficient	-0.0127	-0.0585	0.00541	0.839	2,286	-0.0181	0.0802	-0.418	0.0824
	(0.0607)	(0.0613)	(0.0453)	(0.583)	(5,129)	(0.0657)	(0.518)	(0.470)	(0.119)
Anti-Social	0.0149	-0.0294	0.0387	0.924	6,541	0.128*	-0.272	-0.606	0.0967
	(0.0677)	(0.0681)	(0.0488)	(0.878)	(7,698)	(0.0711)	(0.576)	(0.528)	(0.131)
Male Dummy	-0.118**	-0.0603	0.0496	0.0888	-4,218	0.0210	1.376***	1.353***	0.0603
	(0.0467)	(0.0485)	(0.0395)	(0.712)	(5,513)	(0.0491)	(0.376)	(0.346)	(0.0958)
Age	-0.00247	-0.00281	-0.00368**	0.00309	90.67	0.00105	-0.0191	-0.00827	-0.00611
	(0.00179)	(0.00188)	(0.00151)	(0.0223)	(227.3)	(0.00189)	(0.0143)	(0.0135)	(0.00391)
Proportion of dependents	0.121	0.0613	0.0403	0.0334	-6,881	0.0268	-0.220	0.281	0.462**
	(0.100)	(0.101)	(0.0862)	(1.264)	(12,990)	(0.101)	(0.773)	(0.712)	(0.200)
=1, in richest quartile	-0.0547	-0.0129	-0.0293	0.779	11,324*	0.0725	0.304	0.209	0.151
	(0.0551)	(0.0570)	(0.0396)	(1.015)	(6,619)	(0.0568)	(0.479)	(0.445)	(0.112)

=1, in poorest quartile	0.00296	-0.0214	-0.0532	-0.928	-4,504	-0.203***	-0.250	0.0755	-0.0311
	(0.0551)	(0.0579)	(0.0464)	(0.672)	(4,807)	(0.0612)	(0.458)	(0.437)	(0.110)
=1, if any education	-0.00962	0.0301	-0.0598	1.867	-6,683	0.0730	0.0761	0.573	-0.0872
	(0.0926)	(0.0987)	(0.0792)	(1.930)	(6,767)	(0.0941)	(0.712)	(0.697)	(0.186)
=1, if completed primary education	0.000744	-0.00540	0.0116	-1.215	10,496*	0.0491	-0.0325	-0.300	0.0618
	(0.0786)	(0.0850)	(0.0690)	(1.880)	(6,117)	(0.0782)	(0.618)	(0.600)	(0.145)
Constant	0.916***	0.911***	1.061***	5.112***	13,440	0.306**	1.194	-0.789	0.860***
	(0.138)	(0.148)	(0.113)	(1.434)	(17,151)	(0.154)	(1.143)	(1.037)	(0.284)
Ln(Sigma)							1.279***	1.200***	
							(0.0437)	(0.0472)	
Observations	457	457	327	402	355	443	446	446	407
R-squared	0.067	0.041	0.076	0.142	0.131	0.154			0.073
Blocks FE?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses. Model used is the OLS model except for columns (7) and (8) which are interval regression models since the dependent variable is categorical and so cannot be used in an OLS model. Anderson's sharpened q-values are computed to control for False Discovery Rate when testing multiple hypotheses (Anderson, 2008).

*** p<0.01, ** p<0.05, * p<0.1

Table 14. Explaining real-life cooperation with cooperation displayed in a game, without controlling for block membership.

VARIABLES	(1) Paid bills (LR)	(2) Paid bills (SR)	(3) Contributed any cash or labour	(4) Days of labour contributed	(5) Total cash given	(6) Voted in past election	(7) Interactions with block leadership	(9) Interactions with UWAMKI	(11) Number of disputes
Average Contribution	-0.000382	6.83e-05	0.000496	-0.00340***	-58.01	-0.000510	0.0112***	0.0119***	-0.00148**
	(0.000755)	(0.000742)	(0.00126)	(0.000900)	(39.37)	(0.000756)	(0.00231)	(0.00214)	(0.000656)
P-Value	*0.613*	*0.927*	*0.694*	*0.000*	*0.142*	*0.500*	*0.000*	*0.000*	*0.024*
Sharpened q-value	*0.532*	*0.701*	*0.532*	*0.001*	*0.166*	*0.500*	*0.001*	*0.001*	*0.038*
Risk Loving	-0.374**	-0.279	-0.116	-0.0759	704.1	0.269	0.213	0.849*	-0.216
	(0.180)	(0.175)	(0.323)	(0.244)	(10,100)	(0.185)	(0.516)	(0.482)	(0.172)
Extreme Risk Averse	-0.149	-0.109	-0.252	-0.0250	-11,974**	0.0517	0.800*	1.160***	-0.0172
	(0.143)	(0.138)	(0.232)	(0.181)	(4,766)	(0.140)	(0.416)	(0.387)	(0.133)
Socially Inefficient	-0.00221	-0.137	0.0605	0.330**	259.6	-0.0232	0.0398	-0.505	0.138
	(0.173)	(0.172)	(0.254)	(0.160)	(5,167)	(0.170)	(0.523)	(0.492)	(0.172)
Anti-Social	0.0703	-0.0842	0.272	0.396**	7,297	0.427**	-0.276	-0.412	0.142
	(0.195)	(0.190)	(0.315)	(0.199)	(7,797)	(0.191)	(0.569)	(0.541)	(0.191)
Male Dummy	-0.345**	-0.186	0.288	0.0279	-495.0	0.142	1.372***	1.476***	0.104
	(0.134)	(0.131)	(0.235)	(0.161)	(5,421)	(0.131)	(0.378)	(0.351)	(0.129)
Age	-0.00670	-0.00653	-0.0246***	0.000604	40.93	0.00381	-0.0156	-0.00684	-0.00941*
	(0.00518)	(0.00502)	(0.00930)	(0.00575)	(221.2)	(0.00510)	(0.0143)	(0.0138)	(0.00542)
Proportion of dependents	0.398	0.174	0.187	-0.0116	-5,851	0.0832	-0.266	0.321	0.624**
	(0.285)	(0.274)	(0.446)	(0.261)	(11,982)	(0.276)	(0.772)	(0.741)	(0.297)
=1, in richest quartile	-0.164	-0.0609	-0.300	0.175	12,182	0.235	0.398	0.392	0.184
	(0.152)	(0.151)	(0.235)	(0.197)	(7,625)	(0.153)	(0.479)	(0.432)	(0.143)
=1, in poorest quartile	-0.00715	-0.0119	-0.352	-0.497**	-8,574*	-0.614***	-0.242	0.112	-0.0951
	(0.167)	(0.160)	(0.273)	(0.215)	(4,362)	(0.162)	(0.441)	(0.424)	(0.160)
=1, if any education	0.0110	0.0767	-0.204	0.665**	-59.01	0.305	-0.131	0.497	-0.0926
	(0.272)	(0.260)	(0.401)	(0.326)	(5,505)	(0.256)	(0.711)	(0.701)	(0.260)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
=1, if completed primary education	-0.0462	-0.0132	-0.00662	-0.403	8,738	0.0974	0.202	-0.109	0.0599
	(0.225)	(0.222)	(0.345)	(0.301)	(5,584)	(0.211)	(0.627)	(0.615)	(0.199)
Constant	1.065***	0.863**	2.555***	1.706***	23,331*	-0.442	1.291	-0.487	-0.0239
	(0.396)	(0.387)	(0.704)	(0.362)	(13,698)	(0.396)	(1.085)	(1.007)	(0.383)
Ln(Sigma)							1.304***	1.232***	
							(0.0445)	(0.0473)	
Observations	457	457	327	402	355	443	446	446	407
adj. R^2/Pseudo R^2	0.033	0.014	0.081	0.093	0.058	0.081			0.018
Blocks FE?	No	No	No	No	No	No	No	No	No

Robust standard errors in parentheses. Models (1), (2), (3) and (6) are probit models. Models (4) and (9) Poisson models. Models (7) and (8) are interval regression models. Model (5) is an OLS model. For the risk preferences variables of risk loving and risk-averse, the coefficients are relative to the base variable of risk-averse. For the social preference variables of socially inefficient and anti-social, the coefficients are relative to the base variable of pro-social. Anderson's sharpened q-values are computed to control for False Discovery Rate when testing multiple hypotheses (Anderson, 2008).

*** p<0.01, ** p<0.05, * p<0.1

5. Chapter 5: Discussion Chapter

5.1. Summary of Results

This study examines how risk influences farmers' willingness to cooperate, as measured by a PGG with contributions to private and public accounts. We find that when there is a risk to a public resource in the game, players decrease their contribution to the public account the most, statistically significant at the 1% level. Extremely risk-averse and socially inefficient farmers reduce their cooperation the most in those rounds when public resources are at stake.

We also find that contributions in the game are significantly and positively correlated with a social cooperation index we created but not with a cash-based cooperation index. More specifically, we find that in-game contribution is significantly and positively correlated with the number of interactions a member has with administrators of the Water User Association and the Water User Group, and negatively correlated with days of labour provided for the maintenance of the scheme and the number of water-related disputes.

5.2. Heterogeneity Analysis

5.2.1. By Gender, Education, and Wealth

In this section, we look at the heterogeneity in behaviour in the PGG by gender, education, wealth and block membership. To do this, we run the following model:

$$Contribution_i = \beta_0 + \beta_1 RoundB_i + \beta_2 RoundC_i + \beta_3\ RoundD_i + (\beta_4 RoundB_i \times M_i) + (\beta_5 RoundC_i \times M_i) + (\beta_6 RoundD_i \times M_i) + \varepsilon \tag{11}$$

Where $Contribution_i$ is the amount contributed to the public account, $RoundB_i$, $RoundC_i$, $RoundD_i$ are indicator variables for rounds B, C, and D, respectively. Here, M_i is a binary variable equal to 1 if participant i is a male, 0 if a female.

The results for gender are presented in *Table 15*, column (1). We see that the average contribution is 51.14 TZS less in Round B than in Round A, statistically significant at the 1% level. In Round C, males contribute 19.97 TZS lower than females, statistically significant at the 10% level. This higher contribution of women in Round C matches other results in the literature, where research has found that women tend to be more cooperative in the PGG (Hil & Gurven, 2005). It is also worth noting that the analysis of results for this whole study is done at the individual level and not at the household level. Though memberships to the scheme are at an individual level, we assume that a member is the only one of their household to contribute to the scheme, but that may not be true as other household members can provide help. Additionally, two members of the same household can own separate plots and be members of the scheme. This point is particularly interesting when considering the gender differences in *Table 12* and *Table 13*. We find that men are generally more socially cooperative, while women are more financially cooperative in the scheme. If we think about these differences at the individual level, they appear as opposites of each other; but in the context of a household with a male and female scheme member, these divisions of labour complement each other.

Next, we test for education effects, presented in *Table 15*, columns (2) and (3). Similar to equation (11), we first interact the indicator variable for each round with a binary variable equal to 1 if participant *i* completed primary education (equal to seven years in Tanzania), 0 otherwise. Then, we interact with another binary variable equal to 1 if the participant *i* received any years of education, 0 otherwise. Overall, we find no education effect. Farmers who completed primary school do not behave statistically differently from their counterparts (column 2), nor do farmers who received any years of education (column 3). Once again, we consistently find a decrease in contribution in Round B, as we originally found in Table *8*.

Table 15. Gender effect in contributions.

VARIABLES	(1) Contribution to public account	(2) Contribution to public account	(3) Contribution to public account
Round B	-31.17***	-31.91**	-33.37**
	(9.679)	(13.49)	(16.95)
Round C	18.63*	11.73	16.63
	(9.798)	(14.07)	(18.00)
Round D	-1.705	2.115	3.196
	(9.127)	(13.40)	(16.91)
Round B x Male	-8.921		
	(11.78)		
Round C x Male	-19.97*		
	(11.87)		
Round D x Male	-14.28		
	(10.64)		
Round B x Primary Education		-4.651	
		(13.94)	
Round C x Primary Education		-3.518	
		(14.49)	

Round D x Primary Education		-13.95	
		(13.46)	
Round B x Any Education			-2.434
			(17.17)
Round C x Any Education			-8.863
			(18.21)
Round D x Any Education			-13.74
			(16.88)
Constant	240.1***	240.1***	240.1***
	(5.689)	(5.689)	(5.689)
Observations	1,849	1,849	1,849
Number of Players	463	463	463
R-squared	0.021	0.019	0.019

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

To see if there are wealth effects, we run a similar model as in equation (11), but this time we interact the indicator variables for each round with a binary variable of whether the participant was in the richest or poorest quartile. Results are presented in Table *16*. Farmers in the wealthiest quartile decrease their contribution by, on average, 17.44 TZS in Round B compared to Round A, statistically significant at the 10% level. But, compared to farmers in other wealth quartiles, wealthier farmers contributed the most in Round B, as they contributed 24.1 TZS more than others, with 10% statistical significance. On the other hand, farmers in the poorest quartile contributed on average 60.26 TZS less in Round B compared to Round A, which is 32.9 TZS less in Round B than farmers in all other quartiles, with 5% statistical significance. Overall, there is a modest wealth effect where wealthier farmers decrease their contribution the least when there is a risk to a public resource, but poorer farmers decrease their contribution the most. This is to be expected because wealthier farmers need not worry as much as poorer farmers about potentially making a loss when contributing to the public account. Other studies with the PGG have found the other way around, that the rich always contribute less (Hargreaves Heap et al., 2016), though another study finds no correlation (Bluffstone et al., 2020).

Table 16. Wealth effects on the contribution by round.

VARIABLES	(1) Contribution to the public account	(2) Contribution to the public account
Round B	-41.53***	-27.37***
	(8.792)	(8.652)
Round C	13.08	10.63
	(9.013)	(8.657)
Round D	-5.839	-7.373
	(8.345)	(8.067)
Round B x Wealthiest Quartile	24.09*	
	(13.73)	
Round C x Wealthiest Quartile	-16.10	
	(13.09)	
Round D x Wealthiest Quartile	-10.74	
	(12.34)	
Round B x Poorest Quartile		-32.89**
		(14.36)
Round C x Poorest Quartile		-6.418
		(14.98)
Round D x Poorest Quartile		-4.838
		(13.87)
Constant	240.1***	240.1***
	(5.689)	(5.689)
Observations	1,849	1,849
Number of Players	463	463
R-squared	0.021	0.022

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2.2. By Block Membership

Next, we look at the effect of block membership since blocks differ significantly in infrastructure (Blocks A and B have cemented, lined canals; Blocks C and D have surface, hand-dug canals). To do so, we interact rounds with all indicator variables for block membership in Table *17*. We see a very modest effect of block membership. Participants from Block D have contributions in Round C that are, on average, 40.19 TZS lower than other members, statistically significant at the 10% level. This is interesting because, in Round C, private resources are at risk, so we expect people to contribute more to the safe public account, but we do not find that here. Again, we find a significant decrease in contribution in Round B, which is consistent with the results in Table *8*.

Table 17. Block membership effect on contribution by round.

VARIABLES	(1) Contribution to public account	(2) Contribution to public account	(3) Contribution to public account	(4) Contribution to public account
Round B	-36.40***	-33.84***	-34.29***	-37.04***
	(8.689)	(8.322)	(9.289)	(8.238)
Round C	7.212	11.05	11.27	12.26
	(8.689)	(8.327)	(9.300)	(8.243)
Round D	-9.036	-6.146	-5.107	-6.871
	(8.696)	(8.327)	(9.289)	(8.243)
Round B x Block A	6.679			
	(13.23)			
Round C x Block A	6.080			
	(13.27)			
Round D x Block A	1.248			
	(13.23)			
Round B x Block B		-7.779		
		(17.61)		
Round C x Block B		-19.94		
		(17.62)		
Round D x Block B		-21.84		
		(17.62)		
Round B x Block C			-1.192	
			(11.62)	
Round C x Block C			-6.477	

			(11.63)	
Round D x Block C			-9.154	
			(11.64)	
Round B x Block D				19.93
				(21.00)
Round C x Block D				-40.19*
				(21.00)
Round D x Block D				-21.05
				(21.00)
Constant	239.8***	239.8***	239.8***	240.1***
	(5.717)	(5.713)	(5.717)	(5.719)
Observations	1,857	1,857	1,857	1,849
R-squared	0.018	0.019	0.018	0.021

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2.3. Checking for Order Bias

Finally, we check for any order bias, in other words, if the order in which players played the games has any effect on their contributions to the public account. Recall that Round A was always played first to allow participants to get familiar with the game. Then rounds B to D and the altruism game were played in a random order, hence why rounds B, C or D could be played fifth. To check for an order bias, we run the following OLS models:

$$Y_i = \beta_0 + \beta_1 Order\_3_i + \beta_2\ Order\_4_i + \beta_3 Order\_5_i + \varepsilon \tag{12}$$

Where Y_i is a contribution variable, such as contribution in Round B, C, or D of the PGG. $Order\_3_i$ is an indicator variable equal to 1 if the round in question was played third, $Order\_4_i$ is an indicator variable if the round in question was played fourth, and $Order\_5_i$ is an indicator variable if the round in question was played fifth. Lastly, ε is the error term. Note that there is no indicator variable for the first round played since Round A was always played first. Furthermore, all the coefficients are relative to the contribution in the round played second. The results of these models are shown in Table *18*.

Table 18. Estimating order bias (effect of playing in a certain order).

VARIABLES	(1) Contribution in Round B	(2) Contribution in Round C	(3) Contribution in Round D
Played Second	-	-	-
Played Third	-7.846	-28.38*	-32.76**
	(15.36)	(17.20)	(16.07)
Played Fourth	5.988	-22.56	-21.86
	(16.86)	(17.30)	(13.96)
Played Fifth	-4.135	-11.44	-6.150
	(17.01)	(16.78)	(15.75)
Constant	206.8***	264.2***	245.9***
	(10.98)	(12.43)	(10.78)
Observations	465	464	464
R-squared	0.002	0.007	0.011

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

We find a modest order effect. Participants tend to contribute 28.38 TZS less in Round C when it was played third, compared to when it was played second, significant at the 10% level. Additionally, participants contribute 32.76 TZS less in Round D, when that round was played third, compared to when it was played second, significant at the 5% level. Overall, these results modestly suggest that participants tend to contribute less in the third round they played.

5.3. Discussion of Results

In this section, we discuss the implications of our results, as well as some limitations in our game design.

5.3.1. Implications from In-Game Behaviour

As mentioned above, we find that when the public account is at risk, players decrease their contribution significantly. Given that the money in the game is hypothetical, we suspect we are capturing the lower bound of this decrease. There is no monetary consequence to players' choices in the game, yet we capture a reaction to public risks that is highly statistically significant. Additionally, there might be self-selection of participants, as the participants who decide to share their time with enumerators might have more time and/or be willing to meet with strangers to benefit this study, so participants might already be more inclined to contribute to a public good. This would put a positive bias in our results; however, since we sampled 470 members out of 576, we do not suspect this self-selection bias to be significant.

This study aims to understand whether increased water scarcity, a shared resource, leads to competition or cooperation between irrigated farmers. This question has been left open and unanswered by the literature. One of the challenges to answering this question is that there is no universal measure of water scarcity, and many empirical challenges to measuring it. As such, authors have different measures for water scarcity, namely, self-evaluated measures (Ito, 2012), cropping intensity (Araral, 2009), historical water-quotas (Nie et al., 2020), number of months with access to water and propensity to have lined canals (Bardhan, 1993). Araral (2009) finds a curvilinear relationship between scarcity and cooperation where cooperation collapses when there is severe water scarcity in irrigation schemes, but cooperation is prevalent under moderate scarcity. Other studies find a linear relationship where higher water scarcity enhances cooperation (Ito, 2012; Nie et al., 2020). Here, we use an experimental game where we put risks to in-game resources to mimic real-life resource scarcity. We find that scarcity of shared resources leads to less social cooperation. However, our measure of scarcity is not continuous and is, in fact, binary. Depending on the round, shared resources and/or private resources are either completely safe or completely lost since the accounts become zero in Round B, C, and D. So, we compare farmers' behaviour under scarcity versus no scarcity. As such, we might be capturing only the linear trend of a curvilinear relationship between scarcity and cooperation. With these empirical details in mind, we can now discuss the implication of our results.

If we try to extrapolate the behaviour in the game to real life, the fact that farmers decrease their social cooperation when facing a public risk in the game suggests that these farmers might react the same outside of the game, i.e., a shared risk, such as drought or flood, might push farmers to be less socially cooperative in an irrigation scheme, by communicating less with administrators and having more disputes with other scheme members. Considering how climate change is increasing the risk of drought, these results have important policy implications. The behaviour in the game shows that farmers might require an intervention to create or improve incentives and institutions that promote cooperation, particularly social cooperation, between members of irrigation schemes. Such policies and interventions need to consider some important points. First, our results, along with other studies, suggest that these rural farmers are cash-constrained. Although we do not have any data on these farmers' access to financial services, there is strong evidence that financial constraints, such as constraints in credit access (Atube et al., 2021), in market access (Paavola, 2008), and in off-farm income opportunities (Abdulai & CroleRees, 2001) inhibit smallholder, rural African farmers from adopting climate-smart practices. Cash crop farmers, like the rice farmers in our sample, also have a seasonal cash flow which further limits them from investing and adopting climate-smart practices or behaviour (Douxchamps et al., 2016). Cash crop farmers have a higher cash flow during the harvest as they sell their crops, and a lower cash flow when they tend to their plots. Depending on when natural, covariate shocks happen, farmers might be more or less cash-constrained, which is likely to impact their reaction to and ability to recover from such shocks (Douxchamps et al., 2016). Farmers who only grow one crop, which is the case for our sample, where 89% of participants report to be exclusively growing rice, have a cash flow that is particularly vulnerable to shocks.

The second point that policies need to consider is the high degree of risk aversion in our sample, which echoes the results of other studies with rural African farmers (Katic & Ellis, 2018; Yesuf & Bluffstone, 2009). Studies in sub-Saharan Africa have found strong evidence that financially constrained households are less willing to take on risks, both in games (Yesuf & Bluffstone, 2009) and in farm decisions, such as agricultural insurance (Visser et al., 2020) and technology adoption (Harou et al., 2022; Muzari et al., 2012). Riskier choices can bring higher results, such as a higher yield, but can also bring considerable loss, especially financially. As such, cash-constrained farmers are likely to be averse to risk because riskier choices can be costlier. High risk aversion among farmers in developing countries prevents them from making optimal decisions for themselves and their group (i.e., contributing to a public good) and constrains them from reaching their productive potential (Dercon & Christiaensen, 2011). In Tanzania, risk-aversion has been associated with a lower willingness to pay for an improved hybrid maize seed and local inorganic fertilizer (Shee et al., 2020) and lower adoption rates of improved maize (Magnan et al., 2020). Overall, climate change policies need to consider that risk-averting behaviour limits the ability of farmers to make adequate decisions to adapt to climate change. As such, these policies should aim to attenuate this high degree of risk aversion among rural African farmers. Risk reduction options, such as agricultural insurance, could effectively improve social cooperation between farmers inside irrigation schemes.

Finally, the lack of reaction in Round C brings us to our last discussion point on the behaviour inside of the game. In Round C, the logical, risk-averting choice would be to contribute more to the public account, which is safe because the private account runs the risk of becoming zero. However, we do not capture any statistically significant change in Round C. There could be a few reasons why players did not delegate the private risk by contributing their money to the safe public account. The first technical explanation is that the study might be underpowered. The coefficients in Table *8* for Rounds C and D have the correct signs but do not have statistical significance. The sample size might not be large enough, or players might not have understood the game well, which would introduce noise in the measurements. A more behavioural explanation could be that participants in our sample expect the other player to free-ride and not cooperate when private resources are at risk, which turns cooperation into a risky decision. Studies in experimental economics have found evidence that players of the PGG tend to be conditional contributors (Chaudhuri, 2011), meaning they base their contributions based on their own prior beliefs about the behaviour of their peers (Fischbacher et al., 2001; Fischbacher & Gächter, 2010).

5.3.2. On the External Validity of the PGG

We would now like to discuss what our results imply for the general use of the public goods game in economic research. Even when the payouts and second players were hypothetical, which is our main limitation in this study, we still find statistically significant relationships between in-game contribution and real-life social cooperation. This is promising for experimental economics because it shows that though we had limitations in the game's design, the results are still significant and telling. Experimental methods, such as the PGG, are practical for economic research as they strip down and mimic social constructs to enable researchers to study how external institutions impact individual decision-making. However, because games are quite abstract, it is essential to know what games measure and how the context of games impacts the results. Games are not an exact method to measure variables, and we do not claim that the PGG can quantify social cooperation precisely. Nevertheless, it is significantly linked with real-life behaviour. Researchers can use the game to get a general sense of how socially cooperative a person or population is instead of a precise measure of it.

We next discuss why the public goods game captured might have social but not financial cooperation. First, farmers in the sample are cash-constrained, as other studies in the region have shown (Harou et al., 2022; Tamim, 2020). This constraint limits how financially cooperative a member can be since a cash-constrained farmer might be unable to contribute cash or hire labour to maintain the scheme, even if they want to. Members already need to pay seasonal water bills, so cash-constrained farmers might not have a margin left to contribute more to the scheme. Second, paying dues is a rule of the scheme, but social cooperation is voluntary. Therefore, social cooperation could be a more active choice than cash-based cooperation, particularly if one is limited in cash. As such, the game seems to capture this will to be socially cooperative. Third, the fact that the payouts in the game were hypothetical might influence these results. Since players are not playing with real money and, thus, real consequences, the hypothetical aspect of the game might reveal the general personality of players more. Players who are inherently more socially cooperative will decide to be cooperative in the game because doing so does not cost them anything. On the contrary, players whose personality leans towards competitiveness might decide to be uncooperative in the game, even though it does not cost them anything to be cooperative.

6. Chapter 6: Conclusion

The present study played economic games with 470 members of the Mkindo irrigation scheme in Morogoro, Tanzania, to analyze how farmers' cooperation changes in the face of risk and to test the external validity of the public goods game. We find that when players risk losing public resources, they significantly decrease their contribution and, thus, willingness to cooperate. However, we find no statistically significant behavioural change when they risk losing private resources. We also find that the PGG is externally valid at measuring social cooperation but not cash-based cooperation.

The main limitation of our study is that the money and the second player in the game were hypothetical because of concerns for fairness, anonymity, and physical constraints. This introduces a hypothetical bias in the answers, which we mitigated with "cheap talk" (Cummings & Taylor, 1999) before the start of the study and using the answers from participants who had already played as the answers of the second hypothetical player. Because players faced no real consequences to how they played in the game, our coefficients might capture the lower bound of the effect of public resource scarcity on cooperation. Our results are promising for the field of experimental economics, as they provide reassurance that the PGG is externally valid and insightful for economic analyses.

Cooperation within an irrigation scheme is crucial for its proper functioning, and larger schemes need organization and governance to ensure that the infrastructure is maintained and clean. However, while some members clean and maintain the system, others may free-ride and still benefit from a functioning irrigation system. The results of our study suggest that as farmers face more covariate risks, such as droughts or floods that impact public resources for all, they are likely to decrease their willingness to cooperate socially, i.e., resolve water-related disputes, interact with administrators by going to meetings, etc. This has important policy implications, particularly for regions facing water scarcity due to climate change, because the results reveal that shocks to water resources may lead to farmers decreasing their willingness to cooperate, at least socially, to maintain their irrigation scheme. This suggests that irrigation systems facing water scarcity must also support and promote socially cooperative behaviour.

Future research can explore what kind of tools, policies, and institutions is most effective, in this population or elsewhere, to promote social cooperation between irrigated farmers, particularly in schemes facing water scarcity and in developing nations where the potential of irrigated farming has not been fully tapped into yet. Also, more research is needed to know which risk-reducing option is most effective and available to rural farmers in sub-Saharan Africa. For example, agricultural insurance, particularly weather-based or crop insurance, could reduce the risks of shared shocks, thereby maintaining social cooperation between members. Finally, our results reveal gender differences in how a member cooperates, but more research can be done to study gender-based divisions of labour among irrigated farmers and gender-based reactions to water scarcity.

References

Abdulai, A., & CroleRees, A. (2001). Determinants of income diversification amongst rural households in Southern Mali. *Food Policy*, *26*(4), 437–452. https://doi.org/10.1016/S0306-9192(01)00013-6

Abernethy, C. L. (2010). Governance of irrigation systems: Does history offer lessons for today? *Irrigation and Drainage*, *59*(1), 31–39. https://doi.org/10.1002/ird.552

Adhikari, U., Nejadhashemi, A. P., Herman, M. R., & Messina, J. P. (2017). Multiscale assessment of the impacts of climate change on water resources in Tanzania. *Journal of Hydrologic Engineering*, *22*(2). Scopus. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001467

Adhikari, U., Nejadhashemi, A. P., & Woznicki, S. A. (2015). Climate change and eastern Africa: A review of impact on major crops. *Food and Energy Security*, *4*(2), 110–132. https://doi.org/10.1002/fes3.61

Adong, A., Tinker, J., Levine, D., Mbowa, S., & Odokonyero, T. (2020). Encouraging fertilizer adoption through risk free sales offer: A randomized control trial in Uganda. *World Development Perspectives*, *19*, 100230. https://doi.org/10.1016/j.wdp.2020.100230

Aggarwal, R. M. (2000). Possibilities and Limitations to Cooperation in Small Groups: The Case of Group-Owned Wells in Southern India. *World Development*, *28*(8), 1481–1497. https://doi.org/10.1016/S0305-750X(00)00030-9

Alavaisha, E., Tumbo, M., Senyangwa, J., & Mourice, S. (2022). Influence of Water Management Farming Practices on Soil Organic Carbon and Nutrients: A Case Study of Rice Farming in Kilombero Valley, Tanzania. *Agronomy*, *12*(5), Article 5. https://doi.org/10.3390/agronomy12051148

Ambali, O. I., & Begho, T. (2022). My neighbour as myself? An experimental investigation of spatial patterns of risk preferences among smallholder farmers. *Scientific African*, *16*, e01261. https://doi.org/10.1016/j.sciaf.2022.e01261

Anderson, M. L. (2008). Multiple Inference and Gender Differences in the Effects of Early Intervention: A Reevaluation of the Abecedarian, Perry Preschool, and Early Training Projects. *Journal of the American Statistical Association*, *103*(484), 1481–1495. https://doi.org/10.1198/016214508000000841

Andreoni, J. (1989). Giving with Impure Altruism: Applications to Charity and Ricardian Equivalence. *Journal of Political Economy*, *97*(6), 1447–1458. https://doi.org/10.1086/261662

Araral, E. (2009). What Explains Collective Action in the Commons? Theory and Evidence from the Philippines. *World Development*, *37*(3), 687–697. https://doi.org/10.1016/j.worlddev.2008.08.002

Atube, F., Malinga, G. M., Nyeko, M., Okello, D. M., Alarakol, S. P., & Okello-Uma, I. (2021). Determinants of smallholder farmers' adaptation strategies to the effects of climate change: Evidence from northern Uganda. *Agriculture & Food Security*, *10*(1), 6. https://doi.org/10.1186/s40066-020-00279-1

Balliet, D., Parks, C., & Joireman, J. (2009). Social Value Orientation and Cooperation in Social Dilemmas: A Meta-Analysis. *Group Processes & Intergroup Relations*, *12*(4), 533–547. https://doi.org/10.1177/1368430209105040

Bardhan, P. (1993). Analytics of the institutions of informal cooperation in rural development. *World Development*, *21*(4), 633–639. https://doi.org/10.1016/0305-750X(93)90115-P

Bardhan, P., Ghatak, M., & Karaivanov, A. (2007). Wealth inequality and collective action. *Journal of Public Economics*, *91*(9), 1843–1874. https://doi.org/10.1016/j.jpubeco.2007.03.002

Barrett, S., & Dannenberg, A. (2012). Climate negotiations under scientific uncertainty. *Proceedings of the National Academy of Sciences*, *109*(43), 17372–17376. https://doi.org/10.1073/pnas.1208417109

Bauer, M., Chytilová, J., & Pertold-Gebicka, B. (2014). Parental background and other-regarding preferences in children. *Experimental Economics*, *17*(1), 24–46. https://doi.org/10.1007/s10683-013-9355-y

Biel, A., & Gärling, T. (1995). The role of uncertainty in resource dilemmas. *Journal of Environmental Psychology*, *15*(3), 221–233. https://doi.org/10.1016/0272-4944(95)90005-5

Bluffstone, R., Dannenberg, A., Martinsson, P., Jha, P., & Bista, R. (2020). Cooperative behavior and common pool resources: Experimental evidence from community forest user groups in Nepal. *World Development*, *129*, 104889. https://doi.org/10.1016/j.worlddev.2020.104889

Bosworth, R., & Taylor, L. O. (2012). Hypothetical Bias in Choice Experiments: Is Cheap Talk Effective at Eliminating Bias on the Intensive and Extensive Margins of Choice? *The B.E. Journal of Economic Analysis & Policy*, *12*(1). https://doi.org/10.1515/1935-1682.3278

Carpenter, J. P., & Seki, E. (2005). Competitive Work Environments and Social Preferences: Field Experimental Evidence from a Japanese Fishing Community. *Contributions in Economic Analysis & Policy*, *5*(2). https://doi.org/10.2202/1538-0645.1460

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: A selective survey of the literature. *Experimental Economics*, *14*(1), 47–83. https://doi.org/10.1007/s10683-010-9257-1

Cherry, T. L., Kroll, S., & Shogren, J. F. (2005). The impact of endowment heterogeneity and origin on public good contributions: Evidence from the lab. *Journal of Economic Behavior & Organization*, *57*(3), 357–365. https://doi.org/10.1016/j.jebo.2003.11.010

Cummings, R. G., & Taylor, L. O. (1999). Unbiased value estimates for environmental goods: A cheap talk design for the contingent valuation method. *The American Economic Review*, *89*(3), 649–665.

d'Adda, G., & Levely, I. (2016). Social Preferences and Environmental Quality: Evidence from School Children in Sierra Leone. *Journal of African Economies*, *25*(1), 159–199. https://doi.org/10.1093/jae/ejv019

Daido, K. (2004). Risk-averse agents with peer pressure. *Applied Economics Letters*, *11*(6), 383–386. https://doi.org/10.1080/1350485042000228240

de Brauw, A., & Eozenou, P. (2014). Measuring risk attitudes among Mozambican farmers. *Journal of Development Economics*, *111*, 61–74. https://doi.org/10.1016/j.jdeveco.2014.08.002

de Heus, P., Hoogervorst, N., & Dijk, E. van. (2010). Framing prisoners and chickens: Valence effects in the prisoner's dilemma and the chicken game. *Journal of Experimental Social Psychology*, *46*(5), 736–742. https://doi.org/10.1016/j.jesp.2010.04.013

Dercon, S., & Christiaensen, L. (2011). Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. *Journal of Development Economics*, *96*(2), 159–173. https://doi.org/10.1016/j.jdeveco.2010.08.003

Dietz, T., Ostrom, E., & Stern, P. C. (2003). The Struggle to Govern the Commons. *Science*, *302*(5652), 1907–1912. https://doi.org/10.1126/science.1091015

Doss, C., McPeak, J., & Barrett, C. B. (2008). Interpersonal, Intertemporal and Spatial Variation in Risk Perceptions: Evidence from East Africa. *World Development*, *36*(8), 1453–1468. https://doi.org/10.1016/j.worlddev.2007.06.023

Douxchamps, S., Van Wijk, M. T., Silvestri, S., Moussa, A. S., Quiros, C., Ndour, N. Y. B., Buah, S., Somé, L., Herrero, M., Kristjanson, P., Ouedraogo, M., Thornton, P. K., Van Asten, P., Zougmoré, R., & Rufino, M. C. (2016). Linking agricultural adaptation strategies, food security and vulnerability: Evidence from West Africa. *Regional Environmental Change*, *16*(5), 1305–1317. https://doi.org/10.1007/s10113-015-0838-6

Eckel, C. C., & Grossman, P. J. (2002). Sex differences and statistical stereotyping in attitudes toward financial risk. *Evolution and Human Behavior*, *23*(4), 281–295. https://doi.org/10.1016/S1090-5138(02)00097-1

Falk, A., Fehr, E., & Fischbacher, U. (2005). Driving Forces Behind Informal Sanctions. *Econometrica*, *73*(6), 2017–2030. https://doi.org/10.1111/j.1468-0262.2005.00644.x

Falk, A., & Fischbacher, U. (2006). A theory of reciprocity. *Games and Economic Behavior*, *54*(2), 293–315. https://doi.org/10.1016/j.geb.2005.03.001

Fehr, E., Bernhard, H., & Rockenbach, B. (2008). Egalitarianism in young children. *Nature*, *454*(7208), Article 7208. https://doi.org/10.1038/nature07155

Fehr, E., & Fischbacher, U. (2002). Why Social Preferences Matter—The Impact Of Non-Selfish Motives on Competition, Cooperation and Incentives. *The Economic Journal*, 33.

Fehr, E., & Gächter, S. (2000). Cooperation and Punishment in Public Goods Experiments. *American Economic Review*, *90*(4), 980–994. https://doi.org/10.1257/aer.90.4.980

Fehr, E., Hoff, K., & Kshetramade, M. (2008). Spite and Development. *The American Economic Review*, *98*(2), 494–499.

Fehr, E., & Leibbrandt, A. (2011). A field study on cooperativeness and impatience in the Tragedy of the Commons. *Journal of Public Economics*, *95*(9), 1144–1155. https://doi.org/10.1016/j.jpubeco.2011.05.013

Fehr, E., & Schmidt, K. M. (1999). A Theory of Fairness, Competition, and Cooperation*. *The Quarterly Journal of Economics*, *114*(3), 817–868. https://doi.org/10.1162/003355399556151

Fischbacher, U., & Gächter, S. (2010). Social Preferences, Beliefs, and the Dynamics of Free Riding in Public Goods Experiments. *American Economic Review*, *100*(1), 541–556. https://doi.org/10.1257/aer.100.1.541

Fischbacher, U., Gächter, S., & Fehr, E. (2001). Are people conditionally cooperative? Evidence from a public goods experiment. *Economics Letters*, *71*(3), 397–404. https://doi.org/10.1016/S0165-1765(01)00394-9

Food and Agriculture Organization of the United Nations. (2016). *Rainfed agriculture in Tanzania: A review*. https://www.fao.org/3/i5932e/i5932e.pdf

Fung, J. M. Y., Au, W. T., Hu, W., & Shi, K. (2012). *Effect of risk orientation on cooperation and decision process in public goods dilemma*. https://journals-sagepub-com.proxy3.library.mcgill.ca/doi/full/10.1177/1368430212448443?casa_token=tPRoy9e0p0oAAAAA%3A_zo1UVjP0-3YHHEse4mg6iAZkxqm8rjIiqBS5HFweNcEEz89X163f8fahRv4ssWIkxQ3Aa5n3rq35A

Galizzi, M. M., & Navarro-Martinez, D. (2019). On the External Validity of Social Preference Games: A Systematic Lab-Field Study. *Management Science*, *65*(3), 976–1002. https://doi.org/10.1287/mnsc.2017.2908

Gowele, G. E., Mahoo, H. F., & Kahimba, F. C. (2020). Comparison of Silicon Status in Rice Grown Under the System of Rice Intensification and Flooding Regime in Mkindo Irrigation Scheme, Morogoro, Tanzania. *Tanzania Journal of Agricultural Sciences*, *19*(2), Article 2.

Grossman, G., & Baldassarri, D. (2014). The impact of elections on cooperation: Evidence from a lab-in-the-field experiment in Uganda. In *Analytical Sociology* (pp. 196–232). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118762707.ch08

Hargreaves Heap, S. P., Ramalingam, A., & Stoddard, B. V. (2016). Endowment inequality in public goods games: A re-examination. *Economics Letters*, *146*, 4–7. https://doi.org/10.1016/j.econlet.2016.07.015

Harou, A. P., Madajewicz, M., Michelson, H., Palm, C. A., Amuri, N., Magomba, C., Semoka, J. M., Tschirhart, K., & Weil, R. (2022). The joint effects of information and financing constraints on technology adoption: Evidence from a field experiment in rural Tanzania. *Journal of Development Economics*, *155*, 102707. https://doi.org/10.1016/j.jdeveco.2021.102707

Hasson, R., Löfgren, Å., & Visser, M. (2010). Climate change in a public goods game: Investment decision in mitigation versus adaptation. *Ecological Economics*, *70*(2), 331–338. https://doi.org/10.1016/j.ecolecon.2010.09.004

Hernandez-Aguilera, J. N., Mauerman, M., Herrera, A., Vasilaky, K., Baethgen, W., Loboguerrero, A. M., Diro, R., Tesfamariam Tekeste, Y., & Osgood, D. (2020). Games and Fieldwork in Agriculture: A Systematic Review of the 21st Century in Economics and Social Science. *Games*, *11*(4), Article 4. https://doi.org/10.3390/g11040047

Hil, K., & Gurven, M. (2005). Economic Experiments to Examine Fairness and Cooperation among the Ache Indians of Paraguay. In *Foundations of Human Sociality*. Oxford University Press. https://doi.org/10.1093/0199262055.003.0013

Hill, R. V., Hoddinott, J., & Kumar, N. (2013). Adoption of weather-index insurance: Learning from willingness to pay among a panel of households in rural Ethiopia. *Agricultural Economics*, *44*(4–5), 385–398. https://doi.org/10.1111/agec.12023

Holden, S. T., & Quiggin, J. (2016). Climate risk and state-contingent technology adoption: Shocks, drought tolerance and preferences. *European Review of Agricultural Economics*, eurrag;jbw016v1. https://doi.org/10.1093/erae/jbw016

Inocencio, A. B., Institute, I. W. M., & Harvest (Program), F. (2007). *Costs and Performance of Irrigation Projects: A Comparison of Sub-Saharan Africa and Other Developing Regions*. IWMI.

Ito, J. (2012). Collective Action for Local Commons Management in Rural Yunnan, China: Empirical Evidence and Hypotheses Using Evolutionary Game Theory. *Land Economics*, *88*(1), 181–200. https://doi.org/10.3368/le.88.1.181

Janssen, M. A., Anderies, J. M., & Joshi, S. R. (2011). Coordination and cooperation in asymmetric commons dilemmas. *Experimental Economics*, *14*(4), 547–566. https://doi.org/10.1007/s10683-011-9281-9

Jones, M., Kondylis, F., Loeser, J., & Magruder, J. (2022). Factor Market Failures and the Adoption of Irrigation in Rwanda. *American Economic Review*, *112*(7), 2316–2352. https://doi.org/10.1257/aer.20210059

Kadigi, R. M. J., Tesfay, G., Bizoza, A., Zibadou, G., & Zilberman, D. (2019). Irrigation and water use efficiency in Sub-Saharan Africa. *Gates Open Res*, *3*(587), Article 587. https://doi.org/10.21955/gatesopenres.1115251.1

Kahimba, F. C., Kombe, E. E., & Mahoo, H. F. (2013). The Potential of System of Rice Intensification (SRI) to Increase Rice Water Productivity: A Case of Mkindo Irrigation Scheme in Morogoro Region, Tanzania. *Tanzania Journal of Agricultural Sciences*, *12*(2), Article 2. https://www.ajol.info/index.php/tjags/article/view/130217

Kandel, E., & Lazear, E. P. (1992). Peer Pressure and Partnerships. *Journal of Political Economy*, *100*(4), 801–817. https://doi.org/10.1086/261840

Kangile, R., H.S. Ng'elenge, & Busindeli. (2018). Socio-Economic and Field Performance Evaluation of Different Rice Varieties under System of Rice Intensification in Morogoro, Tanzania. *Agricultural Research & Technology: Open Access Journal*, *17*(2). https://doi.org/10.19080/ARTOAJ.2018.17.556021

Katambara, Z., Kahimba, F. C., Mahoo, H. F., Mbungu, W. B., Mhenga, F., Reuben, P., Maugo, M., & Nyarubamba, A. (2013). Adopting the system of rice intensification (SRI) in Tanzania: A review. *Agricultural Sciences*, *4*(8), Article 8. https://doi.org/10.4236/as.2013.48053

Katic, P., & Ellis, T. (2018). Risk aversion in agricultural water management investments in Northern Ghana: Experimental evidence. *Agricultural Economics*, *49*(5), 575–586. https://doi.org/10.1111/agec.12443

Kebede, H. A. (2022). Risk Aversion and Gender Gaps in Technology Adoption by Smallholder Farmers: Evidence from Ethiopia. *The Journal of Development Studies*, *58*(9), 1668–1692. https://doi.org/10.1080/00220388.2022.2048653

Kirchsteiger, G. (1994). The role of envy in ultimatum games. *Journal of Economic Behavior & Organization*, *25*(3), 373–389. https://doi.org/10.1016/0167-2681(94)90106-6

Koundouri, P., Nauges, C., & Tzouvelekas, V. (2006). Technology Adoption under Production Uncertainty: Theory and Application to Irrigation Technology. *American Journal of Agricultural Economics*, *88*(3), 657–670. https://doi.org/10.1111/j.1467-8276.2006.00886.x

Laffont, J.-J. (1975). Macroeconomic Constraints, Economic Efficiency and Ethics: An Introduction to Kantian Economics. *Economica*, *42*(168), 430–437. https://doi.org/10.2307/2553800

Lamba, S., & Mace, R. (2011). Demography and ecology drive variation in cooperation across human populations. *Proceedings of the National Academy of Sciences*, *108*(35), 14426–14430. https://doi.org/10.1073/pnas.1105186108

Leibbrandt, A. (2012). Are social preferences related to market performance? *Experimental Economics*, *15*(4), 589–603. Scopus. https://doi.org/10.1007/s10683-012-9315-y

Lema, M. A., & Majule, A. E. (2009). Impacts of climate change, variability and adaptation strategies on agriculture in semi arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology*, *3*(8), Article 8. https://doi.org/10.4314/ajest.v3i8

Levati, M. V., Morone, A., & Fiore, A. (2009). Voluntary contributions with imperfect information: An experimental study. *Public Choice*, *138*(1–2), 199–216. https://doi.org/10.1007/s11127-008-9346-2

Levine, D. K. (1998). Modeling Altruism and Spitefulness in Experiments. *Review of Economic Dynamics*, *1*(3), 593–622. https://doi.org/10.1006/redy.1998.0023

Levitt, S. D., & List, J. A. (2007a). *What Do Laboratory Experiments Measuring Social Preferences Reveal About the Real World?* 22.

Levitt, S. D., & List, J. A. (2007b). What Do Laboratory Experiments Measuring Social Preferences Reveal About the Real World? *Journal of Economic Perspectives*, *21*(2), 153–174. https://doi.org/10.1257/jep.21.2.153

Levitt, S. D., & List, J. A. (2008). Homo economicus Evolves. *Science*, *319*(5865), 909–910. https://doi.org/10.1126/science.1153640

Long, N. V. (2017). Mixed-Strategy Kant-Nash Equilibrium and Private Contributions to a Public Good. In W. Buchholz & D. Rübbelke (Eds.), *The Theory of Externalities and Public Goods: Essays in Memory of Richard C. Cornes* (pp. 107–126). Springer International Publishing. https://doi.org/10.1007/978-3-319-49442-5_6

Long, N. V. (2020). A Dynamic Game with Interaction Between Kantian Players and Nashian Players. In P.-O. Pineau, S. Sigué, & S. Taboubi (Eds.), *Games in Management Science: Essays in Honor of Georges Zaccour* (pp. 249–267). Springer International Publishing. https://doi.org/10.1007/978-3-030-19107-8_14

Magnan, N., Love, A. M., Mishili, F. J., & Sheremenko, G. (2020). Husbands' and wives' risk preferences and improved maize adoption in Tanzania. *Agricultural Economics*, *51*(5), 743–758. https://doi.org/10.1111/agec.12589

Mancosu, N., Snyder, R. L., Kyriakakis, G., & Spano, D. (2015). Water Scarcity and Future Challenges for Food Production. *Water*, *7*(3), Article 3. https://doi.org/10.3390/w7030975

Mdemu, M. V., Mziray, N., Bjornlund, H., & Kashaigili, J. J. (2017). Barriers to and opportunities for improving productivity and profitability of the Kiwere and Magozi irrigation schemes in Tanzania. *International Journal of Water Resources Development*, *33*(5), 725–739. https://doi.org/10.1080/07900627.2016.1188267

Meinzen-Dick, R., Lansdowne, W. B. W. R. S. eng 13-15 D. 1994, Mendoza, M., Sadoulet, L., Abiad-Shields, G., & Subramanian, A. (1994). Sustainable water user associations: Lessons from a literature review. In *User Organizations for Sustainable Water Services, World Bank Technical Paper 354*. Washington DC (U.S.A) World Bank.

Meinzen-Dick, R., Raju, K. V., & Gulati, A. (2002). What Affects Organization and Collective Action for Managing Resources? Evidence from Canal Irrigation Systems in India. *World Development*, *30*(4), 649–666. https://doi.org/10.1016/S0305-750X(01)00130-9

Muzari, W., Gatsi, W., & Muvhunzi, S. (2012). The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: A Review. *Journal of Sustainable Development*, *5*(8), p69. https://doi.org/10.5539/jsd.v5n8p69

Nakano, Y., & Magezi, E. F. (2020). The impact of microcredit on agricultural technology adoption and productivity: Evidence from randomized control trial in Tanzania. *World Development*, *133*, 104997. https://doi.org/10.1016/j.worlddev.2020.104997

Nie, Z., Yang, X., & Tu, Q. (2020). Resource scarcity and cooperation: Evidence from a gravity irrigation system in China. *World Development*, *135*, 105035. https://doi.org/10.1016/j.worlddev.2020.105035

Oladimeji, Y. U., & Abdulsalam, Z. (2014). An economic analysis of dry season irrigated farming in Asa River, Kwara State, Nigeria: Implications for poverty reduction. *Journal of Sustainable Development in Africa*, *16*(7), 1–15.

Olson, M. (1965). *The Logic of Collective Action*. Harvard University Press.

Ostrom, E. (2000). Collective Action and the Evolution of Social Norms. *The Journal of Economic Perspectives*, *14*(3), 137–158.

Ostrom, E., & Gardner, R. (1993). Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work. *Journal of Economic Perspectives*, *7*(4), 93–112. https://doi.org/10.1257/jep.7.4.93

Ostrom, E., Gardner, R., Walker, J., & Walker, J. (1994). *Rules, Games, and Common-pool Resources*. University of Michigan Press.

Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science & Policy*, *11*(7), 642–654. https://doi.org/10.1016/j.envsci.2008.06.002

Parks, C. D. (2004). Risk Preference As a Predictor of Cooperation in a Social Dilemma. In *Contemporary psychological research on social dilemmas* (pp. 58–70). Cambridge University Press.

Pittock, J., White, C., & Grafton, Q. (2014). *Water, Food and Agricultural Sustainability in Southern Africa*. Tilde University Press. https://openresearch-repository.anu.edu.au/handle/1885/66328

Prediger, S., Vollan, B., & Herrmann, B. (2014). Resource scarcity and antisocial behavior. *Journal of Public Economics*, *119*, 1–9. https://doi.org/10.1016/j.jpubeco.2014.07.007

Rabin, M. (1993). Incorporating Fairness into Game Theory and Economics. *The American Economic Review*, *83*(5), 1281–1302.

Rand, D. G., Peysakhovich, A., Kraft-Todd, G. T., Newman, G. E., Wurzbacher, O., Nowak, M. A., & Greene, J. D. (2014). Social heuristics shape intuitive cooperation. *Nature Communications*, *5*(1), Article 1. https://doi.org/10.1038/ncomms4677

Raub, W., & Snijders, C. (1997). Gains, losses, and cooperation in social dilemmas and collective action: The effects of risk preferences. *The Journal of Mathematical Sociology*, *22*(3), 263–302. https://doi.org/10.1080/0022250X.1997.9990204

Reuben, P., Kahimba, F. C., Katambara, Z., Mahoo, H. F., Mbungu, W., Mhenga, F., Nyarubamba, A., & Maugo, M. (2016). Optimizing Plant Spacing under the Systems of Rice Intensification (SRI). *Agricultural Sciences*, *7*(4), Article 4. https://doi.org/10.4236/as.2016.74026

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M., & Reinhardt, J. (2017). Climate change impacts in Sub-Saharan Africa: From physical changes to their social repercussions. *Regional Environmental Change*, *17*(6), 1585–1600. https://doi.org/10.1007/s10113-015-0910-2

Shee, A., Azzarri, C., & Haile, B. (2020). Farmers' Willingness to Pay for Improved Agricultural Technologies: Evidence from a Field Experiment in Tanzania. *Sustainability*, *12*(1), Article 1. https://doi.org/10.3390/su12010216

Sweya, L. N., Wilkinson, S., & Chang-Richard, A. (2018). *Understanding Water Systems Resilience Problems in Tanzania*. *212*, 488–495. Scopus. https://doi.org/10.1016/j.proeng.2018.01.063

Tamim, A. (2020). The Long-Term Effects of Information and Vouchers on Adoption, Retention, and Soil Perceptions: Evidence from a Randomized Experiment in Tanzania [M.Sc., McGill University (Canada)]. In *ProQuest Dissertations and Theses*. https://www.proquest.com/pqdtlocal1006845/docview/2514366302/abstract/7ADD22324D164AECPQ/2

Tavoni, A., Dannenberg, A., Kallis, G., & Löschel, A. (2011). Inequality, communication, and the avoidance of disastrous climate change in a public goods game. *Proceedings of the National Academy of Sciences*, *108*(29), 11825–11829. https://doi.org/10.1073/pnas.1102493108

The State of Food and Agriculture 2020. (2020). FAO. https://doi.org/10.4060/cb1447en

Torres-Guevara, L. E., & Schlüter, A. (2016). External validity of artefactual field experiments: A study on cooperation, impatience and sustainability in an artisanal fishery in Colombia. *Ecological Economics*, *128*, 187–201. https://doi.org/10.1016/j.ecolecon.2016.04.022

Uphoff, N., Wickramasinghe, M. L., & Wijayaratna, C. M. (1990). "Optimum" Participation in Irrigation Management: Issues and Evidence from Sri Lanka. *Human Organization*, *49*(1), 26–40.

Van Assen, M., & Snijders, C. (2004). Effects of risk preferences in social dilemmas A game theoretical analysis and evidence from two experiments. In *Contemporary research on social dilemmas* (pp. 24–57). New York, NY: Cambridge University Press.

Visser, M., Jumare, H., & Brick, K. (2020). Risk preferences and poverty traps in the uptake of credit and insurance amongst small-scale farmers in South Africa. *Journal of Economic Behavior & Organization*, *180*, 826–836. https://doi.org/10.1016/j.jebo.2019.05.007

Von Neumann, J., & Morgenstern, O. (1944). *Theory Of Games And Economic Behavior*. http://archive.org/details/in.ernet.dli.2015.215284

Voors, M., Turley, T., Kontoleon, A., Bulte, E., & List, J. A. (2012). Exploring whether behavior in context-free experiments is predictive of behavior in the field: Evidence from lab and field experiments in rural Sierra Leone. *Economics Letters*, *114*(3), 308–311. https://doi.org/10.1016/j.econlet.2011.10.016

Wade, R. (1988). *Village Republics: Economic Conditions for Collective Action in South India*. Cambridge University Press.

Wade, R., & Feeny, D. (1989). Village Republics: Economic Conditions for Collective Action in South India. Cambridge: Cambridge University Press, 1988. Pp. xii, 238. $44.50. *The Journal of Economic History*, *49*(2), 501–502. https://doi.org/10.1017/S0022050700008408

Weber, J. M., Kopelman, S., & Messick, D. M. (2004). A Conceptual Review of Decision Making in Social Dilemmas: Applying a Logic of Appropriateness. *Personality and Social Psychology Review*, *8*(3), 281–307. https://doi.org/10.1207/s15327957pspr0803_4

World Bank. (n.d.). *National Panel Survey 2019-2020—Extended Panel with Sex Disaggregated Data* [dataset]. World Bank, Development Data Group. https://doi.org/10.48529/0Y7D-1V78

Yang, X., Nie, Z., Qiu, J., & Tu, Q. (2020). Institutional preferences, social preferences and cooperation: Evidence from a lab-in-the-field experiment in rural China. *Journal of Behavioral and Experimental Economics*, *87*, 101554. https://doi.org/10.1016/j.socec.2020.101554

Yesuf, M., & Bluffstone, R. A. (2009). Poverty, Risk Aversion, and Path Dependence in Low-Income Countries: Experimental Evidence from Ethiopia. *American Journal of Agricultural Economics*, *91*(4), 1022–1037. https://doi.org/10.1111/j.1467-8276.2009.01307.x

You, L., Ringler, C., Wood-Sichra, U., Robertson, R., Wood, S., Zhu, T., Nelson, G., Guo, Z., & Sun, Y. (2011). What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. *Food Policy*, *36*(6), 770–782. https://doi.org/10.1016/j.foodpol.2011.09.001

Young, S. L., Miller, J. D., Frongillo, E. A., Boateng, G. O., Jamaluddine, Z., & Neilands, T. B. (2021). Validity of a Four-Item Household Water Insecurity Experiences Scale for Assessing Water Issues Related to Health and Well-Being. *The American Journal of Tropical Medicine and Hygiene*, *104*(1), 391–394. https://doi.org/10.4269/ajtmh.20-0417

Appendix A

Appendix A.1 Construction of Asset Index

We construct an asset index using the Principal Component Analysis (CPA) to the following quantities of household, livestock, and productive assets. The asset index is a relative measure of wealth, allowing us to distinguish the different wealth levels within the sample population. We exclude all asset items owned by less than 2% of households and owned by more than 98%. In other words, we include all asset items owned by more than 2% and less than 98% of households in the sample. Given the nature of the index, the asset index has a mean of 0. As shown in Figure A.1, the distribution of the asset index is normal, indicating little sign of inequalities within the sample.

Table A.1. Assets Used for the Construction of the Asset Index

Household Assets	**Productive Assets**	**Livestock Assets**
Bicycle	Power Tiller	Chicken – Local
Motorcycle	Hoe	Ducks
Gas Cooker	Shovel	
Refrigerator	Hand Saw	
Sofa	Barrel	
Chair	Tractor	
Table	Axe	
Bed	Knife	
Sewing Machine	Machete	
TV	Sickle	
Radio		
Phone		

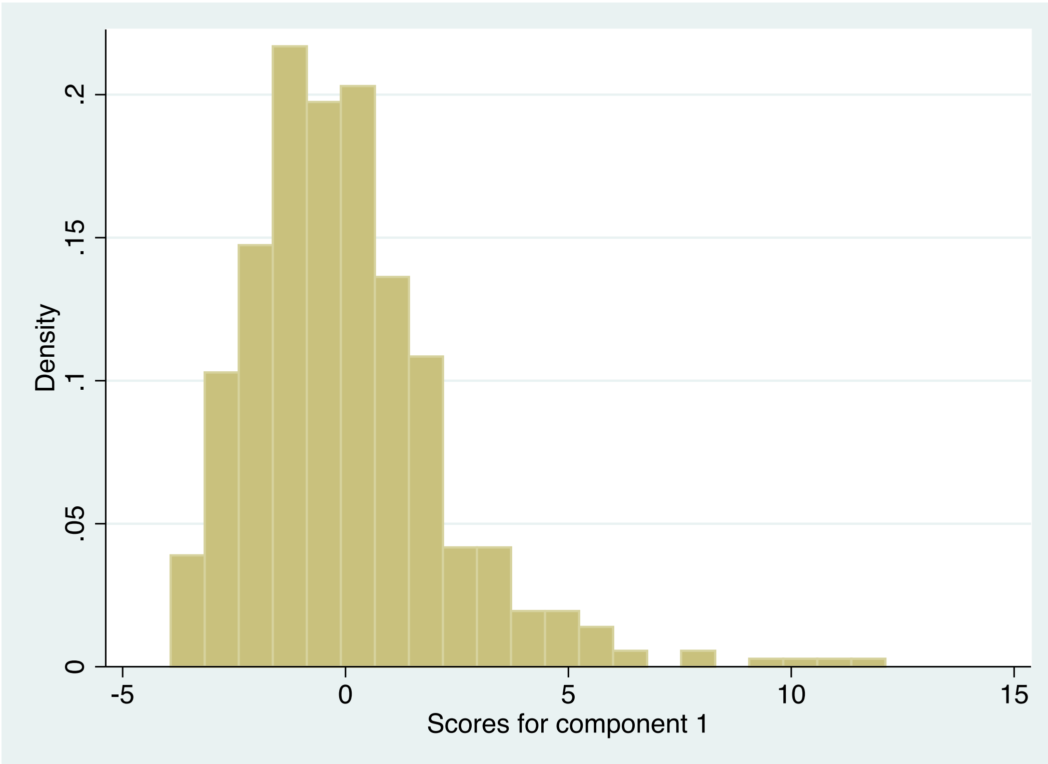


Figure A. 1. Distribution of the PCA asset index scores. The distribution is normal, indicating little sign of inequalities within the community.

Appendix A.2: Construction of cooperation indices

This appendix explains the creation of the cooperation indices. The cooperation indices aim to measure realized cooperative behaviour of farmers. Each individual was given a 0 or 1 if they were below or above the group mean of the nine cooperation variables listed in Table *11*. A value of 1 means they were more cooperative, while 0 means they were less so. We then summed the binary results to create the general cooperation index. The higher the index, the more cooperative the individual is. The general cooperation index embodies all nine variables, but we further divided it into two: one index for cash-based cooperation and one for social cooperation.

General index of cooperation:

Figure A.2 shows the normal distribution of this index. For this index, the nine cooperation variables were turned into binary variables as follows:

- *Paid bills LR/SR*: equal to 1 if the participant paid all their water bills in the long rains/short rains season, 0 otherwise.
- *Contributed*: equal to 1 if contributed anything (cash, labour, hired labour), 0 otherwise.
- *Days of labour contributed*: equal to 1 if above or equal to the group mean of 4.41 days of labour contributed to the maintenance of the canal adjacent to their most important plot, 0 if below the mean.
- *Cash contributed*: equal to 1 if they contributed any positive amount of cash to the maintenance of the canal adjacent to their most important plot, 0 otherwise. This variable is skewed to the left, so we do not use the mean or median as a cut-off.
- *Voted in past election*: equal to 1 if voted in the most recent block elections, 0 otherwise.

- *Interactions with block leadership*: equal to 1 if interacted more than the group mean of 4 times or more in the past 12 months, 0 if otherwise.
- *Interactions with UWAMKI*: equal to 1 if interacted more than the group mean of 4 times or more in the past 12 months, 0 if otherwise.
- *Disputes*: equal to 0 if had one or more water-related disputes in the past 12 months, 1 otherwise.

Cash-based cooperation index:

Includes all cooperation variables that depend on cash: whether they paid their bills in long rain and/or short rain seasons, if they contributed any money or labour, and how many days of labour and cash they contributed. Figure A.3 shows that the distribution is slightly skewed to the right.

Social cooperation index:

Includes all cooperation variables that do not depend on cash and rely on social aspects of cooperation: if they voted in the past block election, how many interactions they've had with the block and scheme leadership, and the number of disputes. Figure A.4 shows the distribution is slightly skewed to the right.

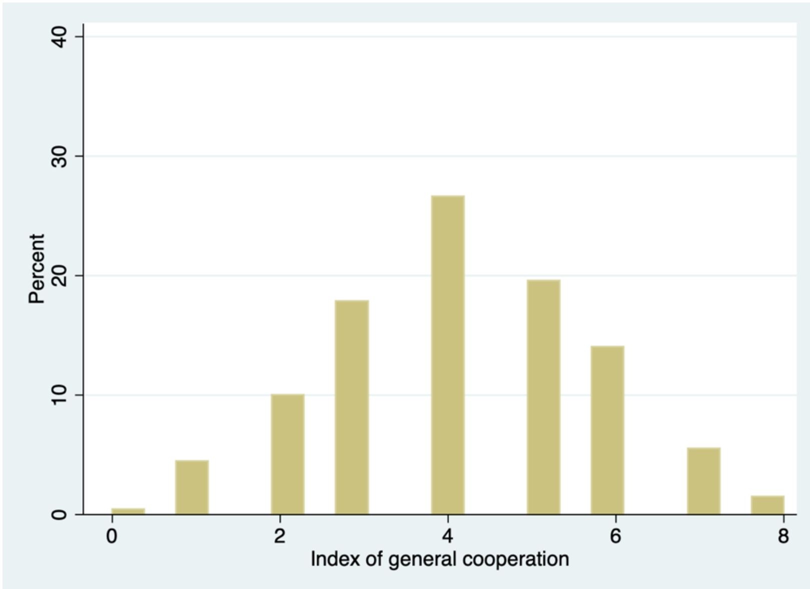


Figure A.2. Distribution of scores for the general cooperation index.

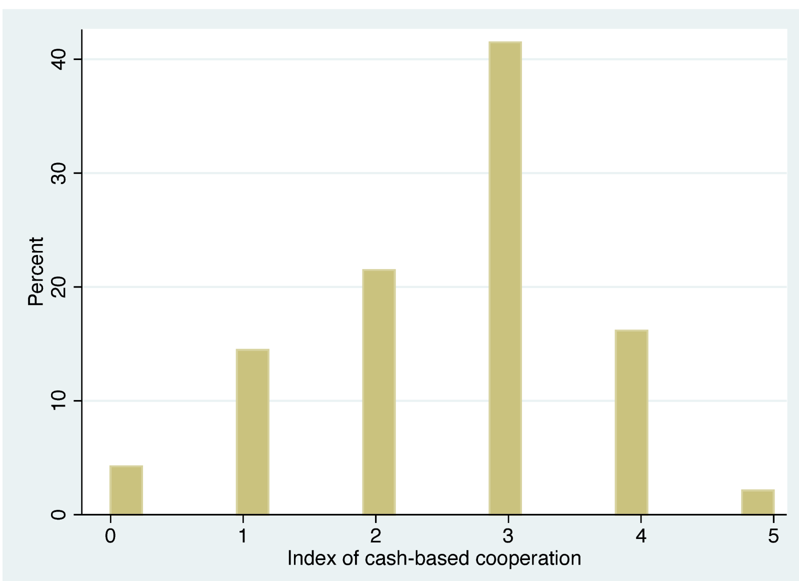


Figure A.3. Distribution of scores on cash-based cooperation index.

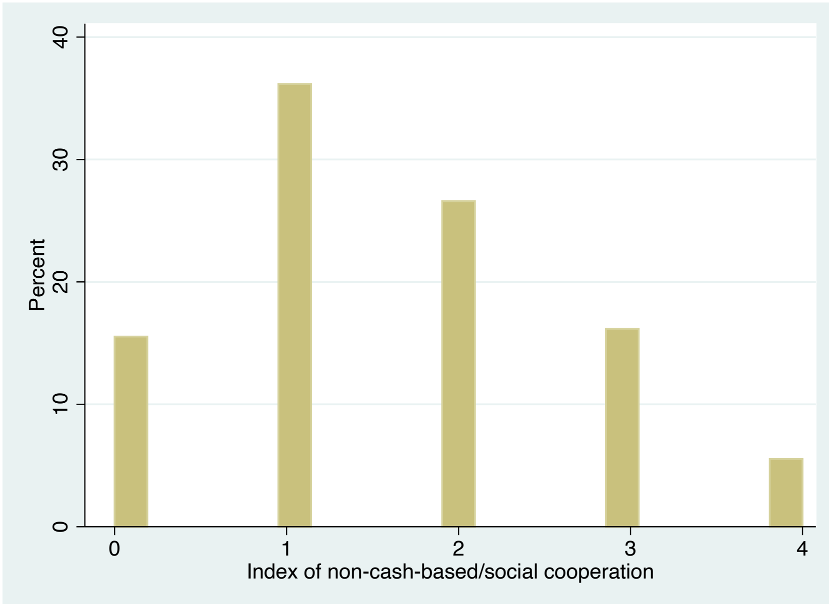


Figure A.4. Distribution of scores on non-cash-based/social cooperation index.