Title: Measuring the Effect of Heterogeneity and Trust on Cooperation in Common-Pool Resources.

Candidate Name: Fijnanda van Klingeren

College Name: Nuffield College

Degree: Doctor of Philosophy in Sociology

Term of Submission: Trinity

Year of Submission: 2021

Abstract

In this doctoral thesis I measure the effect of economic and sociocultural heterogeneity on cooperation through trust in the context of common-pool resources, using different techniques. The thesis is made up of three separate papers that are all trying to answer the same overarching question: how and to what extent does heterogeneity affect cooperation between appropriators of common-pool resources, and what is the role of trust in this process? The first paper applies innovative imputation techniques to use the famous CPR Database, compiled by the Nobel-prize winner Elinor Ostrom, to its full potential. The second paper uses data from a CPR laboratory experiment conducted in the United Kingdom and the Netherlands, in which a cooperation dilemma is simulated that is experienced in fishing grounds. The third paper uses data from the earlier experiment and an additional CPR experiment conducted in India, and analyses and interprets the difference in behaviour between the two experiments by using player type classification and agent-based models. Findings of this thesis suggest that heterogeneity does not necessarily impact cooperation negatively: sociocultural heterogeneity is not found to be negatively related to cooperation, economic heterogeneity is found to be positively related to cooperation under certain conditions and the combination of economic and sociocultural heterogeneity is found to be positively or negatively related to cooperation in CPRs depending on the operationalisation of sociocultural heterogeneity. In addition, it is found that trust has a positive effect on cooperation and that heterogeneity may impact trust negatively under some conditions.

University of Oxford
Department of Sociology

Thesis submitted for the degree of
DOCTOR OF PHILOSOPHY IN SOCIOLOGY

Measuring the Effect of Heterogeneity and Trust on Cooperation in Common-Pool Resources

Fijnanda van Klingeren
fijnanda.vanklingeren@nuffield.ox.ac.uk

Nuffield College

Word count:
38000

Trinity Term 2021

Acknowledgements

I want to thank my supervisor Nan Dirk de Graaf, who did more than his duty as a supervisor by responding to emails within minutes, writing me countless supporting statements, hosting me at High Table more times than I could have dreamed of and by wholeheartedly supporting me in my rowing endeavours.

I want to thank my friends in Oxford, who made the past 3.5 years one of the happiest periods in my life and with whom I made incredible memories. It is hard moving to a new place on your own without knowing anyone, but my Nuffield-family brought me friendships that will last a lifetime. I often think back at our conversations during lunch and afternoon tea and cakes in the JCR, which back then were so common but are now part of precious memories. A special thanks to my housemates at Gread Mead with whom I spent almost half a year in lockdown - you made the spring and summer of 2020 fun despite the circumstances. I want to thank my friends in the Netherlands too for visiting me in Oxford, and for welcoming me back in the Netherlands every time I visited home, as if I never left.

I want to thank my family for supporting me in going to Oxford, even if this meant we only got to see each other a couple of times each year. It was pretty hard not being able to be there for all the birthdays or for casual family dinners for so long, especially during the lockdown period. But through many videocalls, text messages, postcards and surprise parcels full of Dutch food I never felt too far from home.

Lastly I want to thank Roberto. I'm so lucky to have found you here, and I'm even luckier that you came back to the Netherlands with me. We supported each other during our PhDs and had so many big and small adventures together all over the world. We stick together.

Contents

Page No.

Chapter I:
Introduction

This thesis consists of three separate papers that use different data and methods to measure and understand the effect of economic and sociocultural heterogeneity and trust on cooperation in common-pool resources [CPRs]. Case-study data from Elinor Ostrom's CPR Database and experimental data from two laboratory experiments are analysed and interpreted using various techniques. Results suggest that sociocultural heterogeneity does not affect cooperation negatively in CPRs compared to homogeneity, that economic heterogeneity under certain circumstances affects cooperation positively compared to homogeneity, that the effect of the combination of economic and sociocultural heterogeneity on cooperation depends on the type of sociocultural heterogeneity and that trust affects cooperation in CPRs positively but may not play a major role as mediator between heterogeneity and cooperation.

The Tragedy of the Commons

The motivation for this thesis starts with a cooperation dilemma called the 'Tragedy of the Commons'. Hardin (1968) described this dilemma, or problem, as follows:

> Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons [...] As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "what is the utility to me of adding one more animal to my herd?" This utility has a negative and a positive component.
>
> (1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.
>
> (2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of 1.
>
> Adding together the component particular utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another... But this is the conclusion reached by each and every rational herdsman sharing a

> commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination towards which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all. (Hardin, 1968, p. 1244)

In short, users or 'appropriators' of a CPR have two choices: to cooperate by using the resource in a sustainable manner or to defect by overappropriating the resource and gain more profit. When all CPR users follow their dominant strategy they will overappropriate the resource each time. However, unlike a public good, a CPR has high subtractability and can thus run out. This means that a limited resource will be used unlimitedly, which will lead to its inevitable destruction.

While the tragedy of the commons remains an interesting concept today, there is plenty of research showing that the fate of CPRs is not solely decided by myopic rational resource appropriators. Behavioural experiments point out that people's behaviour is more complex than sketched in the rational choice theory, and that they often behave as (conditional) cooperators in social dilemmas (Dawes, 1980; Fischbacher, Gächter, & Fehr, 2001; Gächter, 2006; Herrmann & Thöni, 2009; Kocher, Cherry, Kroll, Netzer, & Sutter, 2008; Kurzban & Houser, 2005; Ostrom, Walker, & Gardner, 1992). In addition, a large body of literature argues that with the use of institutions for collective action, CPR users often manage to use the resource in a sustainable manner, guaranteeing long-term income and a healthy resource (Bravo & De Moor, 2008; De Moor, 2013a, 2013b; Ostrom, 1990, 2000). The most well-known advocate of this literature is Nobel-prize winner Elinor Ostrom, who in her book *Governing the Commons* (1990) analyses numerous cases of CPRs, amongst which many with resource users that successfully manage themselves without formal property rights. By now, there are numerous publications heavily criticising Hardin's original depiction of the tragedy of the commons (see for instance Dasgupta & Dasgupta, 1982; Diekert, 2012). In addition, Hardin's version of the tragedy of the commons can only be applied to resources with open access, and heterogeneity of resources is not accounted for in his predictions. Despite all this, one cannot deny that the tragedy of the commons is part of the origin of research on the topic of sustainable use of CPRs, and that it sparked the interest of researchers to investigate the evolution of cooperation in CPRs.

A Game Theoretic Perspective on CPRs

One tool that has proven useful in the systematic analysis of cooperation dilemmas such as the tragedy of the commons, is game theory. It provides structure to the problem and gives a clear overview of the dilemma that actors face. In addition, the use of payoff matrices can help determine why actors behave in specific, sometimes seemingly inefficient or not profit maximising way. The every-day dilemma that resource users in a CPR setting face is represented in the payoff matrix in Table 1. The payoffs in this matrix are based on the description of Elinor Ostrom (1990) when explaining Hardin's (1968) tragedy of the commons. In this representation, the cost of overappropriation or defection [D] is apparent in the payoff of 0 when both players defect. If all players cooperate [C], the reward will be 10 for each player. If one player defects, they get 11 and the player who still cooperates get -1.

Table 1: The "Hardin herder game" payoff matrix as described by Ostrom (1990, p. 4)

		Player2	
		C	D
Player 1	C	10, 10	-1, 11
	D	11, -1	0, 0

An issue with this representation of the CPR dilemma is that the payoffs represent either a situation in which the resource is very small and one 'round' of overappropriation will already destroy the resource, or it represents the long-term consequences of overappropriation of the resource. In this representation of the payoff matrix, the dominant strategy for both players is to defect. However, mutual defection 'D, D' is not a Pareto optimal outcome, as moving to 'C, C' would yield a higher profit for both players. The relative payoffs are similar to a Prisoner's Dilemma. In the current thesis, two laboratory experiments are conducted that comprise a CPR game. In that game, the reward for overappropriation in each single period played is higher than the reward for cooperation, regardless of what the others do. The payoff matrix for the CPR game used in this thesis - and maybe a better suited payoff matrix to show the problem in the tragedy of the commons for large resources in which the cost of overappropriation is not visible in one period of appropriation - is shown in Table 2.[1] The matrix shows that the payoff of cooperation is 'R' or the Reward of cooperation. The payoff for overappropriating the resource is 'T' or the Temptation of exploitation. Since CPRs grow and shrink over time depending on use and are most often used by appropriators for longer periods of time, we can treat this matrix as a payoff matrix for each time or period it is used. In each period, $T > R$: the payoff of giving into temptation and to overappropriate the resource is *always* bigger than the reward for cooperation. Much like the Prisoner's Dilemma, the situation in which both players have no incentive to change their behaviour, also called the Nash equilibrium, is thus for all players to defect and overappropriate the resource. In this case, 'D, D' is also a Pareto optimal outcome: since T is larger than R, there is no other cell in the matrix that would yield a higher or at least equal outcome for all players. The dominant strategy for each round or period is thus defection.

[1] To keep the payoff matrix simple, it just shows the payoff for one player and 'all other players'. Of course, each player can cooperate or defect, in which case their payoff is 'R' or 'T' respectively.

Table 2: Profit matrix of the current CPR game

		All other players	
		C	D
Player *i*	C	R, R	R, T
	D	T, R	T, T

Although this matrix is a better representation of the payoffs for players each round in the CPR game that is used in this thesis, there is something that this matrix does not quite capture: the decline of the resource after overappropriation. The payoffs of a period after a period in which anyone defected would be R and T minus some shared cost of overappropriation from the previous period $t-1$ (as Hardin (1968) also states in his description of the Tragedy of the Commons). In the CPR games used in this thesis, the payoff of $T_{t=3}$ for any player in the third period will already be smaller than the reward $R_{t=n}$ for cooperation they would have received if all players would have cooperated from the beginning. From here on, $T_{t>3}$ will always be smaller than $R_{t=n}$ if all players cooperated from the first period $t = 1$ on. The only exception to this is a situation in which some players underappropriate the resource so the resource can stay or grow to its full size while other players are overexploiting the resource. An example of the payoff structure for one round in this case is given in Table 3, where 'U' stands for underappropriation, which yields 'S' or a Sacrifice payoff.[2]

Table 3: Alternative profit matrix of a CPR game

		All other players		
		U	C	D
Player *i*	U	S, S	S, R	S, T
	C	R, S	R, R	R, T
	D	T, S	T, R	T, T

In this case, $T > R > S$ will hold within and across periods as long as the average appropriation effort per player is smaller or equal to the cooperative amount. In each single round, 'D, D' is the dominant strategy, a Pareto efficient outcome and a Nash equilibrium.

The cumulative payoff will be largest when the average appropriation effort in each period is the sustainable, cooperative, appropriation amount. The development of resource size and cumulative payoff (utility) under different group behaviours - according to the CPR game resource growth and utility functions used

[2]Again, the payoffs of one player versus 'all other players' are shown instead of showing all combinations for four players for simplicity of the table. Each player can cooperate, defect or underappropriate, in which case their payoff is 'R', 'T' or 'U' respectively.

in this thesis - is shown in Figure 1 and Figure 2 respectively. As is visible from the graphs, collective cooperation is the best long-term strategy for each player. However, as the game is without communication (Hardin, 1968; Ostrom, 1990), it is hard for players to coordinate on this.

Figure 1: Development over time of Resource Size under different appropriation behaviours of groups (sum app = sum of appropriation in the group)

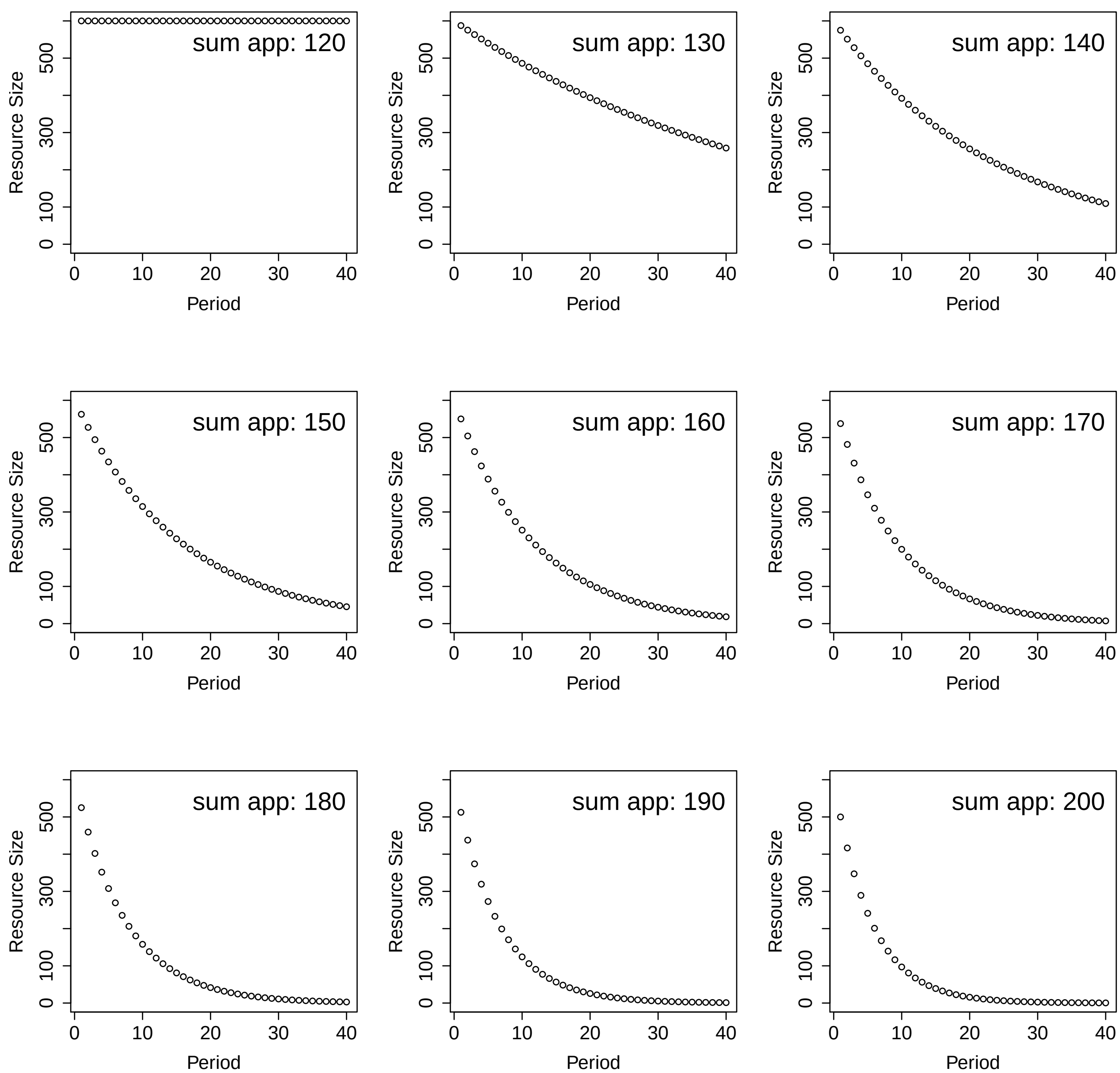
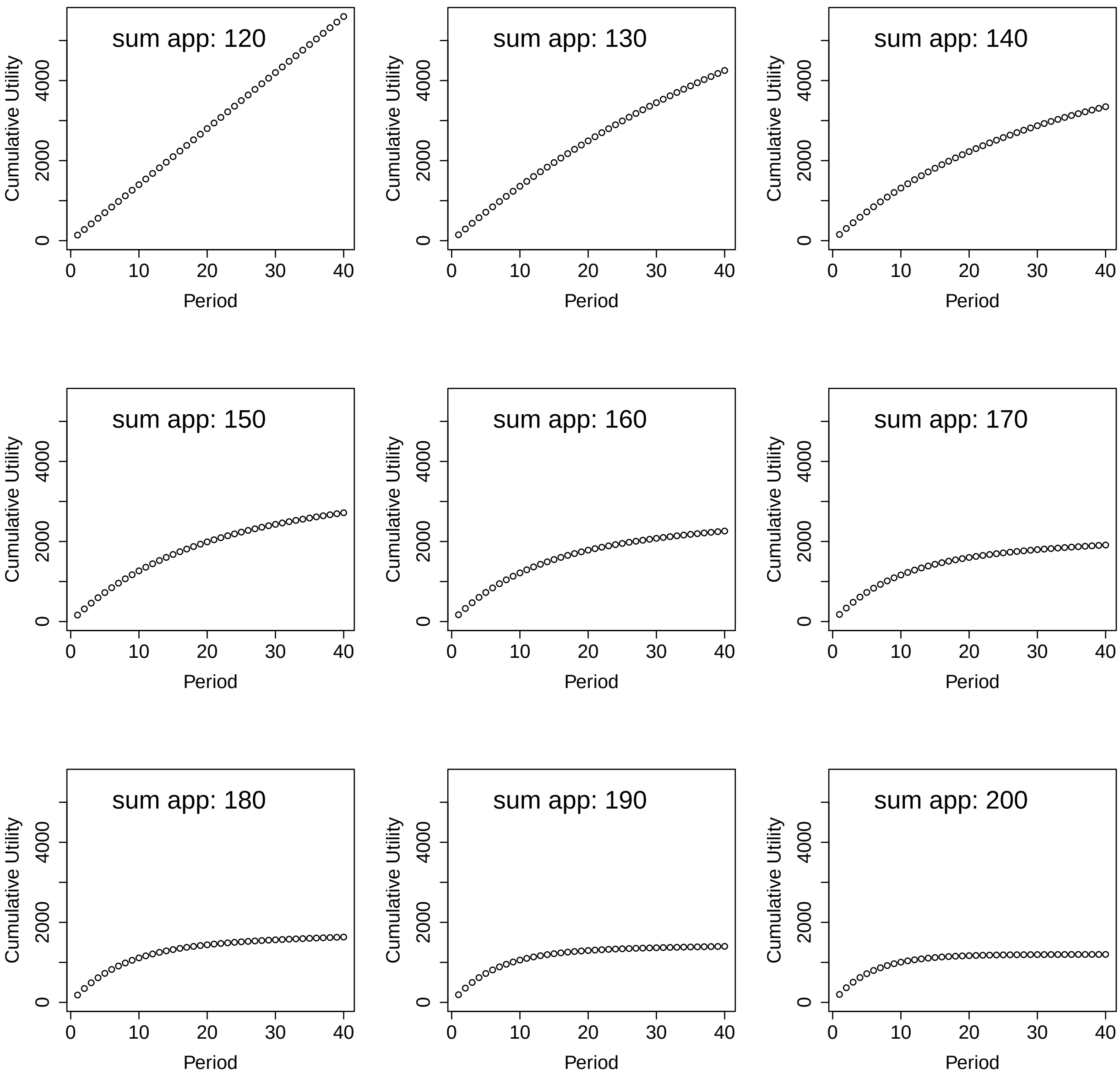


Figure 2: Development over time of Cumulative group Payoff (Utility) under different appropriation behaviours of groups (sum app = sum of appropriation in the group)



In real life, resource users will likely not make decisions solely based on a payoff matrix. Experimental research has shown that people do not behave exclusively myopically rational, and that a large part of people can be classified as cooperators or conditional cooperators (Dong, Zhang, & Tao, 2016; Fischbacher et al., 2001; Fischbacher & Gächter, 2006; Gächter, 2006; Herrmann & Thöni, 2009; Janssen & Baggio, 2016; Kocher et al., 2008; Kurzban & Houser, 2005; Zhang, An, & Dong, 2021). Actors and their actions in cooperation dilemmas are thus more complex than can be fully captured in a schematic overview such as a payoff matrix. In addition, there are plenty of real-life situations in which actors can communicate and can thus coordinate cooperation. However, a large part of this thesis focuses on the setting of a fishing ground, in which communication during fishing - so during the decision-making stage of the game - is not necessarily self-evident.

Heterogeneity, Trust and Cooperation

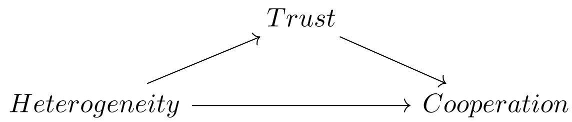
Inspired by the difficulty of the cooperation dilemma that was just described, this thesis was written to investigate the relation between heterogeneity, trust and cooperation in CPRs. An increase in migration all over the world (*International Migration Report 2019*, 2019) is causing societies to become more diverse on sociocultural and economic dimensions. This increase in heterogeneity may affect successful cooperation between resource users in two ways.

Firstly, there may be a direct effect of heterogeneity on cooperation in which it diversifies the interests and goals amongst people. Existing research shows that heterogeneity can increase the cost of negotiation and bargaining due to a lack of shared ideas, values and incentives (Aksoy, 2019; Bardhan & Dayton-Johnson, 2002), that it may lead to unequal sharing of decision-making rights and different motivations to cooperate (Anderson & Paskeviciute, 2006; Fung & Au, 2014; Komakech, Van der Zaag, & Van Koppen, 2012), and that it may decrease social cohesion (Flache & Mäs, 2008; Jehn, Northcraft, & Neale, 1999). On the other hand, the economist Mancur Olson (1965) suggests a positive effect of economic heterogeneity on cooperation: the so called 'Olson-effect' describes how economic inequality can lead to an inequality of incentives, which results in some actors being motivated enough to invest in collective action on their own - hereby carrying the costs of cooperation.

Secondly, there may be an indirect effect of heterogeneity on cooperation in which it reduces trust amongst people, which in its turn leads to a decrease in cooperation. There is plenty of evidence that trust is affected by heterogeneity (Alesina & La Ferrara, 2002; Delhey & Newton, 2005; Ostrom, 1990; Putnam, 2007) and that trust plays an important role in influencing societal outcomes (Fukuyama, 1995; Putnam, 2000; Uslaner, 2002; Zak & Knack, 2001). However, it is not clear to what degree trust mediates the effect of heterogeneity, whether this is different for economic and sociocultural heterogeneity, and whether this mechanism can even be found in CPRs.

Especially in the context of CPRs, where cooperation is vital for both the survival of the resource as well as the livelihood of the resource users, it is important to know how heterogeneity and trust impact cooperation. Figure 3 provides a simple schematic overview of the main theoretical model that this thesis is based on.

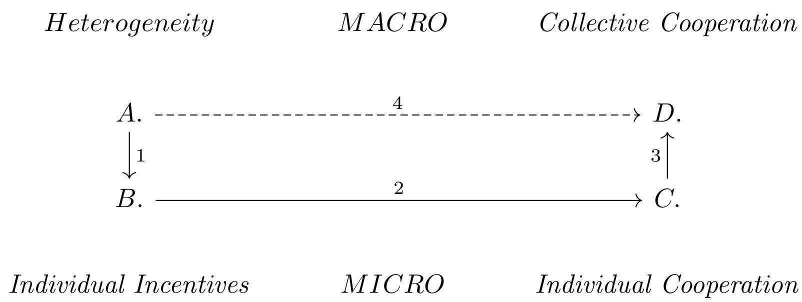
Figure 3: Schematic graph of research question



Micro-foundations to Macro-problems

This thesis will not only look at the influence of heterogeneity and trust on cooperation in CPRs on the macro-level. A large part of the mechanism may depend on what happens on the micro-level (Coleman, 1987, 1994; Hedström, 2005; Raub, Buskens, & Van Assen, 2011). To analyse how economic and sociocultural heterogeneity influence the macro-outcomes of CPRs insights on what happens on the micro-level are necessary. Figure 4 presents a macro-micro-macro model: a stylised scheme designed by Coleman (1987) as a way for representing macro-micro-macro links in the reconstruction and analysis of social phenomena. The initial macro-condition in this figure is economic or sociocultural heterogeneity (or both) in a population (A). Arrow 1 represents assumptions on how economic and sociocultural heterogeneity as macro-conditions influence the micro-conditions of individual resource users or appropriators (B). The micro-conditions are the incentives for appropriators to behave in a certain way; to cooperate and appropriate the resource in a sustainable manner, or to defect and overexploit the resource. This is also the part where mutual trust amongst appropriators plays a role; more trust amongst appropriators is expected to keep them from defecting. These incentives lead to the expression of certain behaviour of the individual appropriator, represented by arrow 2. In this case, the behaviour is the individual level of cooperation of the resource users, which is represented by the appropriation effort (C). Subsequently, arrow 3 represents assumptions on how the combination of individual actions - the aggregate of cooperative or defective appropriation behaviour - is translated into macro-outcomes; in this case the consequences for the CPR in terms of collective cooperation which is directly measured as the resource size (D). Together, these arguments provide a complete mechanism on how economic and sociocultural heterogeneity may affect resource size and collective cooperation, as represented by arrow 4.

Figure 4: Macro-micro-macro model



Structure of the Thesis

The following three chapters of this thesis comprise three research papers that are all investigating the effect of heterogeneity and trust on cooperation in CPRs. All three papers use a different methodological approach.

The first paper of this thesis, 'Heterogeneity, Trust and Common-Pool Resource Management', is based on the well-known CPR Database (1989); a database that was compiled by Elinor Ostrom and her team, based on a selected subset of a bibliography containing over 1800 original published and unpublished CPR case studies from before 1990. The database holds information that was gathered in over 40 person-years of fieldwork conducted by researchers in the field of social science, history and engineering. The part of the database used in the paper contains 32 fisheries and 52 irrigation systems, enabling the investigation of the theoretical mechanism for two types of resources. In this paper, advanced computational techniques such as multiple imputation with chained equations, random forests and predictive mean matching are employed in order to make the data suitable for statistical analyses. The paper is the only out of the three papers in this thesis that is able to measure the indirect effects of economic and sociocultural heterogeneity on cooperation through trust. Using unique meta-data on real CPRs adds information from real-life contexts to the thesis, which is otherwise based on experimental data. This paper addresses the mechanism on the macro-level by looking at the relation between heterogeneity and CPR success. In addition, it addresses the micro-level to some extent, by taking into account the mediating role of trust between appropriators, which takes place on the individual level. Lastly, the paper explores differences in the hypothesised mechanism between irrigation systems and fisheries.

The second paper of this thesis, 'Playing Nice in the Sandbox: on the role of heterogeneity, trust and cooperation in common-pool resources', is based on a laboratory experiment in which 344 subjects from the United Kingdom and the Netherlands make decisions in a 40-period CPR game, modelled to simulate decisions that real-life appropriators of fishing grounds face every day. The controlled laboratory setting enables for the detection of causality; something that was not possible in the first paper. While the first paper measures the separate effects of either economic and sociocultural heterogeneity while controlling for the other, the second paper adds the measurement of the effect of the combination of economic and sociocultural heterogeneity. This paper addresses the macro- and micro-level as both individual actions and collective conditions and outcomes are measured.

The third paper of this thesis, 'Using Player Types to Understand Cooperative Behaviour under Heterogeneity in CPRs: evidence from lab experiments and agent-based models', uses multilevel and ordinal logistic regression models in tandem with linear conditional-contribution profiles and agent-based models to analyse, interpret and replicate experimental outcomes. The data comes from the experiment of the second paper and a new CPR experiment conducted in India comprising 144 subjects from Mumbai and Bangalore. Both experiments have the same setup, except for the operationalisation of sociocultural heterogeneity: whereas the experiment conducted in the United Kingdom and the Netherlands (henceforth called the UKNL study) uses an artificial identity based on a trivial criterion following the Minimal Group paradigm, the experiment conducted in India (henceforth called the IND study) uses real identities and bases sociocultural heterogeneity on whether subjects are originally from Mumbai or Bangalore. This paper adds to the thesis by providing a comparison of experimental data and interpretation of results using novel tools such as player type classification and agent-based models.

The experimental data in this thesis consist mainly of students. The subject pool of the UKNL study is, as Henrich, Heine & Norenzayan (2010) point out, 'WEIRD': a sample taken from Western, Educated, Industrialised, Rich, and Democratic societies. While the subject pool of the IND study does not entirely fit this description, the message for both studies is the same: can outcomes of laboratory experiments be generalised with subject pools that mainly consist of students? Whereas it is strictly true that observed outcomes from a study only hold for the group from which the data was collected, Gächter (2010) argues that generalisability of results depends on the research question that is asked. In the current thesis, I am interested in understanding cooperative behaviour under heterogeneity in CPR settings, without the specification of a particular group of people. Whereas it is true that a subject pool of students does not represent a group of fishermen or farmers in an actual CPR, the subject pool can be informative about whether the theoretical predictions or hypotheses contain behavioural validity (Gächter, 2010). To establish a clean benchmark result on how subjects from different cultures and societies behave in the same, controlled decision situation, student subject pools are often the best readily available and cost effective choice (Bohnet, Greig, Herrmann, & Zeckhauser, 2008; Herrmann, Thöni, & Gächter, 2008). In addition, the availability and the low cost increase the ease of replication of the results (Gächter, 2010). After establishing these benchmark results of causality between treatments and outcomes, it would be interesting and important to proceed to investigate how the results extend to specific subject pools of interest (Bellemare, Kröger, & Soest, 2008; Carpenter, Connolly, & Myers, 2008; Gächter, 2009, 2010).

In the last chapter of this thesis I will summarise and discuss the findings of all three papers, place them in context with each other and place them in context of the overarching research question: does heterogeneity affect cooperation in CPRs and what is the role of trust in this process?

Taken together, this thesis forms a substantive source of information on the topic of economic heterogeneity, sociocultural heterogeneity, trust and cooperation in CPRs. It addresses external validity by using real-world metadata on CPRs, addresses internal validity by establishing causality of effects through laboratory experiments, and provides in-depth analysis and interpretation of the results through innovative imputation techniques, statistical analyses, player type classification and agent-based models. Both the macro-level and micro-level of the relation between heterogeneity, trust and cooperation in CPRs are tackled in this thesis, providing insight into the entire mechanism. The multi-method approach secures robustness of the found effects, while also highlighting the differences in results when using different methods - the latter indicating the danger of relying purely on one source and stressing the importance of multi-method approaches in research.

In a time where deforestation of tropical forests, overfishing of the seas and the general depletion of the earth's resources are the order of the day, it is important now more than ever to research when people do and do not cooperate in the use and preservation of natural and man-made resources. The outcomes of this thesis are not only relevant for classic CPRs as fisheries and irrigation systems, but also for the growing number of modern CPRs, such as citizen initiatives producing green energy and urban agriculture projects.

References

Aksoy, O. (2019). Crosscutting circles in a social dilemma: Effects of social identity and inequality on cooperation. *Social Science Research*, *82*, 148–163. doi: 10.1016/j.ssresearch.2019.04.009

Alesina, A., & La Ferrara, E. (2002). Who trusts others? *Journal of Public Economics*, *85*(2), 207–234. doi: 10.1016/S0047-2727(01)00084-6

Anderson, C. J., & Paskeviciute, A. (2006). How Ethnic and Linguistic Heterogeneity Influence the Prospects for Civil Society: A Comparative Study of Citizenship Behavior. *The Journal of Politics*, *68*(4), 783–802. doi: 10.1111/j.1468-2508.2006.00470.x

Bardhan, P., & Dayton-Johnson, J. (2002). Unequal irrigators: Heterogeneity and commons management in large-scale multi-variate research. In E. Ostrom, T. Dietz, N. Dolsak, P. C. Stern, S. Stonich, & E. U. Weber (Eds.), *The Drama of the Commons* (pp. 87–112). Washington, D. C.: National Academy Press, Washington, D. C.

Bellemare, C., Kröger, S., & Soest, A. V. (2008). Measuring Inequity Aversion in a Heterogeneous Population Using Experimental Decisions and Subjective Probabilities. *Econometrica*, *76*(4), 815–839. doi: 10.1111/j.1468-0262.2008.00860.x

Bohnet, I., Greig, F., Herrmann, B., & Zeckhauser, R. (2008). Betrayal Aversion: Evidence from Brazil, China, Oman, Switzerland, Turkey, and the United States. *American Economic Review*, *98*(1), 294–310. doi: 10.1257/aer.98.1.294

Bravo, G., & De Moor, T. (2008). The commons in Europe: From past to future. *International Journal of the Commons*, *2*(2), 155–161.

Carpenter, J., Connolly, C., & Myers, C. K. (2008). Altruistic behavior in a representative dictator experiment. *Experimental Economics*, *11*(3), 282–298. doi: 10.1007/s10683-007-9193-x

Coleman, J. S. (1987). Microfoundations and Macroscoial Behaviour. In J. C. Alexander (Ed.), *The Micro-Macro Link.*

Coleman, J. S. (1994). *Foundations of social theory.* Cambridge, MA: Harvard University Press, Cambridge, MA.

Dasgupta, F. R. P. o. E. P., & Dasgupta, P. (1982). *The Control of Resources.* Harvard University Press.

Dawes, R. M. (1980). Social Dilemmas. *Annual Review of Psychology*, *31*(1), 169–193. doi: 10.1146/annurev.ps.31.020180.001125

Delhey, J., & Newton, K. (2005). Predicting Cross-National Levels of Social Trust: Global Pattern or Nordic Exceptionalism? *European Sociological Review*, *21*(4), 311–327.

De Moor, T. (2013a). De herontdekking van het Collectief. *Samenleving en politiek*, *20*(4), 29–38.

De Moor, T. (2013b). *Homo Cooperans: Institutions for collective action and the compassionate society* [Inaugural Lecture].

Diekert, F. K. (2012). The Tragedy of the Commons from a Game-Theoretic Perspective. *Sustainability*, *4*(8), 1776–1786. doi: 10.3390/su4081776

Dong, Y., Zhang, B., & Tao, Y. (2016). The dynamics of human behavior in the public goods game with institutional incentives. *Scientific Reports*, *6*(1), 28809. doi: 10.1038/srep28809

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

Fischbacher, U., & Gächter, S. (2006). *Heterogeneous Social Preferences and the Dynamics of Free Riding in Public Goods* (SSRN Scholarly Paper No. ID 874928). Rochester, NY: Social Science Research Network.

Flache, A., & Mäs, M. (2008). Why do faultlines matter? A computational model of how strong demographic faultlines undermine team cohesion. *Simulation Modelling Practice and Theory*, *16*(2), 175–191. doi: 10.1016/j.simpat.2007.11.020

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity.* New York: The Free Press, New York.

Fung, J. M., & Au, W.-t. (2014). Effect of inequality on cooperation: Heterogeneity and hegemony in public goods dilemma. *Organizational Behavior and Human Decision Processes*, *123*(1), 9–22. doi: 10.1016/j.obhdp.2013.10.010

Gächter, S. (2009). *Improvements and Future Challenges for the Research Infrastructure in the Field "Experimental Economics"* (Working Paper No. 56). RatSWD Working Paper.

Gächter, S. (2010). *(Dis)Advantages of Student Subjects: What is Your Research Question?* (SSRN Scholarly Paper No. ID 1639334). Rochester, NY: Social Science Research Network. doi: 10.2139/ssrn.1639334

Gächter, S. (2006). Conditional cooperation: Behavioral regularities from the lab and the field and their policy implications. , 33.

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(3859), 1243–1248.

Hedström, P. (2005). *Dissecting the Social : On the Principles of Analytical Sociology.* Cambridge: Cambridge University Press.

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences*, *33*(2-3), 61–83. doi: 10.1017/S0140525X0999152X

Herrmann, B., & Thöni, C. (2009). Measuring conditional cooperation: A replication study in Russia. *Experimental Economics*, *12*(1), 87–92. doi: 10.1007/s10683-008-9197-1

Herrmann, B., Thöni, C., & Gächter, S. (2008). Antisocial Punishment Across Societies. *Science*, *319*(5868), 1362–1367. doi: 10.1126/science.1153808

International Migration report 2019 (Tech. Rep.). (2019). Department of Economic and Social Affairs, United Nations.

Janssen, M., & Baggio, J. A. (2016). Using agent-based models to compare behavioral theories on experimental data: Application for irrigation games. *Journal of Environmental Psychology*, *46*, 106–115. doi: 10.1016/j.jenvp.2016.04.003

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why Differences Make a Difference: A Field Study of Diversity, Conflict, and Performance in Workgroups. *Administrative Science Quarterly*, *44*(4), 741–763. doi: 10.2307/2667054

Kocher, M. G., Cherry, T., Kroll, S., Netzer, R. J., & Sutter, M. (2008). Conditional cooperation on three continents. *Economics Letters*, *101*(3), 175–178. doi: 10.1016/j.econlet.2008.07.015

Komakech, H. C., Van der Zaag, P., & Van Koppen, B. (2012). The dynamics between water asymmetry, inequality and heterogeneity sustaining canal institutions in the Makanya catchment, Tanzania. *Water Policy*, *14*(5), 800–820.

Kurzban, R., & Houser, D. (2005). Experiments investigating cooperative types in humans: A complement to evolutionary theory and simulations. *Proceedings of the National Academy of Sciences*, *102*(5), 1803–1807. doi: 10.1073/pnas.0408759102

Olson, M. (1965). *The logic of collective action: Pubic goods and the theory of groups.* Cambridge, MA: Harvard University Press, Cambridge, MA.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action.* Cambridge ; New York: Cambridge University Press.

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

Ostrom, E., Agrawal, A., Blomquist, W., Schlager, E., & Tang, S. Y. (1989). *CPR Coding Manual.* Indiana University, Bloomington, Indiana.

Ostrom, E., Walker, J., & Gardner, R. (1992). Rules, Games and Common-Pool Resources. *The American Political Science Review*, *86*(2), 404–417. doi: 10.2307/1964229

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community.* New York: Simon & Schuster, New York.

Putnam, R. D. (2007). E Pluribus Unum: Diversity and Community in the Twenty-first Century The 2006 Johan Skytte Prize Lecture. *Scandinavian Political Studies*, *30*(2), 137–174. doi: 10.1111/j.1467-9477.2007.00176.x

Raub, W., Buskens, V., & Van Assen, M. a. L. M. (2011). Micro-Macro Links and Microfoundations in Sociology. *The Journal of Mathematical Sociology*, *35*(1-3), 1–25. doi: 10.1080/0022250X.2010.532263

Uslaner, E. M. (2002). *The moral foundations of trust.* Cambridge: Cambridge University Press.

Zak, P. J., & Knack, S. (2001). Trust and Growth. *The Economic Journal*, *111*(470), 295–321.

Zhang, B., An, X., & Dong, Y. (2021). Conditional cooperator enhances institutional punishment in public goods game. *Applied Mathematics and Computation*, *390*, 125600. doi: 10.1016/j.amc.2020.125600

Chapter II:

Heterogeneity, Trust and Common-Pool Resource Management

Fijnanda van Klingeren

Nan Dirk de Graaf

Research published in the Journal of Environmental Studies and Sciences

https://doi.org/10.1007/s13412-020-00640-7

Abstract

Increasing migration, leading to more heterogeneous societies, may challenge the successful management of common-pool resources [CPRs] directly due to the lack of shared interests, and indirectly by reducing trust amongst local commons users, speeding up depletion of vital natural and man-made resources. Since little research has been done on this topic, we analyse the relation between economic and sociocultural heterogeneity, trust and successful commons management for fisheries and irrigation systems. Using multiple imputation with chained equations, random forests, and predictive mean matching, we adopt an innovative and technically advanced approach to employ Elinor Ostrom's famous CPR Database. Our approach enables us to include economic and sociocultural heterogeneity, trust, and control variables in one model and to investigate both direct and indirect effects of heterogeneity on CPR success, which has not been attempted before. Results show no evidence of the negative relation between heterogeneity and CPR success. However, economic heterogeneity is negatively related to trust, and trust is found to be positively related to CPR success. Evidence is found for an indirect effect of economic heterogeneity through trust on CPR success.

1 Introduction

Societies are becoming more diverse on ethnic, cultural and economic dimensions due to growing migrant populations all over the world, especially in Northern Africa, Western Asia and sub-Saharan Africa (*International Migration Report 2019*, 2019). This increasing heterogeneity may pose a challenge to the successful management of common-pool resources [CPRs] in two ways: (1) directly by diversifying interests among users and (2) indirectly by reducing trust amongst users. Both ways lead to decreased cooperation in CPRs. CPRs are natural or man-made resources - such as grasslands, communal forests, fishing grounds or irrigation systems - for which it is costly to exclude potential users (Ostrom, 1990). Different from a public good, a common-pool resource may run out, making it vulnerable to the 'tragedy of the commons' as described by Hardin (1968); a situation where the short-term dominant strategy of users is to use the limited resource unlimitedly, which leads to its decay. The effect of increasing heterogeneity on the success of CPRs, and the role of trust in this process, is still contested (Baland & Platteau, 1999; Bardhan & Dayton-Johnson, 2002; Ruttan, 2006, 2008; Varughese & Ostrom, 2001). The aim of this paper is to gain insight into whether and how two types of heterogeneity – economic and sociocultural – and their interplay with trust affect the success of a CPR, that is, its sustainable long-term use and quality of the resource.

Economic heterogeneity expresses inequalities in wealth, income and access to resources, and sociocultural heterogeneity represents disparities in language, ethnicity, religion and other cultural expressions (Baland & Platteau, 1996; Bardhan & Dayton-Johnson, 2002; Ruttan, 2006). Most research argues that economic and sociocultural heterogeneity may result in increased costs of negotiation and bargaining due to a lack of shared ideas, values and incentives between individuals or groups of individuals (Aksoy, 2019; Bardhan & Dayton-Johnson, 2002), that it may lead to unequal sharing of decision-making rights and different motivations to cooperate (Anderson & Paskeviciute, 2006; Fung & Au, 2014; Komakech, Van der Zaag, & Van Koppen, 2012), and that it may decrease social cohesion (Flache & Mäs, 2008; Jehn, Northcraft, & Neale, 1999). On the other hand, some research suggests positive effects of economic heterogeneity on the provision of collective goods, stating that it can lead to an inequality of incentives, which results in some appropriators being motivated enough to invest in collective action on their own – hereby carrying the costs of cooperation (Olson, 1965).

In order to understand the indirect relation between heterogeneity and CPR success, we introduce trust as a mediator: there is evidence that trust is influenced by heterogeneity (Alesina & La Ferrara, 2002; Delhey & Newton, 2005; Ostrom, 1990; Putnam, 2007) and that it plays an important role in influencing societal outcomes (Fukuyama, 1995; Putnam, 2000; Uslaner, 2002; Zak & Knack, 2001). We will investigate the relation between trust and CPR success, and the role of trust in the indirect relation between heterogeneity and CPR success.

This paper studies 32 fisheries and 50 irrigation systems using Elinor Ostrom's well-known Common-Pool Resource Database (Ostrom, Agrawal, Blomquist, Schlager, & Tang, 1989).[1] Considering the field of study, which typically uses in-depth case studies, this is a relatively large database (Poteete & Ostrom, 2004; Ruttan, 2006). While the CPR Database was used before to investigate the relation between heterogeneity and CPR outcomes this was done with correlations and Mann-Whitney U tests on the available data, which contains a lot of missing observations (Ruttan, 2006, 2008). Instead, the current paper uses innovative and advanced imputation techniques such as multiple imputation with chained equations, random forests and predictive mean matching to make the data suitable for including economic and sociocultural heterogeneity, trust and control variables all in the same model. This enables us to test the effects of one type of heterogeneity while controlling for the other without decreasing the sample size due to the large amount of missing data; something that - to the extent of our knowledge - has not been attempted yet in previous research using this database. On top of that, our preparation of the data allows to test both direct effects of heterogeneity and trust on CPR success and indirect effects of heterogeneity on CPR success through trust. This enables us to uncover part of the 'black box' of the theoretical mechanism.

We aim for theoretical progress in two ways. First, we test general hypotheses regarding the relation between economic and sociocultural heterogeneity and CPR success both for the combined sample and for two subsamples for fishing grounds and irrigation systems.[2] Second, we formulate and test a hypothesis regarding the relation between trust and CPR success specifically for fisheries and irrigation systems. The outcomes are relevant not only for classic CPRs as fisheries and irrigation systems, but also for the rising number of contemporary institutions for collective action on food, infrastructure, health and energy, such as citizen initiatives producing green energy and urban agriculture projects (Bravo & De Moor, 2008; De Moor, 2013a, 2013b, 2018). In a time

[1] The database can be viewed and retrieved from `https://seslibrary.asu.edu/cpr`

[2] Ruttan (2006, 2008) takes two subsamples for irrigation systems and fisheries, but does not take economic and sociocultural heterogeneity, trust and/or control variables into account in one and the same model and does not test indirect effects.

where the earth's resources are being depleted rapidly, research on success and failure of CPRs is more important than ever.

2 Existing Literature

2.1 The Negative Influence of Heterogeneity

Regarding economic heterogeneity, it is suggested that large differences in wealth may result in a loss of incentives to cooperate for less wealthy appropriators, if the benefits of cooperation are not high enough (Baland & Platteau, 1999), if there is no wealthy appropriator willing to initiate collective action, or if the wealthy appropriators turn to their exit options - alternative ways to generate income - instead (Bardhan & Dayton-Johnson, 2002; Jones, 2004; Molinas, 1998). Adding to this argument, Shanmugaratnam (1996) argues that sustainable use of CPRs is more challenging under a more unequal distribution of private wealth, as it leads to a diversification of interests amongst appropriators of the CPR. When actors have different interests, assurance mechanisms such as sanctioning are harder to implement since the actors are less likely to agree on them. However, these assurance mechanisms are needed for successful CPR management, making diversification of the interests of actors problematic. Heterogeneity in access to exit options can also have negative effects on the CPR itself: if resource appropriators have relatively rewarding earning opportunities outside of the appropriation of the resource, they may be more willing to comply with effort-restricting measures that are set in place to maintain the CPR. On the other hand, appropriators without access to exit options may not be willing to restrict their appropriation efforts as it will have a greater impact on their total income (Bardhan & Dayton-Johnson, 2002; Gaspart & Platteau, 2007). Evidence from observations and experiments supporting these arguments are manifold (Bardhan, 2000; Hackett, Schlager, & Walker, 1994; Varughese & Ostrom, 2001).

With respect to sociocultural heterogeneity, the general argument is that collective action is more likely to be established when the individuals involved have strong, multi-stranded, interpersonal relationships, share common interests and have relatively stable group memberships (Anderson & Paskeviciute, 2006; Ostrom, 1990; Ostrom, Walker, & Gardner, 1992; Varughese & Ostrom, 2001). Furthermore, Anderson and Paskeviciute (2006) consider heterogeneity to be an impediment to cooperation, as people feel threatened by others who are not part of their 'ingroup'.

If subgroups of appropriators within a CPR differ in ownership of assets, skills, knowledge or sociocultural characteristics, it is likely that these subgroups also differ in interests and preferred use of the resource. Johnson and Libecap (1982) illustrate this in a case study concerning fishermen:

fishermen with more skills and knowledge on trawling speed, how to set traps, and the best locations for a good catch turn out to be the more successful fishermen. This heterogeneity in productivity will lead to different points of view regarding uniform fishing quotas and other restricting policies on resource use, thus to higher transaction costs and a higher probability of conflict. Differences between resource users can make it hard to reach agreements on the making and enforcing of rules due to a lack of mutual trust and the inability to understand each other. It can be reason for conflict and thus impedes collective action (Carpenter & Cardenas, 2011; Gehrig, Schlüter, & Hammerstein, 2019; Johnson & Libecap, 1982; Keuschnigg & Schikora, 2014; Ostrom, 1990; Varughese & Ostrom, 2001). For instance, farmers may have different interests than nomads when it comes to the use of the resource, and men and women may have different actual and perceived costs and benefits, caused by a long history of gender inequality (Agarwal, 1994, 1997; Molinas, 1998; Varughese & Ostrom, 2001).

Nettle and Dunbar (1997) focus on another aspect of sociocultural background, namely language; they state that speaking the same language facilitates a feeling of social allegiance, which is deemed important for the maintenance of group cohesion. Evidence in favour of these arguments is found by Wiessner (1977) with respect to language differences between tribes in Botswana. Another example of sociocultural homogeneity having a positive effect on sustainable cooperation, is given by Singleton (2001) in an analysis of contemporary Pacific Northwest salmon fishing. The study describes how homogeneous Aboriginal tribes were very efficient and sustainable in the appropriation of salmon fishing grounds, despite the sometimes unequal economic results between individual members. The study describes how conflicts about appropriation only arose between Aboriginal tribes and the state. Based on a survey study of group membership in the US, Alesina and La Ferrara (2000) concluded that residents from racially heterogeneous communities participate less in social activities. Carpenter and Cardenas (2011), employing a laboratory experiment with Colombians and Americans, discovered that mixed groups cooperate less than homogeneous groups. Keuschnigg and Schikora (2014) found in a study using Public Good Games that religious heterogeneity decreases cooperation in the presence of a leader: whereas a generous contribution of leaders in homogeneous groups is met with reciprocity from the followers, this was not the case in heterogeneous groups. Vermillion (1999) mentions that the absence of social divisions is a requirement for collective action amongst farmers in devolution programs of irrigation systems, in which rights and responsibilities are transferred from the government to local water user groups. Lastly, Gaspart and Platteau (2007) concluded on basis of their case study of Senegalese fisheries that the division between native and migrant appropriators forms an insuperable problem for cooperation and mutual trust. Here, agreement on regulatory schemes has become nigh impossible.

Although the literature theoretically and empirically suggests predominantly a negative effect of heterogeneity, there are arguments for a positive effect, indirectly based on a well-known theory by Olson (1965), also known as the "Olson-effect":

> In smaller groups marked by considerable degrees of inequality - that is, in groups of members of unequal "size" or extent of interest in the collective good - there is the greatest likelihood that a collective good will be provided; for the greater the interest in the collective good of any single member, the greater the likelihood that that member will get such a significant proportion of the total benefit from the collective good that he will gain from seeing that the good is provided, even if he has to pay all of the cost himself. (Olson, 1965, p. 34)

Although the link with economic heterogeneity cannot directly be distilled out of this quote, it is often interpreted as an argument in favour of a positive effect of economic heterogeneity on collective action; those with higher incomes will act as catalysts for collective action because they can afford it, and it is in their interest to do so (Baland & Platteau, 1997, 1999; Bardhan & Dayton-Johnson, 2002; Jones, 2004; Ruttan, 2006, 2008). In addition, it is likely that the Olson-effect will only take place when inequality is large, and there are actors that are indeed so rich that they can afford to pay to see collective action happen. It is unlikely that there are many of these cases in the CPR Database. Based on the discussed literature we therefore expect negative effects to be more probable. Hence our first hypothesis reads:

Hypothesis 1 *(a) Economic and (b) sociocultural heterogeneity have a negative relation with CPR success*

2.2 The Role of Trust

A variable that we consider to play a role in the indirect effect of heterogeneity on CPR success is trust. The first part of the argument, illustrating the relation between heterogeneity and trust, is that people are more likely to trust someone who is more similar to themselves (Alesina & La Ferrara, 2002; Coleman, 1994), implying more mutual trust in a more homogeneous setting and less mutual trust in a heterogeneous one. People tend to trust members of their family and members of the same ingroup; be it racial, social, ethnic or based on something else (Alesina &

La Ferrara, 2002; Romano, Balliet, Yamagishi, & Liu, 2017). Many studies point out a negative association between heterogeneity and trust. For instance, in their study using individual level data from the United States, Alesina and La Ferrara (2002) observe a negative relation between social distance and trust. Their results suggest that being economically unsuccessful and living in a neighbourhood with a high degree of income inequality reduces trust. Delhey and Newton (2005) find that general trust is closely related to homogeneity in religious, cultural, social and political identification as well as to economic equality. Similarly, Gehrig, Schlüter and Hammerstein (2019) find in a lab-in-field CPR experiment in Zanzibar that less trusting fishermen overexploit the CPR more in heterogeneous groups, while they cooperate and achieve sustainable use of the resource in homogeneous groups. Regarding causality, Leigh (2006a, 2006b) uses an instrumental variable approach in two studies to show that increasing inequality and ethnic and linguistic fractionalisation reduce trust. Adding to that, Romano et al. (2017) find in a series of trust games in 17 countries that people are generally more trusting towards ingroup members than towards outgroup members.

The second part of the argument concerns the relation of trust with positive societal outcomes - in our case CPR success. Societies with high levels of trust amongst individuals have a lesser need for the individuals to protect themselves from being taken advantage of by others in transactions (Knack & Keefer, 1997). Instead of formal institutions, mutual trust amongst individuals facilitates the use of informal agreements, leading to a decrease in transaction costs and a greater likelihood of economic efficiency and success (Alesina & La Ferrara, 2002; Knack & Keefer, 1997; Zak & Knack, 2001). Next to economic success, trust is known to promote cooperation and participation in social activities (Alesina & La Ferrara, 2000; La Porta, Lopez-de-Silanes, Shleifer, & Vishny, 1997; Romano et al., 2017). Regarding the causal direction of the effects of trust, Acedo and Gomilla (2013) find in an experiment involving an iterated Prisoner's Dilemma that higher trust results in higher levels of cooperation. Likewise, Gächter, Herrmann and Thöni (2004) find that more trusting people contribute more than less trusting people in three-person one-shot public good games.

Summarising, we hypothesise that:

Hypothesis 2 *(a) Economic and (b) sociocultural heterogeneity have a negative relation with trust*

Hypothesis 3 *Trust has a positive relation with CPR success*

Hypothesis 4 *(a) Economic and (b) sociocultural heterogeneity have a negative indirect relation with CPR success through trust*

2.3 The Relevance of Sector Type

The cases analysed in this paper are either fisheries or irrigation systems. These two types of CPR vary in a multitude of aspects, which may influence the way heterogeneity and trust impact their success. Firstly, whereas fishing grounds can be considered natural resources, irrigation systems are entirely man-made. This influences the way appropriators see the resource: an open-access resource available to everyone versus a self-made system only available to the ones who are granted access and/or are contributing to its maintenance (Gaspart & Platteau, 2007). Secondly, whereas there are many different techniques to appropriate a fishing ground, which can be cause for conflict between appropriators (Gaspart & Platteau, 2007), irrigation systems work one way for all users. Thirdly, while mutual monitoring for irrigation systems is easy, this is more difficult for fishing grounds, where fishing boats cannot see each other during appropriation and where illegal appropriation forms a daily threat to the success of the CPR (Gaspart & Platteau, 2007; Regmi, 2007).[3] Fourth, while the resource flow of a fishing ground can be considered relatively stable - conditional on the resource not being nearly depleted -, the flow of water coming from the river that provides water to the irrigation system is less predictable (Regmi, 2007). This poses a challenge for devising appropriation rules. For fishing grounds, many countries impose individual fishery quotas to improve sustainability of fishing activities (Sanchirico, Holland, Quigley, & Fina, 2006) or even moratoriums until specific fish populations regrow (see for instance Jiang, Cheng, & Li, 2009; Khan, Gray, Mill, & Polunin, 2018; Palmer & Sinclair, 2008). However, these rules do not necessarily make sense for an irrigation system since the total discharge of a river is likely to change over time and is less dependent on use by farmers and more dependent on external factors such as the weather. Instead, time-allocation rules are used that can vary depending on the availability of water (Regmi, 2007). Fifth, whereas a fishing ground does not require much - if any - maintenance, irrigation systems do: man-made components such as check-gates have to be checked regularly and fixed when broken. The government will take care of the maintenance if the system is government owned, but for systems that are not government owned this requires farmers to work together (Vermillion, 1999). This type of collective action is not required for fishermen, whose profits are not dependent on each other in this way. Lastly, a big difference between fishing grounds and irrigation systems is the constant disadvantage of appropriators in an irrigation system that are located downstream as

[3] This problem may be solved to an extent with modern technologies such as Vessel Monitoring Systems [VMS] and Automatic Identification Systems [AIS], used to track fishing vessels. However, our data comes from before 1990, when neither VMS nor AIS were in use.

opposed to at the head of the river (Ostrom, 1990; Regmi, 2007). The appropriators upstream are the first ones to receive water and are the least likely to be disadvantaged when other appropriators overexploit the resource. The appropriators downstream, on the other hand, will experience the worst consequences of overexploitation of the resource by more upstream appropriators. Whereas fisheries usually have a rotation system of sorts to equalise appropriation time at better spots, this is not possible for irrigation systems (Ostrom, 1990; Regmi, 2007). A table describing differences in nature and various characteristics between fishing grounds and irrigation systems using variables from the CPR Database can be found in Appendix A.

The differences between the two sector types may have implications for the expected effects of trust on CPR success: due to almost automatic mutual monitoring and the closed-access and man-made nature of the irrigation system, trust amongst appropriators may be less vital in order for this resource to be successful. For fisheries however, trust amongst appropriators may play a more important role in reaching sustainable appropriation, as appropriators would need to trust each other not to overexploit the resource while not being able to see each other, or each other's actions, straight away. Based on the above we draw the following hypothesis:

Hypothesis 5 *The relation of trust with CPR success is stronger for fishing grounds than for irrigation systems*

3 Data & Methods

3.1 Data

We use the Common-Pool Resource Database compiled by Elinor Ostrom and her team (1989) to test our hypotheses. This database is based on a bibliography comprising over 1800 published and unpublished original CPR case studies from before 1990. A small subset of this bibliography was selected,[4] and coded into the CPR Database using extensive survey forms containing over 600 questions on topics such as geographic and demographic features of the CPR location, boundaries and physical characteristics of the CPR, the situations faced and actions performed by appropriators of the CPR, and the strategies of appropriators in subgroups (Ostrom, 1990; Ostrom et al., 1989; Schlager, 1990; Tang, 1989)). It was required that the material is written "by a researcher who has spent considerable time in the field" (Ostrom et al., 1989, p. 10) and that the material contains

[4]Selection criteria are that the case study is the result of "extended fieldwork and that information be provided about (1) the structure of the resource system, (2) the attributes and behaviors of the appropriators, (3) the rules that the appropriators were using, and (4) the outcomes resulting from the behaviors of the appropriators" (Ostrom, 1990, p. xv).

"key information about the structure of the resource, the rules used in organising the resource, the strategies adopted by the appropriators, and the outcomes achieved" (Ostrom et al., 1989, p. 10). This way, 40 person-years of fieldwork, conducted by researchers interested in the field of CPRs, such as social scientists, historians and engineers, are captured in one database (Ostrom et al., 1989). The first major publication based on the CPR Database is Elinor Ostrom's *Governing the Commons* (1990), contributing to the Nobel Memorial Prize in Economic Sciences that she won together with Oliver E. Williamson for her analysis of economic governance in CPRs. The database contains 32 fisheries and 50 irrigation systems for analysis of the variables of interest for this paper. The three CPRs that are neither fisheries nor irrigation systems are not included in this paper since they lack observations for making a comparison between sector types. The CPRs are located in 29 different countries from all over the world, although many are situated in the Middle East and Asia. A table comprising the cases and their sources used in this study can be found in Appendix B.

3.2 Measurements

Many of the variables that are available in the database are recorded for both the beginning and the end of a period of time during which "the actions of the appropriators are relatively consistent" (Ostrom et al., 1989, o. 352). These periods are of variable length, and different survey forms are provided for each period. These period forms, or 'time slices', are the observations in the database. Of the 82 separate CPRs that will be used for our analyses, seven have more than one period form filled out, so more than one time slice; this means that researchers conducting the case study found that during their study several periods could be distinguished with specific information on the CPR for each of the periods. Separate periods are considered as different observations since this period-specific information would get lost otherwise. Though the data has a multilevel structure - subgroups nested in time slices nested in CPR cases - we take all variables on the time slice level: variables used in the analysis are either original CPR-level variables for a specific period or aggregated subgroup-level variables for that period. We do this because not all CPRs have multiple time slices or multiple forms coded for their separate subgroups: there are 123 forms for 82 CPRs, existing of 95 cases due to the extra period files.[5] Cases that are twice in the database

[5]The seven items used for sociocultural heterogeneity are, according to the codebook, only filled out if there are multiple subgroups present in the CPR (Ostrom et al., 1989). We thus assume that for each case there are multiple subgroups; since even for cases without an extra coding form, at least one of the seven items are still filled out. Even if there is one subgroup, filled out items about sociocultural heterogeneity provide information on the levels of heterogeneity in that CPR.

due to multiple coding forms for different subgroups are deleted, as we only use the aggregate information, which otherwise would be duplicate. The three cases that are neither fisheries nor irrigation systems are removed. In total the number of observations that can be used for analyses is $N = 92$. If variables are recorded for both the beginning and the end of the period, the variables for the *end* of the period will be used (following Ruttan, 2006, 2008). See the CPR Coding Manual for a more detailed description of the data (Ostrom et al., 1989).

3.3 Dependent Variables

Unit quality: This variable is operationalised with an item indicating the 'quality of the units that are withdrawn from the resource'. There are five answering categories, ranging from 'extremely poor quality' (0), to 'extremely high quality' (4). The quality of the appropriated units is an indicator of the quality of the resource in general, and thus represents a substantive part of the success of the CPR.

Balance: This variable is operationalised with an item indicating the 'balance between the quantity of [resource] units withdrawn and the number of units available in the resource'. There are five answering categories, ranging from 'extreme shortage' (0) to 'quite abundant' (4). The balance between withdrawal and renewal of the resource indicates the health of the resource as well as the sustainability of the behaviour of the appropriators, and thus represents another substantive part of the success of the CPR.

3.4 Independent Variables

Sector type: This independent variable indicates whether the CPR is an irrigation system (1) or not (0). Since the database exists only of irrigation systems and fishing grounds, the variable can be interpreted as being an irrigation system (1) versus a fishing ground (0). In the regression tables, this variable will be named "Irrigation" for the main effects and will be abbreviated to "Irr." when used in an interaction effect.

Economic heterogeneity: The independent variable economic heterogeneity is operationalised as the highest level of variation in income within any subgroup within a CPR time slice (cf. Ruttan, 2008). The item on variation in income has three categories, ranging from 'low' (0) to 'moderate' (1) to 'high' (2).

Sociocultural heterogeneity: This independent variable consists of the maximum value found per time slice in any of seven items: the extent to which ethnic, racial, religious, caste, clan and gender identification and the language spoken affect communication between subgroups.[6] All seven items have the same five-point response scale ranging from 'no difference along this variable' (0) to 'large differences which significantly affect communication' (4).

Trust: This variable serves as both independent and dependent. It is an item indicating the extent of mutual trust amongst appropriators within the CPR on a three-point scale, with the categories 'low levels of trust' (0), 'modest levels of trust' (1) and 'moderate to high levels of trust' (2).

3.5 Control Variables

The following control variables were added to the final unit quality and balance models because they could influence success of the CPR: cultural view of the resource, number of users of the resource, closed access to the resource, opportunities for exit options, monetary, physical and social sanctions, pollution, level of financial pressure for immediate returns from the CPR, dependence on CPR for family income, the presence of consistently disadvantaged appropriators who are cut off from benefits, and variation in availability of units over space. A more detailed description of the variables can be found in Appendix C. Since most variables have no significant relations with the outcome variables, these models are not considered for the interpretation of the results but are presented in Appendix C.

[6] We take this approach following Ruttan (2006) with the same rationale; we are interested in any kind of socio-cultural heterogeneity that may take place, not in all of them at the same time.

To visualise the data, Table 1 shows the descriptive statistics for all main and control variables that were used in the analyses.[7]

Table 1: Descriptive statistics: key variables above line, control variables below line

	Mean	Mode	Range	Min	Max
Unit Quality	2.27	2	[0,3]	1	3
Balance	1.75	2	[0,3]	0	3
Economic heterogeneity	0.837	1	[0,2]	0	2
Sociocultural heterogeneity	1.14	1	[0.4]	0	4
Trust	1.66	2	[0,2]	0	2
Cultural view of resource	1.26	1	[1,5]	1	5
Number of users	127.83			1	800
Closed access	2.04	1	[1,7]	1	6
Exit options	2.66	1	[1,6]	1	5
Monetary sanctions	3.67	4	[1,5]	1	5
Physical sanctions	2.65	2	[1,5]	1	5
Social sanctions	3.89	4	[1,5]	1	5
Pollution	1.01	0	[1,4]	1	2
Pressure	0.07	0	[0,1]	0	1
Income dependence	2.64	3	[1,3]	1	3
Worst off	0.92	1	[0,1]	0	1
Variation over space	0.23	0	[0,1]	0	1

3.6 Analytical Strategy and Causality

To test the hypotheses, OLS regression will be used and the unstandardised coefficients will be interpreted. Even though the variables unit quality, balance, economic heterogeneity, sociocultural heterogeneity, and trust are not continuous but ordinal, we will consider them continuous in the interest of simplicity of interpretation of the models. This allows us to retain statistical power - especially given the small sample size in the subsamples - by reducing degrees of freedom. In addition, it allows us to calculate indirect effects in a meaningful way. Following argumentation of amongst others Pasta (2009) and Williams (2018) on treating ordinal independent variables as continuous, a likelihood-ratio test was completed to establish whether the models would significantly differ between treating the variables as ordinal or continuous (see Williams (2018) for a more extensive explanation of the test). The test concluded that economic heterogeneity, sociocultural

[7] Due to the nature of the data, i.e. being 100 imputed datasets, the descriptive statistics are taken from the 'average dataset'. This dataset is derived by taking the mean of numeric variables, and the mode of factor variables of the 100 imputed datasets.

heterogeneity, and trust can be treated as continuous in the models.[8] Ordinal logistic regression was also performed, with ordinal independent variables added as dummies. These models can be found in Appendix D. The main results from the OLS analyses are largely supported by the more conservative ordinal logistic models. In addition, a robustness check was performed with an alternative operationalisation of economic and sociocultural heterogeneity, by taking the mean per time slice of the variation of income in CPR subgroups for economic heterogeneity and the mean of the seven sociocultural heterogeneity items instead of the maximum value. The results are very similar to the OLS models and can be found in Appendix E. Relations found in the OLS models that are not backed up by the ordinal logistic models or the robustness check models will not be considered robust.

Part of the analytical strategy is to analyse the entire sample, including both fisheries and irrigation systems, as well as two subsamples of fisheries- and irrigation-only cases. This allows us to look at the general picture as well as to look at associations between variables that may be specific to the sector type. Questions that may arise after looking at the combined sample may be answered when looking at the separate samples. In addition, analysing the combined sample allows us to not miss out on the detection of associations between variables by retaining statistical power compared to the subsample analyses, given the small sample size. To test hypothesis 5 regarding the differences in the effect of trust on CPR success between fishing grounds and irrigation systems, an interaction between trust and sector type [Irr. x Trust] is added in addition to measuring the effect of trust in the two subsamples.

Although causal phrases are used throughout the discussion of the results, the observational data only allows to test associations, and causal conclusions can in principle not be drawn. However, we have some confidence in the assumed causal directions. Even though one could argue that trust could bring homogeneity about instead of homogeneity inducing trust, it is important to realise that sociocultural heterogeneity (ethnic, racial, clan, caste, religious and gender identification and the language spoken) is rather fixed, as is economic inequality, although less so. Hence, in this respect we have some confidence in the assumed causality (see also Leigh (2006a, 2006b) and Romano et al. (2017)). With respect to trust and CPR success, it might also be possible that a high score on CPR unit quality and balance increases trust. However, experimental research of Acedo and

[8] A likelihood-ratio tests between a constrained model treating the variables as continuous variables and an unconstrained model treating the variables as factors (Williams, 2018) was performed for each iteration of the imputed dataset, and the p-values were plotted. For each test, the average p-value was higher than $\alpha = 0.05$, hence we conclude that treating economic heterogeneity, sociocultural heterogeneity and trust as factor variables does not improve significantly on treating them as continuous variables.

Gomilla (2013) and Gächter, Herrmann and Thöni (2004) discussed earlier, provides evidence for the causal direction reflected in our hypotheses.

3.7 Multiple Imputation: mice, random forests, and predictive mean matching

All main independent variables have missing values - some more than others. The missingness of the independent variables is not correlated with relevant variables in the model. We assume the missing values to be missing at random [MAR] (Rubin, 1987) and not dependent on unobserved data. For instance, the missingness of the variable economic heterogeneity is assumed to be a consequence of the way the data was constructed; the data is based on a survey that was filled out on the basis of information given by published case studies. Many case studies did not provide information on the variance of family incomes within CPRs, and the missingness is thus more likely related to the research objective of the case study or external factors rather than unobserved variables that could be of importance to the analyses and interpretation of results (see also Dong & Peng, 2013). It is likely that a similar story holds for missing observations for other variables. This is, however, an untestable assumption. To prevent having to perform analyses on a smaller sample size than 92 cases due to missing observations in key variables, multiple imputation with chained random forests [RFs] (Breiman, 2001; Van Buuren, 2019) was performed, using the *MissRanger* package in *R* (Mayer, 2019), an adaptation of the *MissForest* package by Stekhoven and Bühlmanm (2012) using the *Ranger* package (Wright, Wager, & Probst, 2019). RF imputation accommodates non-linearities and interactions and does not need a specific regression model to be defined. Predictive Mean Matching [PMM] was used to fill in the missing values with realistic imputations, that is, avoiding the imputation of continuous values in a discrete variable, for each iteration. PMM also enables imputed values to be endowed with realistic levels of local variability, effectively raising the variance of the resulting RF-estimated conditional distributions to a more realistic level (Mayer, 2019). We created 100 simulations and ensured the chained RFs would stop re-fitting after 30 iterations, though in every simulated imputed dataset, this procedure took at most 5 iterations, suggesting quick convergence to optimally imputed values. Imputation diagnostics, including the 'out of bag error' [OOB][9] distribution per imputed variable, were inspected for key variables and supported our confidence in the imputation model. Research comparing *MissForest* imputation to other imputation techniques shows that *MissForest* performs well and in a lot of cases better

[9] The out of bag error is the mean prediction error on each training sample; for a categorical variable it means 'how often is a 'wrong' class imputed in a variable' and for continuous variables it is 1 - R^2 , that is, the unexplained variance (Stekhoven & Bühlmann, 2012).

than other established imputation techniques, even when applied to data with up to 30% missing values (Stekhoven & Bühlmann, 2012). As the current database has 28% missing data, using the *MissRanger* package based on the *MissForest* package is well suited. By making use of multiple imputation, both sociocultural and economic heterogeneity can be included in one model without reducing the sample size. The value of including both forms of heterogeneity in the model is that the risk of overestimating the influence of one by not controlling for the other is reduced.

Table 2 provides insights in the original versus the imputed dataset. The adjusted R^2 including the 95% confidence interval is provided for the models where possible.[10] In addition, the fraction of missing information [FMI] is reported for the models where it was possible to calculate, providing information on the uncertainty about the missing data, which affects the pooled standard errors (Pan & Wei, 2016; Wagner, 2010). These statistics are retrieved using the pool function of the *Mice* package (Van Buuren, 2019). In addition, the Akaike information criterion [AIC] will be reported for every model. Lastly, tables stating the FMI per variable for main models will be provided in Appendix F.

[10]For some of the subsample models, adjusted R^2 and FMI could not be calculated, as the Fisher transformation for pooled simulations could not be performed since some of the simulations had a negative R^2.

Table 2: Imputed data statistics: key variables above line, control variables below line

	Observations per simulation 1:100						
	Complete	Incomplete	Imputed	Total	Used N^*	OOB mean	OOB s.d.
Economic heterogeneity**	-	-	-	123	92		
Income variance	65	58	58	123	92	0.13	0.02
Sociocultural heterogeneity**	-	-	-	123	92		
Ethnic identification	101	22	22	123	92	0.00	0.01
Race identification	101	22	22	123	92	0.02	0.00
Religious identification	88	35	35	123	92	0.03	0.01
Gender identification	101	22	22	123	92	0.04	0.01
Clan identification	92	31	31	123	92	0.10	0.01
Caste identification	71	52	52	123	92	0.06	0.01
Language spoken	115	8	8	123	92	0.01	0.01
Unit quality	118	5	5	123	92	0.05	0.01
Balance	119	4	4	123	92	0.11	0.02
Trust	112	11	11	123	92	0.06	0.01
Cultural view of resource	102	21	21	123	92	0.08	0.01
Pollution	91	32	32	123	92	0.01	0.00
Pressure	37	86	86	123	92	0.05	0.01
Income dependence	97	26	26	123	92	0.07	0.01
Variation over space	105	18	18	123	92	0.02	0.01
Worst off	74	49	49	123	92	0.01	0.00
Exit options	80	43	43	123	92	0.12	0.01
Social sanctions (informal)	72	51	51	123	92	0.17	0.02
Physical sanctions (informal)	64	59	59	123	92	0.17	0.02
Formal sanctions	62	61	61	123	92	0.22	0.02
Number of users	102	21	21	123	92	0.37	0.03

**Used N is the total number of cases (123; all CPR types plus duplicates due to multiple subgroup forms) minus duplicates (-28), minus other sector types (-3), but keeping the different 'time slices' as mentioned before.*
***These variables were constructed after multiple imputation, before deleting duplicates*

4 Results

In this section, Spearman's rank correlations will be discussed to get an initial idea of the relation between variables. To test the hypotheses, we will conduct OLS regressions for the combined sample of both fishing grounds and irrigation systems, and the two subsamples separately. Both direct and indirect effects will be discussed. Lastly, the robustness of the found results is assessed by crosschecking the OLS regressions with the ordinal logistic regressions and the OLS regressions with the alternative operationalisation of the heterogeneity variables, which can be found in Appendix D and E respectively.

4.1 Correlations

Table 3 shows the relation between key variables using Spearman's rank correlation. The table shows the average coefficients over 100 imputed datasets and includes the standard errors in parentheses. The same table for the available case data is shown in Appendix G, showing very similar results. It is shown that economic heterogeneity is significantly negatively correlated with trust in all three samples. In addition, it is negatively correlated with balance in the combined and irrigation system sample. Sociocultural heterogeneity is negatively correlated with trust in the combined sample and the irrigation sample and negatively correlated to balance and unit quality in the irrigation sample. Trust has a positive relation to both CPR success outcomes in all three samples except unit quality in irrigation systems. So far, the results partially support hypothesis 2a, 2b and largely support hypothesis 3. Only limited support is found for hypothesis 1a and 1b. Hypothesis 5 does not hold for balance but could yet hold for unit quality.

Table 3: Spearman correlation for main variables

	Combined Sample			Fishing Grounds			Irrigation Systems		
	Unit Quality	Balance	Trust	Unit Quality	Balance	Trust	Unit Quality	Balance	Trust
EH	-0.09	-0.20†	-0.40***	-0.18	-0.04	-0.39*	0.00	-0.36*	-0.54*
	(0.07)	(0.06)	(0.06)	(0.10)	(0.09)	(0.07)	(0.07)	(0.09)	(0.01)
SH	-0.04	-0.17	-0.23†	-0.12	-0.15	-0.05	-0.25†	-0.33*	-0.42*
	(0.07)	(0.06)	(0.07)	(0.10)	(0.11)	(0.01)	(0.01)	(0.06)	(0.08)
Trust	0.23*	0.44**	-	0.47**	0.33*	-	-0.14	0.51***	-
	(0.03)	(0.03)	-	(0.07)	(0.03)	-	(0.02)	(0.05)	-
N	92	92	92	40	40	40	52	52	52

Standard errors in parentheses
*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

4.2 Combined Sample Results

The OLS regression models on CPR success using the imputed data are presented in Table 4. Model 1 and model 2 show that irrigation systems have significantly lower scores on unit quality (B = -0.53, p < .001) and balance (B = -0.52, p = 0.005) than fishing grounds, indicating that there may be fundamental differences in success variables between the sector types. Model 3 and model 4 include the effect of sociocultural and economic heterogeneity and show that there is no significant relation between either sociocultural or economic heterogeneity and unit quality or balance, so far thus rejecting hypotheses 1a and 1b stating a negative relation of heterogeneity with CPR success.

Model 5 and model 6 include the effect of trust; model 5 shows a significant relation between trust and unit quality (B = 0.20, p = 0.040) and model 6 shows a significant relation between trust and balance (B = 0.54, $p < .001$), supporting hypothesis 3 stating that higher levels of trust are associated with CPR success. To test hypothesis 5, model 7 and 8 include the interaction effect between trust and sector type. Model 8 shows no improvement in fit, but model 7 shows an increase from 0.28 to 0.39 for the adjusted R^2. The main effect of trust on unit quality, thus the relation between trust and unit quality in fishing grounds, is significant and positive (B = 0.53, $p < .001$), adding to the support for hypothesis 3. The interaction effect is significant and negative (B = -0.57, $p < .001$) indicating that the relation between trust and unit quality for irrigation systems is basically zero and thus that trust amongst appropriators in a fishing ground may play a bigger role in achieving high levels of unit quality than in irrigation systems.[11] This result only partially supports hypothesis 5; only in the case of unit quality. The main effect of trust on balance in model 8, thus the relation between trust and balance for fishing grounds, is marginally significant and substantive (B = 0.43, p = 0.053), indicating a 0.43 unit increase on a five-point scale of balance per increased unit of economic heterogeneity. Model 9 shows that economic heterogeneity (B = -0.32, p = 0.004) has a significant negative relation with trust, supporting hypothesis 2a. No evidence for hypothesis 2b is found. Lastly, model 10 shows that there is no significant main effect of sector type on trust, indicating that irrigation systems and fisheries do not necessarily differ in levels of trust, even though trust within each sector type may affect CPR success differently.

The indirect effects of economic heterogeneity on unit quality and balance through trust are calculated manually, using Sobel's (1982) Product of Coefficients Approach for the coefficient, and Monte Carlo simulations for the standard error and two-sided p-value.[12] Taking the coefficient of trust for fisheries from model 7, we calculate a significant indirect effect of economic heterogeneity on unit quality through trust (B = -0.17, p = 0.017). [13] Using the trust coefficient for irrigation systems, we find a significant indirect effect of economic heterogeneity on balance through trust (B = -0.20, p = 0.033). These results partially support hypothesis 4a stating the negative indirect

[11] The main effect of trust for irrigation systems in model 7 is the main effect for trust (B = 0.53) minus the interaction coefficient (B = -0.59) which adds up to an effect of B = -0.06.

[12] Since the distribution of the product can be considered normal, as the product yields the same outcome as the Difference Between Coefficients approach by Judd and Kenny (1981) (see also MacKinnon, Warsi, & Dwyer, 1995), a Monte Carlo simulation was used, with 100,000 observations using two normal distributions based on the respective coefficients and standard errors of economic heterogeneity on trust and trust on unit quality or balance, after which a z-score, t-score and the two-sided p-value of the indirect effect could be calculated.

[13] The combined sample is used, but as the main effect of trust in models 7 and 8 is interpreted as the main effect of trust for fisheries, due to the addition of an interaction effect of sector type (irrigation system = 1) and trust. The main effect of trust for irrigation systems is now the main effect of trust minus the interaction term coefficient. Hence, we can and must specify indirect effects of heterogeneity through trust for each sector type separately.

effect of economic heterogeneity on CPR success through trust, but as no other significant indirect effects are found for the combined sample, the supportive evidence for hypothesis 4a is very limited and hypothesis 4b is so far rejected. To check the robustness of the tests for the indirect effects, moderated mediation models using the *mediate* function in the statistical software *R* were applied (Tingley, Yamamoto, Hirose, Keele, & Imai, 2014), to test the difference in mediation effects of heterogeneity through trust on CPR success between fishing grounds and irrigation systems.[14] The results support the found indirect effects and can be seen in Appendix H.

Table 4: OLS regression on main variables and interaction effect using the imputed sample of both fisheries and irrigation systems

	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Unit Quality	(6) Balance	(7) Unit Quality	(8) Balance	(9) Trust	(10) Trust
Irrigation	-0.53***	-0.52**	-0.54***	-0.55**	-0.51***	-0.47**	0.45	-0.78		-0.16
	(0.10)	(0.18)	(0.10)	(0.18)	(0.10)	(0.17)	(0.28)	(0.49)		(0.13)
Irr. × Trust							-0.58***	0.18		
							(0.16)	(0.28)		
Trust					0.20*	0.54***	0.53***	0.43†		
					(0.09)	(0.15)	(0.13)	(0.22)		
SH			-0.06	-0.21	-0.02	-0.10	-0.07	-0.09	-0.19	-0.20
			(0.09)	(0.15)	(0.09)	(0.14)	(0.09)	(0.15)	(0.14)	(0.14)
EH			-0.05	-0.21	0.01	-0.04	0.00	-0.03	-0.32**	-0.31**
			(0.08)	(0.15)	(0.08)	(0.15)	(0.08)	(0.15)	(0.10)	(0.10)
Constant	2.57***	2.03***	2.70***	2.50***	2.25***	1.26***	1.74***	1.43**	2.17***	2.28***
	(0.08)	(0.14)	(0.15)	(0.26)	(0.27)	(0.45)	(0.29)	(0.50)	(0.19)	(0.20)
Adj.^{2}	0.24	0.08	0.24	0.14	0.28	0.25	0.39	0.25	0.19	0.19
95% CI Adj.^{2}	(0.98, 0.40)	(0.01, 0.21)	(0.10, 0.41)	(0.02, 0.31)	(0.13, 0.45)	(0.10, 0.42)	(0.21, 0.56)	(0.10, 0.42)	(0.03, 0.40)	(0.03, 0.40)
FMI	0.04	0.05	0.10	0.26	0.11	0.16	0.27	0.16	0.48	0.48
AIC	-137.80	-25.28	-136.74	-29.95	-142.52	-38.54	-159.67	-37.18	-98.90	-99.02
N	92	92	92	92	92	92	92	92	92	92

Standard errors in parentheses
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

4.3 Separate Sample Results

Table 5 shows the models testing the hypotheses separately for the fishing ground sample ($N = 40$) and the irrigation system sample ($N = 52$). In the fishing ground sample, a positive significant relation between trust and unit quality (B = 0.54, p = 0.004) in model 3 and a marginally significant

[14] Due to incompatibility of the moderated mediation analysis with the *Mice* paradigm and computational tools, we cannot obtain pooled standard errors for the estimates of the moderated mediation. As a result, we resolve to fit the moderated mediation to a representative dataset; this dataset is derived by taking the mean of numeric variables, and the mode of factor variables of the 100 imputed datasets, to create an average dataset.

relation between trust and balance (B = 0.50, p = 0.062) in model 4 are found. Both results add to the support for hypothesis 3. A marginally significant relation between economic heterogeneity and trust is visible (B = -0.28, p = 0.071) in model 5. Although not significant at the 5% level, it is a substantive effect of a 0.28 point decrease in the three-point scale of trust per increased unit of economic heterogeneity, providing modest support for hypothesis 2a.

With respect to the irrigation system sample, a hint of the indirect effect of economic heterogeneity by trust can be seen from model 2, 4 and 5. Model 2 shows a marginally significant negative relation of economic heterogeneity and balance (B = -0.35, p = 0.10), modestly supporting hypothesis 1a. Model 4 shows a significant relation of trust and balance (B = 0.59, p = 0.007), supporting hypothesis 3. In addition, it shows the disappearance of the significance of economic heterogeneity. Lastly, model 5 shows a significant negative relation between economic heterogeneity and trust (B = -0.29, p = 0.050), providing some support for hypothesis 2a. Possibly, the results support hypotheses 4a for balance: the disappearance of the significant effect of economic heterogeneity from model 2 to 4 combined with the significant negative relation between economic heterogeneity on trust could be an indicator of an indirect effect of economic heterogeneity through trust on balance. Regarding sociocultural heterogeneity, model 1 shows a significant negative relation between sociocultural heterogeneity and unit quality (B = -0.15, p = 0.034) and model 5 shows a negative relation with trust (B = -0.37, p = 0.026), providing partial support for respectively hypotheses 1b and 2b for irrigation systems. However, the significant effect of sociocultural heterogeneity on unit quality remains in model 3 (B = -0.19, p = 0.025) and trust is not significant, indicating that there is no indirect effect of sociocultural heterogeneity on unit quality through trust.

The indirect effects of economic or sociocultural heterogeneity on balance and unit quality for fishing grounds are not significant. For irrigation systems, the indirect effect of sociocultural heterogeneity on balance is marginally significant (B = -0.22, p = 0.079), indicating modest support for the role of trust as stated in hypothesis 4b. The indirect effect of economic heterogeneity on balance through trust is just about not significant on the marginal level, but should, given the small sample size, not be ignored (B = -0.17, p = 0.109). To check the robustness of the tests for the indirect effects, moderated mediation models were applied. The models can be found in Appendix H.

Table 5: OLS regression on main variables using the imputed sample for fishing grounds (left) and irrigation systems (right)

	Fishing Grounds					Irrigation Systems				
	Unit Quality	Balance	Unit Quality	Balance	Trust	Unit Quality	Balance	Unit Quality	Balance	Trust
Trust			0.54**	0.50†				-0.10	0.59**	
			(0.18)	(0.26)				(0.07)	(0.21)	
SH	-0.01	-0.14	0.01	-0.12	-0.05	-0.15*	-0.23	-0.19*	-0.01	-0.37*
	(0.18)	(0.24)	(0.16)	(0.24)	(0.17)	(0.07)	(0.20)	(0.08)	(0.20)	(0.16)
EH	-0.14	-0.01	0.01	0.13	-0.28†	0.03	-0.35†	0.01	-0.18	-0.29*
	(0.16)	(0.23)	(0.16)	(0.24)	(0.15)	(0.07)	(0.20)	(0.07)	(0.20)	(0.14)
Constant	2.71***	2.26***	1.60**	1.23**	2.05***	2.18***	2.09***	2.40***	0.73**	2.29***
	(0.30)	(0.43)	(0.46)	(0.70)	(0.28)	(0.08)	(0.27)	(0.20)	(0.56)	(0.20)
Adj. R^2	-$^*_*$	-$^*_*$	0.22	-$^*_*$	-$^*_*$	0.09	-$^*_*$	0.12	0.29	0.30
95% CI Adj. R^2	-$^*_*$	-$^*_*$	(0.02, 0.51)	-$^*_*$	-$^*_*$	(0.00, 0.31)	-$^*_*$	(0.00, 0.34)	(0.09, 0.53)	(0.06, 0.56)
AIC	-34.51	-7.44	-46.99	-8.31	-39.12	-137.81	-20.47	-138.23	-25.71	-60.68
N	40	40	40	40	40	52	52	52	52	52

Standard errors in parentheses

*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

$^*_*$ *Adjusted R^2 and FMI could not be calculated: the Fisher transformation for pooled simulations could not be performed since some of the simulations had a negative R^2*

4.4 Summary

Table 6 shows an overview of the results found per hypothesis. Counting the three samples - combined, fishery and irrigation - and the three methods - OLS regression as shown in main tables, the ordinal logistic regression [OLR] and the robustness check [RC] models with the alternative operationalisation of economic and sociocultural heterogeneity - there are nine tests for each hypothesis, except for hypotheses 4a and 4b which have not been calculated with the OLR models and thus have six tests. From this overview, we can conclude that there is convincing evidence for hypothesis 2a on the negative relation of economic heterogeneity with trust and hypothesis 3 on the positive relation of trust with CPR success; confirmed in respectively eight and nine tests out of nine. Hypothesis 1b is only supported for balance in irrigation systems, and hypothesis 5 is only supported regarding unit quality; it is marked as supported in all tests because all tests point out that trust is more important for fishing grounds than irrigation systems for unit quality, but the hypothesis as a whole - encompassing both balance and unit quality - is still only partially supported. Hypothesis 4a is partially supported with three significant indirect effects out of six tests in addition to the supported hypotheses 2a and 3.

Table 6: Overview of results of hypotheses tests, where '×' marks that support is found

	Combined Sample			Fishing Grounds			Irrigation Systems		
	OLS	OLR	RC	OLS	OLR	RC	OLS	OLR	RC
1a							×**		×**
1b							×*	×*	×*
2a	×	×	×	×	×	×	×		×
2b							×		×
3	×	×	×	×	×	×	×**	×	×**
4a	×	-	×		-			-	×**
4b		-			-		×**	-	
5	×*	×*	×*	×*	×*	×*	×*	×*	×*

** Only confirmed for unit quality*
*** Only confirmed for balance*
Note: considering the small sample size and limited statistical power, a hypothesis is marked '×' when supported with evidence on at least the marginal significance level of $\alpha = 0.1$

5 Discussion

The aim of this paper is to study whether and how economic and sociocultural heterogeneity affect the successful management of CPRs, to explore the role of trust and to see whether these relations differ for fisheries and irrigation systems. Using advanced imputation techniques to prepare the famous but challenging CPR Database allowed us to test the influence of two types of heterogeneity on CPR success at the same time, as well as looking at direct and indirect mechanisms. Existing literature predominantly suggests that both types of heterogeneity negatively influence collective action and therefore CPR success, that heterogeneity negatively affects mutual trust, and that trust has a positive effect on societal outcomes.

For the multivariate analysis we applied OLS regression models instead of ordinal logistic regression, favouring a simpler interpretation of coefficients. However, we tested all hypotheses in an ordinal logistic regression as well, plus we ran a model with alternative operationalisations of heterogeneity as a robustness check. In addition, we tested the found indirect effects through a moderated mediation analysis. Results are only considered robust if they are found for most of the combined and separate samples over the three analysis types. It appeared that neither form of heterogeneity has a robust significant relation with either measure of CPR success, contrary to a large body of existing literature. Economic heterogeneity, however, is found to be significantly negatively related to trust in all but one test, indicating that the role of economic heterogeneity regarding trust in CPRs is relevant. Trust has a positive association with both unit quality and balance in all tests, confirming the importance of mutual trust for positive CPR outcomes. A distinction between sector type proves relevant, since the significant interaction of trust with sector type on unit quality implies that trust only has a positive effect on unit quality for fisheries, and not for irrigation systems; something we later confirm in the subsample analyses. Trust seems to play a role in upkeeping balance in irrigation systems, so the role of trust cannot be disregarded for irrigation systems. Regarding our calculations for the indirect effects, we find partial support: a significant indirect effect of economic heterogeneity on balance through trust is found in the combined sample. To invigorate the results, and to explore the findings that were not considered robust in the current analysis, more data should be gathered and more research conducted.

The difference between findings in the subsamples may be related to fundamental differences between sector types. For fishing grounds, both the quality (for instance, health or size of the fish) and the balance between renewal and withdrawal of the resource may be affected by trust between appropriators through its effect on cooperation. For irrigation systems on the other hand, the balance may be affected but the quality of the water in an irrigation system may be less threatened by a lack of trust. These findings illustrate the difficulty of drawing conclusions from results across sector types since a specific measure of CPR success might mean different things for different CPR types. It is especially because of these differences that it is theoretically interesting to compare different CPRs, as it helps to understand the mechanisms behind the failure or success of different types of resources.

The findings are relevant given the increasing number of contemporary CPRs, also known as citizen collectives, or institutions for collective action, such as local communities producing their own green energy and urban agriculture projects with community farms (De Moor, 2013b). Like irrigation systems, green energy production and community farms are self-made systems, monitoring is relatively easy, production may be unstable due to the dependency on the weather, and maintenance is required - either by the government if government-owned, or through collective actions of farmers if not. If indeed our findings for irrigation systems apply to such CPRs, we can expect that trust amongst appropriators will benefit the balance rather than the quality of these CPRs, and maybe that trust may in general play a smaller role in achieving collective action given that monitoring is easy which makes trust a less important factor. For CPRs where monitoring requires more effort, such as fisheries and communal forests, trust will be more important in achieving high quality of the resource units and a balanced resource.

It has to be noted that this study has some shortcomings and that there is potential for improvement and replication. Firstly, although the database provides a relatively large sample for a field of research dominated by case studies, the sample size has limited statistical power. A substantial number of missing data for specific variables implied a suboptimal operationalisation of economic heterogeneity. However, the imputation method used is innovative and provides imputation diagnostics, such as the OOB, that gives us confidence in the imputation process and its results. Next to this, we reported the FMI where possible, herewith disclosing the level of uncertainty we have about the imputation of missing data. Secondly, individual level data instead of our case study level data could have provided more information on the role of trust; there may be individual confounding factors influencing the level of mutual trust of appropriators, such as general level of trust in society, how long an appropriator has resided in the community, individual cultural views or the history of interactions between individual appropriators. In addition, the CPR Database only provides very broad categorisations, even for variables of great interest like trust; more detailed measurements would provide more detailed results and subsequently more detailed conclusions. Thirdly, the cases in the CPR Database are all from before 1989. Whereas the argument of difficult monitoring in fishing grounds may be true for most fisheries back then, there currently exist modern solutions: the Vessel Monitoring System [VMS], used from the late 1990's on, and the Automatic Identification System [AIS], implemented in the early 2000's. Both systems have significantly improved monitoring of fishing activities worldwide (Longépé et al., 2018; Natale, Gibin, Alessandrini, Vespe, & Paulrud, 2015). AIS has the main purpose of avoiding collisions, but can also be used to track fishing activities (Kurekin et al., 2019; Longépé et al., 2018; Matsumoto, Furusho, & Fuchi, 2016; Natale et al., 2015; Wu, Xu, Wang, & Wang, 2016). This may reduce the need for high levels of mutual trust amongst fishermen as real-time monitoring is now a possibility. It is unlikely however, that such systems are in use in the smallest CPRs in less developed areas. Depending on the availability of these modern technologies the role of trust in achieving high unit quality and balance may thus not be discarded. Lastly, as we discussed, there may be reversed causality. As argued we have reasons to believe that heterogeneity is indeed influencing trust and CPR success; we referred to studies using instrumental variables showing that heterogeneity negatively affects trust, and experimental studies showing that trust indeed positively affects societal outcomes such as cooperation. However, in future research the causality issues could be addressed by replicating our research on CPR success using for instance experimental methods, since laboratory experiments are tailor-made to point out causality.

6 Conclusion

Using innovative methods, this paper was able to use a unique database to its full potential in a way that it hasn't been used before - gaining information on the relation between economic and sociocultural heterogeneity, trust and cooperation from one of the richest databases on CPRs the field. Whereas the lion's share of existing literature suggests a negative relation between sociocultural heterogeneity and cooperation and trust, the findings from this paper do not support this. The findings do suggest that economic heterogeneity impacts trust negatively, and that economic heterogeneity may have a negative indirect relation with CPR success through trust. The findings underscore the importance of separating the effects of economic and sociocultural heterogeneity on cooperation. In addition, the paper adds evidence to the empirical regularity that trust has a positive influence on societal outcomes.

The research question on cooperative behaviour in CPRs is not only fundamental to social sciences, but also to the current state of affairs concerning the use and depletion of natural and man-made resources, such as rainforests, fish populations, oil and gas. There is currently a rise of new CPRs: an increasing amount of green energy cooperatives, local community farms, collective gardens and care cooperatives are part of every-day life due to an increasing privatisation of social services (De Moor, 2013a, 2013b, 2018). These commons too, may become subject to the risk of overexploitation. Next to that, 'classic' commons like fishing grounds, forests, and pastures have new meanings nowadays, and are not only regarded as sources of products but also as conservation tools and leisure areas. Contemporary problems surrounding CPRs include amongst others landscape planning, water management and even climate change (Bravo & De Moor, 2008). The investigation of the impact of societal characteristics such as heterogeneity and trust on cooperation could provide new insights into the use and preservation of these CPRs, demonstrating the contributions that social and environmental sciences can make to a sustainable society.

References

Acedo, C., & Gomila, A. (2013). Trust and cooperation: A new experimental approach: Trust and cooperation. *Annals of the New York Academy of Sciences*, *1299*(1), 77–83. doi: 10.1111/nyas.12142

Agarwal, B. (1994). Gender and command over property: A critical gap in economic analysis and policy in South Asia. *World Development*, *22*(10), 1455–1478. doi: 10.1016/0305-750X(94)90031-0

Agarwal, B. (1997). Environmental Action, Gender Equity and Women's Participation. *Development and Change*, *28*(1), 1–44. doi: 10.1111/1467-7660.00033

Aksoy, O. (2019). Crosscutting circles in a social dilemma: Effects of social identity and inequality on cooperation. *Social Science Research*, *82*, 148–163. doi: 10.1016/j.ssresearch.2019.04.009

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904.

Alesina, A., & La Ferrara, E. (2002). Who trusts others? *Journal of Public Economics*, *85*(2), 207–234. doi: 10.1016/S0047-2727(01)00084-6

Anderson, C. J., & Paskeviciute, A. (2006). How Ethnic and Linguistic Heterogeneity Influence the Prospects for Civil Society: A Comparative Study of Citizenship Behavior. *The Journal of Politics*, *68*(4), 783–802. doi: 10.1111/j.1468-2508.2006.00470.x

Baland, J.-M., & Platteau, J.-P. (1996). *Halting Degradation of Natural Resources: Is There a Role for Rural Communities?* Rome, Italy: Food and Agriculture Organization of the United Nations, Rome, Italy.

Baland, J.-M., & Platteau, J.-P. (1997). Wealth Inequality and Efficiency in the Commons. Part I: The Unregulated Case on JSTOR. *Oxford Economic Papers*, *49*, 451–482.

Baland, J.-M., & Platteau, J.-P. (1999). The Ambiguous Impact of Inequality on Local Resource Management. *World Development*, *27*(5), 773–788. doi: 10.1016/S0305-750X(99)00026-1

Bardhan, P. (2000). Irrigation and Cooperation: An Empirical Analysis of 48 Irrigation Communities in South India. *Economic Development and Cultural Change*, *48*(4), 847–865. doi: 10.1086/452480

Bardhan, P., & Dayton-Johnson, J. (2002). Unequal irrigators: Heterogeneity and commons management in large-scale multi-variate research. In E. Ostrom, T. Dietz, N. Dolsak, P. C. Stern, S. Stonich, & E. U. Weber (Eds.), *The Drama of the Commons* (pp. 87–112). Washington,

D. C.: National Academy Press, Washington, D. C.

Bravo, G., & De Moor, T. (2008). The commons in Europe: From past to future. *International Journal of the Commons*, *2*(2), 155–161.

Breiman, L. (2001). Random Forests. *Machine Learning*, *45*(1), 5–32. doi: 10.1023/A:1010933404324

Carpenter, J., & Cardenas, J. C. (2011). An Intercultural Examination of Cooperation in the Commons. *Journal of Conflict Resolution*, *55*(4), 632–651. doi: 10.1177/0022002710393922

Coleman, J. S. (1994). *Foundations of social theory.* Cambridge, MA: Harvard University Press, Cambridge, MA.

Delhey, J., & Newton, K. (2005). Predicting Cross-National Levels of Social Trust: Global Pattern or Nordic Exceptionalism? *European Sociological Review*, *21*(4), 311–327.

De Moor, T. (2013a). De herontdekking van het Collectief. *Samenleving en politiek*, *20*(4), 29–38.

De Moor, T. (2013b). *Homo Cooperans: Institutions for collective action and the compassionate society* [Inaugural Lecture].

De Moor, T. (2018). De toekomst van bewonersoverlegorganisaties. *Sociaal Bestek*, *80*, 52–54.

Dong, Y., & Peng, C.-Y. J. (2013). Principled missing data methods for researchers. *SpringerPlus*, *2*. doi: 10.1186/2193-1801-2-222

Flache, A., & Mäs, M. (2008). Why do faultlines matter? A computational model of how strong demographic faultlines undermine team cohesion. *Simulation Modelling Practice and Theory*, *16*(2), 175–191. doi: 10.1016/j.simpat.2007.11.020

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity.* New York: The Free Press, New York.

Fung, J. M., & Au, W.-t. (2014). Effect of inequality on cooperation: Heterogeneity and hegemony in public goods dilemma. *Organizational Behavior and Human Decision Processes*, *123*(1), 9–22. doi: 10.1016/j.obhdp.2013.10.010

Gächter, S., Herrmann, B., & Thöni, C. (2004). Trust, voluntary cooperation, and socio-economic background: Survey and experimental evidence. *Journal of Economic Behavior & Organization*, *55*(4), 505–531. doi: 10.1016/j.jebo.2003.11.006

Gaspart, F., & Platteau, J.-P. (2007). Heterogeneity and collective action for effort regulation: Lessons from the Senegalese small-scale fisheries. In J.-M. Baland, P. Bardhan, & S. Bowles (Eds.), *Inequality, Cooperation, and Environmental Sustainability.* New York: Russell Sage Foundation, New York.

Gehrig, S., Schlüter, A., & Hammerstein, P. (2019). Sociocultural heterogeneity in a common pool resource dilemma. *PLoS ONE*, *14*(1). doi: 10.1371/journal.pone.0210561

Hackett, S., Schlager, E., & Walker, J. (1994). The Role of Communication in Resolving Commons Dilemmas: Experimental Evidence with Heterogeneous Appropriators. *Journal of Environmental Economics and Management*, *27*(2), 99–126. doi: 10.1006/jeem.1994.1029

International Migration report 2019 (Tech. Rep.). (2019). Department of Economic and Social Affairs, United Nations.

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why Differences Make a Difference: A Field Study of Diversity, Conflict, and Performance in Workgroups. *Administrative Science Quarterly*, *44*(4), 741–763. doi: 10.2307/2667054

Jiang, Y., Cheng, J., & Li, S. (2009). Temporal changes in the fish community resulting from a summer fishing moratorium in the northern East China Sea. *Marine Ecology Progress Series*, *387*, 265–273. doi: 10.3354/meps08078

Johnson, R. N., & Libecap, G. D. (1982). Contracting Problems and Regulation: The Case of the Fishery. *The American Economic Review*, *72*(5), 1005–1022.

Jones, E. C. (2004). Wealth-Based Trust and the Development of Collective Action. *World Development*, *32*(4), 691–711. doi: 10.1016/j.worlddev.2003.10.009

Judd, C. M., & Kenny, D. A. (1981). Process Analysis: Estimating Mediation in Treatment Evaluations. *Evaluation Review*, *5*(5), 602–619. doi: 10.1177/0193841X8100500502

Keuschnigg, M., & Schikora, J. (2014). The dark side of leadership: An experiment on religious heterogeneity and cooperation in India. *The Journal of Socio-Economics*, *48*, 19–26. doi: 10.1016/j.socec.2013.09.006

Khan, A. M., Gray, T. S., Mill, A. C., & Polunin, N. V. (2018). Impact of a fishing moratorium on a tuna pole-and-line fishery in eastern Indonesia. *Marine Policy*, *94*, 143–149. doi: 10.1016/j.marpol.2018.05.014

Knack, S., & Keefer, P. (1997). Does Social Capital Have an Economic Payoff? A Cross-Country Investigation. *The Quarterly Journal of Economics*, *112*(4), 1251–1288.

Komakech, H. C., Van der Zaag, P., & Van Koppen, B. (2012). The dynamics between water asymmetry, inequality and heterogeneity sustaining canal institutions in the Makanya catchment, Tanzania. *Water Policy*, *14*(5), 800–820.

Kurekin, A. A., Loveday, B. R., Clements, O., Quartly, G. D., Miller, P. I., Wiafe, G., & Agyekum, K. A. (2019). Operational Monitoring of Illegal Fishing in Ghana through Exploitation of Satellite Earth Observation and AIS Data. *Remote Sens*, *11*(3), 293. doi: doi:10.3390/rs11030293

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1997). Trust in Large Organizations. *The American Economic Review*, *87*(2), 333–338.

Leigh, A. (2006a). Does equality lead to fraternity? *Economics Letters*, *93*(1), 121–125. doi: 10.1016/j.econlet.2006.04.003

Leigh, A. (2006b). Trust, Inequality and Ethnic Heterogeneity. *Economic Record*, *82*(258), 268–280. doi: 10.1111/j.1475-4932.2006.00339.x

Longépé, N., Hajduch, G., Ardianto, R., De Joux, R., Nhunfat, B., Marzuki, M. I., ... Gaspar, P. (2018). Completing fishing monitoring with spaceborne Vessel Detection System (VDS) and Automatic Identification System (AIS) to assess illegal fishing in Indonesia. *Marine Pollution Bulletin*, *131*, 33–39.

MacKinnon, D. P., Warsi, G., & Dwyer, J. H. (1995). A Simulation Study of Mediated Effect Measures. *Multivariate Behavioral Research*, *30*(1), 41–62. doi: 10.1207/s15327906mbr3001$_3$

Matsumoto, H., Furusho, M., & Fuchi, M. (2016). Research on the Utilization of AIS for Fishing Boat. *Journal of Maritime Researches*, *5*, 25–34.

Mayer, M. (2019). *Package 'missRanger', Fast Imputation of Missing Values.*

Molinas, J. (1998). The impact of inequality, gender, external assistance and social capital on local-level cooperation. *World Development*, *26*(3), 413–431. doi: 10.1016/S0305-750X(97)10066-3

Natale, F., Gibin, M., Alessandrini, A., Vespe, M., & Paulrud, A. (2015). Mapping Fishing Effort through AIS Data. *PLOS ONE*, *10*(6), e0130746. doi: 10.1371/journal.pone.0130746

Nettle, D., & Dunbar, R. I. M. (1997). Social Markers and the Evolution of Reciprocal Exchange. *Current Anthropology*, *38*(1), 93–99.

Olson, M. (1965). *The logic of collective action: Pubic goods and the theory of groups.* Cambridge, MA: Harvard University Press, Cambridge, MA.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action.* Cambridge ; New York: Cambridge University Press.

Ostrom, E., Agrawal, A., Blomquist, W., Schlager, E., & Tang, S. Y. (1989). *CPR Coding Manual.* Indiana University, Bloomington, Indiana.

Ostrom, E., Walker, J., & Gardner, R. (1992). Rules, Games and Common-Pool Resources. *The American Political Science Review*, *86*(2), 404–417. doi: 10.2307/1964229

Palmer, C. T., & Sinclair, P. R. (2008). Perceptions of a Fishery in Crisis: Dragger Skippers on the Gulf of ST. Lawrence Cod Moratorium. *Society & Natural Resources*, *9*(3), 267–279.

Pan, Q., & Wei, R. (2016). Fraction of Missing Information (γ) at Different Missing Data Fractions in the 2012 NAMCS Physician Workflow Mail Survey. *Applied mathematics*, *7*(10), 1057–1067. doi: 10.4236/am.2016.710093

Pasta, D., J. (2009). Learning When to Be Discrete: Continuous vs. Categorical Predictors. In *SAS Global Forum 2009* (p. 10). Washington, D. C.: ICON Clinical Research, San Francisco, CA.

Poteete, A. R., & Ostrom, E. (2004). Heterogeneity, group size and collective action: The role of institutions in forest management. *Development and change*, *35*(3), 435–461.

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community.* New York: Simon & Schuster, New York.

Putnam, R. D. (2007). E Pluribus Unum: Diversity and Community in the Twenty-first Century The 2006 Johan Skytte Prize Lecture. *Scandinavian Political Studies*, *30*(2), 137–174. doi: 10.1111/j.1467-9477.2007.00176.x

Regmi, A. R. (2007). *The role of group heterogeneity in collective action: A look at the intertie between irrigation and forests. Case studies from Chitwan, Nepal* (Ph.D.). Indiana University, United States – Indiana.

Romano, A., Balliet, D., Yamagishi, T., & Liu, J., H. (2017). Parochial trust and cooperation across 17 societies. *Proceedings of the National Academy of Sciences of the United States of America*.

Rubin, D. B. (1987). *Multiple Imputation for Nonresponse in Surveys.* New York: John Wiley & Sons, Inc., New York.

Ruttan, L. M. (2006). Sociocultural Heterogeneity and the Commons. *Current Anthropology*, *47*(5), 843–853. doi: 10.1086/507185

Ruttan, L. M. (2008). Economic Heterogeneity and the Commons: Effects on Collective Action and Collective Goods Provisioning. *World Development*, *36*(5), 969–985. doi: 10.1016/j.worlddev.2007.05.005

Sanchirico, J. N., Holland, D., Quigley, K., & Fina, M. (2006). Catch-Quota Balancing in Multispecies Individual Fishing Quotas. *Marine Policy*.

Schlager, E. (1990). *Model specification and policy analysis: The governance of coastal fisheries* (Unpublished doctoral dissertation). Indiana University Bloomington, IN.

Shanmugaratnam, N. (1996). Nationalisation, Privatisation and the dilemmas of common property management in Western Rajasthan. *The Journal of Development Studies*, *33*(2), 163–187. doi: 10.1080/00220389608422461

Singleton, S. (2001). How distributional conflicts shape co-management institutions and collaborative environmental policy in the United States. In *"Economic Inequality, Collective Action and Environmental Sustainability" workshop.* Santa Fe Institute.

Sobel, M. E. (1982). Asymptotic Confidence Intervals for Indirect Effects in Structural Equation Models. *Sociological Methodology*, *13*, 290–312. doi: 10.2307/270723

Stekhoven, D. J., & Bühlmann, P. (2012). MissForest—non-parametric missing value imputation for mixed-type data. *Bioinformatics*, *28*(1), 112–118. doi: 10.1093/bioinformatics/btr597

Tang, S. Y. (1989). *Institutions and collective action in irrigation systems* (Ph.D.). Indiana University, United States – Indiana.

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). **Mediation** : *R* Package for Causal Mediation Analysis. *Journal of Statistical Software*, *59*(5). doi: 10.18637/jss.v059.i05

Uslaner, E. M. (2002). *The moral foundations of trust.* Cambridge: Cambridge University Press.

Van Buuren, S. (2019). *Package 'mice', Multivariate Imputation by Chained Equations.*

Varughese, G., & Ostrom, E. (2001). The Contested Role of Heterogeneity in Collective Action: Some Evidence from Community Forestry in Nepal. *World Development*, *29*(5), 747–765.

Vermillion, D. (1999). Property rights and collective action in the devolution of irrigation system management. *Workshop on Devolution of Natural Resource Management*.

Wagner, J. (2010). The Fraction of Missing Information as a Tool for Monitoring the Quality of Survey Data. *Public Opinion Quarterly*, *74*(2), 223–243. doi: 10.1093/poq/nfq007

Wiessner, P. W. (1977). *Hxaro: A Regional System of Reciprocity for Reducing Risk Among the !kung San. (volumes I and Ii)* (Ph.D.). University of Michigan, United States – Michigan.

Williams, R. (2018). *Ordinal Independent Variables.* University of Notre Dame.

Wright, M., N., Wager, S., & Probst, P. (2019). *Package 'ranger', A Fast Implementation of Random Forests.*

Wu, L., Xu, Y., Wang, Q., & Wang, F. (2016). Mapping Global Shipping Density from AIS Data — The Journal of Navigation — Cambridge Core. *Cambridge University Press*. doi: 10.1017/S0373463316000345

Zak, P. J., & Knack, S. (2001). Trust and Growth. *The Economic Journal*, *111*(470), 295–321.

Appendix A

Table 7: Differences between fishing grounds and irrigation systems

		Fishing Ground (N = 40)	Irrigation System (N = 52)
Variation of flow of resource units over space?			
	Yes	40	32
	No	0	20
Variation of flow of resource units from year to year?			
	Yes	38	37
	No	2	15
Variation of flow of resource units within a year?			
	Yes	40	49
	No	0	3
Predictable variation of flow of resource units over space?			
	1 (Highly Predictable)	0	0
	2	26	5
	3	7	44
	4	6	3
	5 (Highly Unpredictable)	1	0
Predictable variation of flow of resource units within a year?			
	1 (Highly Predictable)	0	0
	2	29	6
	3	5	44
	4	2	2
	5 (Highly Unpredictable)	4	0
Predictable variation flow of resource units from year to year?			
	1 (Highly Predictable)	0	0
	2	0	0
	3	0	1
	4	39	51
	5 (Highly Unpredictable)	1	0
*Closed access***			
	1 (Yes, de jure and effective)	11	52
	2	1	0
	3	0	0
	4	12	0
	5	3	0
	6	3	0
	7 (No)	10	0
*Exit options***			
	Less than 10%	10	39
	10-25%	1	1
	26-50%	0	0
	51-75%	1	2
	76-90%	3	0
	91-100%	25	10

N.B. See the CPR Coding Manual (Ostrom et al., 1989) for detailed description of variables
****See appendix C for description of these variables*

Appendix B

Table of CPR Cases in the CPR Database (Ostrom et al., 1989). Generated with online CPR Database tool, `https://seslibrary.asu.edu/cpr`

Country	*Resource name*	*Sector*	*Cases*	*Source(s)*
Australia	Lakes Entrance	Fishery	2	Sturgess, Dow & Belin (1982)
Australia	Port Phillip Bay	Fishery	4	Sturgess, Dow & Belin (1982)
Bangladesh	Nabagram Irrigation	Irrigation	1	Coward, Walter & Badaruddin (1979)
Belize	Caye Caulker Lobsterfishing	Fishery	1	Sutherland (1986)
Belize	San Pedro Spiny Lobster Fishery	Fishery	1	Gordon (1981)
Brazil	Arembepe Fishery	Fishery	1	Kottak (1966)
Brazil	Coqueiral Raft Fishery	Fishery	1	Forman (1970)
Brazil	Valenca Fishery	Fishery	3	Cordell (1984)
Canada	Baccalaos Cove Cod Fishery	Fishery	1	Powers (1984)
Canada	Cat Harbour Cod Fishery	Fishery	1	Faris (1972)
Canada	Chisasibi - James Bay Fishery	Fishery	1	Berkes (1977; 1982; 1987)
Canada	Fermeuse Cod Fishery	Fishery	1	Martin (1973; 1979)
Canada	Petty Harbour Cod Fishery	Fishery	1	Shortall (1973)
Canada	Port Lameron - Pagesville Finfishery	Fishery	2	Davis (1975), Davis (1984)
Greece	Messolonghi-Etolico Lagoon Fishery	Fishery	1	Kotsonias (1984)
India	A Tailend Watercourse in Area Two	Irrigation	1	Bottral (1981)
India	Chawk 16000L Dhabi Minor Irrigation	Irrigation	1	Reidinger (1974; 1980), Gustafson & Reidinger (1971), Vander Velde (1971; 1980)
India	Jambudwip Fishery	Fishery	1	Raychaudhuri (1968; 1980)
India	Kottapalle - Irrigation	Irrigation	1	Wade (1985; 1988)
India	Sananeri Tank	Irrigation	1	Meinzen-Dick (1984)
Indonesia	A Watercourse in Area Three	Irrigation	1	Bottrall (1981)

Country	*Resource name*	*Sector*	*Cases*	*Source(s)*
Indonesia	Bondar Parhudagar Irrigation	Irrigation	1	Lando (1979)
Indonesia	Saebah Communal System	Irrigation	1	Hafid & Hayami (1979)
Indonesia	Silean Banua Irrigation	Irrigation	1	Lando (1979)
Indonesia	Subak A	Irrigation	1	Geertz (1967)
Indonesia	Takkapala Communal System	Irrigation	1	Hafid & Hayami (1979)
Iran	Deh Salm Irrigation	Irrigation	1	Spooner (1971; 1972l 1974)
Iran	Nayband Irrigation	Irrigation	1	Spooner (1971; 1972; 1974)
Iraq	El Mujarilin Irrigation	Irrigation	1	Fernea (1970)
Jamaica	Farquhar Beach	Fishery	1	Davenport (1956)
Japan	Ebibara Fishing Ground	Fishery	1	Brameld (1968)
Korea	Kagoda anchovy grounds	Fishery	1	Han (1972)
Laos	A watercourse in Nam Tan	Irrigation	1	Coward (1980)
Malaysia	Kampong Mee Trawl Fishery	Fishery	1	Anderson & Anderson (1977)
Malaysia	Perupok Fishery	Fishery	1	Firth (1966)
Mexico	A Tramo in Diaz Ordaz	Irrigation	1	Downing (1974)
Mexico	Andres Quinta Roo Lobster	Fishery	1	Miller (1982)
Mexico	Andres Quintana Roo Scalefish	Fishery	1	Miller (1982)
Mexico	Ascension Bay Lobster Fishery	Fishery	1	Miller (1988)
Nepal	Argali Raj Kulo Irrigation (Jethi Kulo)	Irrigation	1	Martin & Yoder (1983a; 1983b; 1986)
Nepal	Char Hazar Irrigation System (Charhajar)	Irrigation	1	Pradhan (1988), Laitos (1986)
Nepal	Chhahare Khola Ko Kulo, Baruwa Village Panchayat	Irrigation	1	Water and Energy Commission Secretariat (1987)
Nepal	Chherlung Thulo Kulo Irrigation	Irrigation	1	Pradhan (1988); Martin & Yoder (1983; 1983; 1986) Sharma et al (1989)
Nepal	Lothar Irrigation System	Irrigation	1	Nirola & Pandey (1987), Pradhan (1988), Laitos (1986)

Country	*Resource name*	*Sector*	*Cases*	*Source(s)*
Nepal	Naya Dhara Ko Kulo (Kot Village Panchayat)	Irrigation	1	Water and Energy Commission Secretariat (1987)
Nicaragua	Miskito Turtle Fishery	Fishery	1	Nietschmann (1972; 1973)
Pakistan	A Watercourse in Area One	Irrigation	1	Bottrall (1981)
Pakistan	Main Watercourse in Gondalpur	Irrigation	1	Merrey & Wolf (1986)
Pakistan	Watercourse Ten - Dakh Branch	Irrigation	1	Mirza & Merrey (1979)
Pakistan	Watercourse in Punjab	Irrigation	1	Lowdermilk, Clyma & Early (1975)
Peru	Hanan Sayoc Irrigation	Irrigation	1	Mitchell (1976; 1977)
Peru	Lurin Sayoc Irrigation	Irrigation	2	Mitchell (1976; 1977)
Philippines	A Sitio in Zanjera Danum	Irrigation	1	Coward (1979)
Philippines	Agcuyo Irrigation System	Irrigation	1	De Los Reyes (1980)
Philippines	Cadchog Irrigation	Irrigation	1	De Los Reyes (1980)
Philippines	Calaoaan Irrigation	Irrigation	1	De Los Reyes (1980)
Philippines	Laoag-Vintar Irrigation	Irrigation	1	Ongkingco (1973)
Philippines	Mauraro Irrigation	Irrigation	1	De Los Reyes (1980)
Philippines	NIA Irrigation in San Antonio	Irrigation	2	De Los Reyes et al. (1980)
Philippines	Nazareno-Gamutan Irrigation	Irrigation	1	Ongkingco (1973)
Philippines	Oaig-Daya Irrigation System	Irrigation	1	De Los Reyes (1980)
Philippines	Pinagbayanan Water Pumps	Irrigation	1	Cruz (1975)
Philippines	Sabangan Bato Irrigation System	Irrigation	1	De Los Reyes (1980)
Philippines	Silag-Butir Irrigation System	Irrigation	1	De Los Reyes et al. (1980)
Philippines	Tanowong Bwasao Irrigation	Irrigation	1	Bacdayan (1980)
Philippines	Tanowong Traditional Irrigation	Irrigation	1	Bacdayan (1980)
Sri Lanka	Gahavalla Village	Fishery	3	Alexander (1982)
Switzerland	Felderin Irrigation	Irrigation	1	Netting (1974; 1981)
Taiwan	A Watercourse in Area Four	Irrigation	1	Bottrall (1981)
Tanzania	Kheri Irrigation	Irrigation	1	Gray (1963)
Thailand	A Chaek in Amphoe Choke Chai	Irrigation	1	Gillespie (1975)

Country	*Resource name*	*Sector*	*Cases*	*Source(s)*
Thailand	A Chaek in Kaset Samakee	Irrigation	1	Gillespie (1975)
Thailand	Chiangmai Irrigation	Irrigation	1	Potter (1976)
Thailand	Muang Mai Irrigation	Irrigation	1	Tan-Kim-Yong (1983)
Thailand	Na Pae Irrigation	Irrigation	1	Tan-Kim-Yong (1983)
Thailand	Rusembilan Kembong Fishery	Fishery	1	Fraser (1960; 1966)
Turkey	Alanya Fishery, Turkey	Fishery	1	Berkes (1986)
Turkey	Ayvalik-Haylazli Coop Lagoon, Turkey	Fishery	1	Berkes (1986)
Turkey	Tasucu Bay Fishery, Turkey	Fishery	1	Berkes (1986)
U.S.A.	Lobsterfishing, Mount Desert Island, Maine	Fishery	1	Grossinger (1975)
Venezuela	Chiguana	Fishery	1	Breton (1973)

Appendix C

A description of the control variables is provided following the table.

Table 9: OLS regression analyses on main dependent variables using the combined sample, including control variables

	(12) Unit Quality	(13) Balance
Irrigation	0.50	-0.87
	(0.40)	(0.65)
Irr. x Trust	-0.60*	0.12
	(0.23)	(0.37)
Trust	0.48*	0.23
	(0.22)	(0.34)
Sociocultural heterogeneity	0.02	-0.01
	(0.09)	(0.17)
Economic heterogeneity	0.01	0.00
	(0.08)	(0.16)
Cultural view of the resource	-0.06	-0.14
	(0.09)	(0.15)
Number of users	0.00	0.00
	(0.00)	(0.00)
Closed access	-0.03	-0.08
	(0.05)	(0.08)
Exit options	0.01	0.03
	(0.04)	(0.06)
Monetary sanctions	0.00	-0.16
	(0.06)	(0.11)
Physical sanctions	-0.08	-0.12
	(0.06)	(0.10)
Social sanctions	0.07	0.14
	(0.07)	(0.13)
Pollution	-1.20*	-0.77
	(0.51)	(0.92)
Pressure	0.03	-0.05
	(0.17)	(0.30)
Income dependence	-0.09	0.27
	(0.13)	(0.21)
Worst off	-0.04	0.07
	(0.24)	(0.43)
Variation over space	-0.05	0.64*
	(0.14)	(0.29)
Constant	2.04**	1.36
	(0.73)	(1.24)
Adj. R^2	0.43	0.34
95% CI Adj. R^2	(0.24, 0.60)	(0.16, 0.52)
FMI	0.33	0.30
AIC	-156.00	-34.86
N	92	92

Standard errors in parentheses

*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

Description of control variables (as cited from the CPR Codebook (Ostrom et al., 1989)

Cultural view of the resource	How does the general cultural view of the resource system and its use affect communication between subgroups? (scale 1-5)
Number of users	What is the actual number of individuals in this group at the end of the period? (number)
Closed access	As of the end of this period, are the appropriators exercising or attempting to exercise closed access to this resource? Closed access is exercised on a de facto base if it is NOT specifically sanctioned by some legitimate authority/ by a de jure base if it IS sanctioned. Outsiders are persons who are not originally appropriators. (scale 1-7)
Exit options	What proportion of this subgroup works a substantial amount of time in activities not associated with appropriation from this resource? (scale 1-6)
Monetary sanctions	If someone violated rules-in-use related to the appropriation process from this resource, how likely is it that an official monitor or guard will move to impose sanctions? (scale 1-5)
Physical sanctions	If someone violates rules-in-use related to the appropriation process from this resource, how likely is he/she to encounter physical sanctions imposed by other appropriators (who are not official monitors? (scale 1-5)
Social sanctions	If someone violates rules-in-use related to the appropriation process form this resource how likely is he/she to encounter social sanctions imposed by other appropriators who are not monitors? (scale 1-5)
Pollution	Are there problems of pollution of this or other resources resulting from the way units are appropriated in end of period? (scale 1-4)
Pressure	Does the amount of capital required to set up an appropriation team, given the assets of members of this subgroup, place pressure upon the appropriators to get immediate returns from appropriation (Y/N)
Income dependence	For most people in this subgroup, how dependent are they on this resource as a major source of family income? (scale 1- 3)

Worst off	Have the relatively worst off been cut out of their benefits from this resource or substantially harmed? (Y/N)
Variation over space	Is there considerable variation over space in the availability of these units within the resource? (Y/N)

Appendix D

Note: For some models, the maximum likelihood estimates provide unreliably high standard errors due to the small sample size and the splitting of ordinal variables into multiple dummies in the model, as this increases the number of parameters to be estimated. We resolve to use a Bayesian approach for the models where the standard errors are too extreme, using the R function *bayespolr* from the *arm* package (Gelman & Su, 2018). For instance, we are working on the logit scale, so a reasonable value for the standard deviation of a parameter over which we are very uncertain is around 2.5.[15] The maximum likelihood approach for some of the models go up to over 200 points on the standard deviation, which is effectively meaningless, and an artefact of the small sample size. Hence, we resolve to regularise these standard deviation estimates by using a Bayesian prior encoding a reasonably large degree of uncertainty over the parameters. We stress however, that this prior is noninformative and only serves to control the standard deviation where needed.

For the subsamples, sociocultural heterogeneity was treated as continuous for two reasons. Firstly, the combined sample model was modelled once with and once without treating sociocultural heterogeneity as continuous (the latter presented here in the appendix), which did not affect the coefficients of the other variables. Based on this we believe that treating sociocultural heterogeneity as either continuous or as ordinal does not impact the model significantly. Secondly, the subsamples are so small that adding the variable as separate dummies would decrease the already limited statistical power of the model, making it impossible to detect any possible relations between covariates.

[15] Which is the default scale parameter in the R function *bayespolr*.

Table 11: Ordinal Logistic regression on main variables using the combined sample, treating unit quality, balance, trust, and heterogeneity as ordinal variables

	(1) Unit Quality	(2) Balance	(3) Unit Quality (Bayes)	(4) Balance	(5) Unit Quality (Bayes)	(6) Balance	(7) Unit Quality	(8) Balance (Bayes)	(9) Trust (Bayes)	(10) Trust (Bayes)
Irrigation	-2.63***	-1.09**	-2.60***	-1.41**	-2.63***	-1.40**	-0.46	-2.16†		-0.76
	(0.55)	(0.40)	(0.57)	(0.48)	(0.60)	(0.48)	(1.28)	(1.13)		(0.59)
Irr. x Trust										
= 1							0.90	1.41		
							(1.78)	(1.43)		
= 2							-3.23*	0.95		
							1.57	(1.20)		
Trust										
= 1					2.63†	2.16*	2.30	0.81		
					(1.42)	(0.97)	(2.05)	(1.16)		
= 2					2.20†	3.29***	4.59**	2.35*		
					(1.21)	(0.89)	(1.73)	(1.00)		
SH										
= 1			0.41	-0.66	0.24	-0.34	0.33	0.30	0.22	0.26
			(1.08)	(1.87)	(1.07)	(1.89)	(1.10)	(0.96)	(1.09)	(1.09)
= 2			-0.68	-2.05	-0.66	-1.44	-0.69	-0.65	-0.69	-0.76
			(1.19)	(1.98)	(1.21)	(2.05)	(1.23)	(1.10)	(1.22)	(1.24)
= 3			0.81	-1.65	0.76	-1.32	0.65	-0.29	0.19	0.13
			(1.64)	(2.54)	(1.63)	(2.58)	(1.61)	(1.34)	(1.65)	(1.68)
= 4			-0.56	-2.05	-0.12	-0.77	-0.41	0.09	-1.25	-1.27
			(1.45)	(2.14)	(1.38)	(2.23)	(1.48)	(1.27)	(1.77)	(1.70)
EH										
= 1			-0.24	-0.55	-0.21	-0.22	-0.25	-0.19	-1.62	-1.59
			(0.62)	(0.60)	(0.64)	(0.61)	(0.69)	(0.55)	(1.06)	(1.05)
= 2			-0.36	-0.97	0.10	-0.26	0.14	-0.19	-2.54*	-2.56*
			(0.73)	(0.72)	(0.82)	(0.75)	(0.90)	(0.74)	(1.14)	(1.13)
N	92	92	92	92	92	92	92	92	92	92
AIC	121.11	234.81	149.89	235.32	148.50	226.31	145.10	261.08	141.55	143.39

Standard errors in parentheses
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

Table 12: Ordinal Logistic regression on main variables using separate samples for fishing grounds (left) and irrigation systems (right)

	Fishing Grounds							Irrigation Systems						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Unit Quality	Balance	Unit Quality	Balance	Unit Quality (Bayes)	Balance	Trust (Bayes)	Unit Quality (Bayes)	Balance	Unit Quality (Bayes)	Balance	Unit Quality (Bayes)	Balance	Trust (Bayes)
Trust														
= 1	1.87	0.43			0.71	-0.09		4.06†	3.34*			2.70	3.70†	
	(1.77)	(1.50)			(1.48)	(2.86)		(2.18)	(1.36)			(2.02)	(1.98)	
= 2	3.42*	1.86†			2.50†	2.07†		1.10	4.73***			-0.45	5.00*	
	(1.37)	(1.10)			(1.26)	(1.19)		(1.55)	(1.35)			(1.62)	(2.11)	
SH			-0.08	-0.33	-0.04	-0.33	-0.12			-1.30†	-0.57	-1.50†	0.20	-1.31
			(0.64)	(0.39)	(0.61)	(0.42)	(0.77)			(0.73)	(0.54)	(0.84)	(0.77)	(0.85)
EH														
= 1			-1.10	-0.22	-0.57	-0.13	-1.24			0.69	-1.06	0.24	-0.69	-1.28
			(1.00)	(0.86)	(0.86)	(0.89)	(1.23)			(1.33)	(0.83)	(1.39)	(0.88)	(1.13)
= 2			-0.87	-0.01	0.19	1.11	-2.12†			0.24	-1.79	0.03	-0.95	-1.87
			(1.21)	(0.98)	(1.20)	(2.49)	(1.37)			(1.50)	(1.16)	(1.49)	(1.26)	(1.29)
N	40	40	40	40	40	40	40	52	52	52	52	52	52	52
AIC	61.26	100.34	72.84	104.78	83.88	105.59	59.95	41.59	117.63	48.30	128.73	49.48	122.94	83.97

Standard errors in parentheses

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

Appendix E

Robustness checks for operationalisation of economic and sociocultural heterogeneity; mean instead of max

Table 13: OLS regression on main variables and interaction effect using the imputed sample of both fisheries and irrigation systems

	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Unit Quality	(6) Balance	(7) Unit Quality	(8) Balance	(9) Trust	(10) Trust
Irrigation	-0.53***	-0.52**	-0.47***	-0.31*	-0.47***	-0.32	0.61†	-0.61		-0.16
	(0.10)	(0.18)	(0.12)	(0.22)	(0.12)	(0.20)	(0.31)	(0.27)		(0.13)
Irr. x Trust							-0.60***	0.16		
							(0.16)	(0.28)		
Trust					0.20*	0.54***	0.54***	0.44*		
					(0.09)	(0.15)	(0.13)	(0.22)		
SH (mean)			-0.19	-0.60	-0.11	-0.37	-0.32	-0.32	-0.41	-0.43
			(0.24)	(0.41)	(0.23)	(0.40)	(0.23)	(0.42)	(0.25)	(0.30)
EH (mean)			-0.06	-0.25	0.01	-0.06	0.01	-0.05	-0.36***	-0.36***
			(0.08)	(0.15)	(0.09)	(0.16)	(0.08)	(0.17)	(0.11)	(0.11)
Constant	2.57***	2.03***	2.93***	3.25***	2.36***	1.67*	2.05***	1.76**	2.92***	2.94***
	(0.08)	(0.14)	(0.32)	(0.58)	(0.42)	(0.74)	(0.40)	(0.74)	(0.39)	(0.43)
Adj. R^2	0.24	0.08	0.24	0.14	0.28	0.25	0.39	0.25	0.19	0.19
95% CI Adj.R^2	(0.98, 0.40)	(0.01, 0.21)	(0.10, 0.40)	(0.02, 0.30)	(0.13, 0.44)	(0.10, 0.42)	(0.21, 0.56)	(0.10, 0.42)	(0.04, 0.439)	(0.03, 0.39)
FMI	0.04	0.05	0.07	0.22	0.09	0.15	0.26	0.14	0.39	0.39
AIC	-137.80	-25.28	-136.74	-29.92	-142.70	-38.96	-161.73	-37.31	-97.43	-95.79
N	92	92	92	92	92	92	92	92	92	92

Standard errors in parentheses
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

Table 14: OLS regression on main variables and interaction effect using the imputed sample of both fisheries and irrigation systems

	Fishing Grounds					Irrigation Systems				
	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Trust	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Trust
Trust			0.53**	0.53*				-0.07	0.57**	
			(0.17)	(0.25)				(0.07)	(0.20)	
SH (Mean)	0.23	-0.92	0.07	-1.09	-0.30	-0.41**	-0.34	-0.44**	-0.01	-0.59†
	(0.82)	(1.18)	(0.74)	(1.15)	(0.71)	(0.14)	(0.45)	(0.15)	(0.44)	(0.35)
EH (Mean)	-0.16	-0.06	-0.01	0.10	-0.29†	0.04	-0.43*	0.02	-0.22	-0.37*
	(0.19)	(0.26)	(0.18)	(0.27)	(0.16)	(0.07)	(0.20)	(0.07)	(0.21)	(0.15)
Constant	2.71***	3.31***	1.58	2.32**	1.88***	2.18***	2.85***	2.82***	1.01	3.23***
	(0.30)	(1.72)	(1.13)	(1.74)	(1.03)	(0.08)	(0.69)	(0.31)	(0.94)	(0.54)
Adj. R^2	-$^{*}_{*}$	-$^{*}_{*}$	0.22	-$^{*}_{*}$	-$^{*}_{*}$	0.12	-$^{*}_{*}$	0.12	0.30	0.25
95% CI Adj. R^2	-$^{*}_{*}$	-$^{*}_{*}$	(0.02, 0.51)	-$^{*}_{*}$	-$^{*}_{*}$	(0.00, 0.33)	-$^{*}_{*}$	(0.00, 0.33)	(0.09, 0.53)	(0.06, 0.56)
AIC	-35.33	-7.94	-46.77	-8.93	-37.42	-137.05	-18.37	-135.52	-25.71	-54.61
N	40	40	40	40	40	52	52	52	52	52

Standard errors in parentheses

*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

$^{*}_{*}$ *Adjusted R^2 and FMI could not be calculated: the Fisher transformation for pooled simulations could not be performed since some of the simulations had a negative R^2*

Appendix F

Fraction of missing information per variable for main tables

Table 15: FMI per variable for OLS regression on main variables using the combined imputed sample

	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Unit Quality	(6) Balance	(7) Unit Quality	(8) Balance	(9) Trust	(10) Trust
Irrigation	0.04	0.05	0.08	0.12	0.08	0.11	0.17	0.09		0.17
Irr. x Trust							0.20	0.12		
Trust					0.21	0.17	0.24	0.10		
SH			0.48	0.41	0.39	0.35	0.54	0.37	0.69	0.66
EH			0.29	0.38	0.32	0.40	0.33	0.40	0.38	0.38
N	92	92	92	92	92	92	92	92	92	92
AIC	-137.80	-25.28	-136.74	-29.95	-142.52	-38.54	-159.67	-37.18	-98.90	-99.02

Table 16: FMI per variable for OLS regression for imputed sample of fishing grounds

	Fishing grounds				
	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Trust
Trust			0.20	0.17	
SH	0.35	0.30	0.31	0.32	0.43
EH	0.32	0.33	0.37	0.36	0.32
N	40	40	40	40	40
AIC	-34.51	-7.44	-46.99	-8.31	-39.12

Table 17: FMI per variable for OLS regression for imputed sample of irrigation systems

	Irrigation systems				
	(1) Unit Quality	(2) Balance	(3) Unit Quality	(4) Balance	(5) Trust
Trust			0.21	0.28	
SH	0.34	0.39	0.43	0.37	0.46
EH	0.38	0.46	0.36	0.48	0.40
N	52	52	52	52	52
AIC	-137.81	-20.47	-138.23	-25.71	-60.68

Appendix G

Table 18: Spearman correlation of main variables with available (unimputed) data

	Combined Sample			Fishing Grounds			Irrigation Systems		
	Unit Quality	Balance	Trust	Unit Quality	Balance	Trust	Unit Quality	Balance	Trust
EH	-0.19	-0.25†	-0.56***	-0.17	0.09	-0.54†	-0.28	-0.51**	-0.59**
	(N = 50)	(N = 49)	(N = 21)	(N = 21)	(N = 20)	(N = 29)	(N = 28)	(N = 25)	
SH	0.19†	0.04	-0.17	-0.01	0.42†	0.06	-0.27†	-0.37†	-0.46**
	(N = 81)	(N = 82)	(N = 77)	(N = 35)	(N = 36)	(N = 35)	(N = 46)	(N = 46)	(N = 42)
Trust	0.21†	0.43***	-	0.43**	0.30†	-	-0.15	0.53***	-
	(N = 79)	(N = 80)		(N = 36)	(N = 37)		(N = 43)	(N = 43)	

Standard errors in parentheses

*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

Appendix H

Moderated Mediation models

Table 19: Moderated mediation models, testing the mediated effect of heterogeneity on CPR success through trust for fishing grounds and irrigation systems

	Unit Quality				Balance			
	Fishing Grounds		Irrigation Systems		Fishing Grounds		Irrigation Systems	
	EH	SH	EH	SH	EH	SH	EH	SH
ACME	-0.233***	-0.185***	0.046	0.036	-0.193*	-0.155*	-0.283***	-0.230*
ADE	-0.028	-0.163†	-0.035	-0.167†	-0.069	0.057	-0.076	-0.065
Total Effect	-0.261***	-0.348***	0.012	-0.130	-0.262†	0.211	-0.359**	-0.295**
Prop. Mediated	0.898***	0.537***	0.350	-0.207	0.716†	0.596	0.792**	0.745*
N	92	92	92	92	92	92	92	92
Simulations	1000	1000	1000	1000	1000	1000	1000	1000

Results are created using the mediate function in R (Tingley et al., 2014)
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

Note: Due to incompatibility of the moderated mediation analysis with the *Mice* paradigm and computational tools, we cannot obtained pooled standard errors for the estimates of the moderated mediation. As a result, we resolve to fit the moderated mediation to a representative dataset; this dataset is derived by taking the mean of numeric variables, and the mode of factor variables of the 100 imputed datasets, to create an average dataset.

The above table supports the indirect effects as found using Sobel's (1982) Product of Coefficients Approach for the coefficient, and Monte Carlo simulations for the standard error and two-sided p-value. In addition, the indirect effect of sociocultural heterogeneity through trust on unit quality for fishing grounds is found in the moderated mediation analysis, but this will not be regarded as a robust finding as we did not find this result using the more conservative data.

Chapter III: Playing Nice in the Sandbox: on the role of heterogeneity, trust and cooperation in common-pool resources

Fijnanda van Klingeren

Research published in PLoS ONE

10.1371/journal.pone.0237870

Abstract

The increasing heterogeneity of populations affects cooperation in common-pool resources in a time where the depletion of natural resources is a growing problem. This study investigates the effects of economic and sociocultural heterogeneity on trust and cooperation in common-pool resources using a laboratory experiment. The experiment comprises two Investment Games and a Common-Pool Resource Game, with a sample of 344 subjects from the United Kingdom and the Netherlands. By measuring the effects of economic and sociocultural heterogeneity separately as well as combined, this study disentangles the effects of specific heterogeneity types on cooperation in common-pool resources; something that has not been done before. Higher levels of trusting behaviour are found to have a positive effect on cooperation on the micro- and macro-level over time. While theory suggests negative effects of both forms of heterogeneity on cooperation through decreased levels of trust, the results show a surprising positive effect of economic heterogeneity on cooperation, but a negative effect if economic and sociocultural heterogeneity are combined. This study concludes that economic inequality can promote cooperation in CPRs, unless this inequality is lined up with sociocultural differences.

1 Introduction

Growing migrant populations all over the world make that societies are becoming more diverse on cultural, ethnic and economic dimensions (*International Migration report 2019*, 2019). The successful management of common-pool resources [CPRs] may be challenged by this increase in diversity and inequality, as heterogeneity is thought to diversify interests and decrease trust between appropriators (Seabright, 1993). Especially when there are multiple larger groups of different sociocultural backgrounds living together, intergroup antagonism becomes stronger and coordination between groups becomes harder (Bazzi, Gaduh, Rothenberg, & Wong, 2019). The deforestation of tropical forests and overfishing of the seas are examples of appropriators failing to work together on the preservation of natural resources. However, how and to what extent economic and sociocultural heterogeneity, and importantly the combination of the two, affect cooperation is still contested (L. R. Anderson, Mellor, & Milyo, 2006; Andersson & Agrawal, 2011; Bardhan & Dayton-Johnson, 2002; Flache & Mäs, 2008; Kölle, 2015; Olson, 1965; Poteete & Ostrom, 2004; Ruttan, 2008; Vedeld, 2000). In particular experimental research looking into the effect of heterogeneity on cooperation in CPRs is still relatively rare (Cherry, Kroll, & Shogren, 2005). The aim of this paper is to provide insights into the relation between economic and sociocultural heterogeneity and sustainable cooperation in CPRs, both on the individual and the collective level. To do so, this study employs an Investment Game and a CPR game in a computerised laboratory experiment. Since part of the theoretical mechanism is often suggested to be the negative influence of heterogeneity on trust (see Alesina & La Ferrara, 2002; C. J. Anderson & Paskeviciute, 2006; Delhey & Newton, 2005; Keller, 2001; Putnam, 2007) and the beneficial influence of trust on society (see Fukuyama, 1995; Knack & Keefer, 1997; La Porta, Lopez-de-Silanes, Shleifer, & Vishny, 1997; Putnam, 1993; Uslaner, 2002; You, 2012; Zak & Knack, 2001), this paper will consider trust as an important variable in the theoretical framework. Disentangling effects of economic and sociocultural heterogeneity using experiments in CPR settings has, to the extent of my knowledge, not been done before.

Two key characteristics of CPRs are their non-excludability and high subtractability: it is hard to exclude potential users from accessing CPRs, and the resource may run out (Ostrom, Walker, & Gardner, 1992). These characteristics make CPRs vulnerable to the 'tragedy of the commons' as famously described by Hardin (1968) as a situation in which the CPR is locked into a system that provides each resource-user incentives to use the limited resource unlimitedly, which will lead to its inevitable decay. From a game theoretic perspective, this tragedy will always take place, as a (myopic) rational individual will free-ride and overexploit the resource despite the long-term benefits of cooperation. Although there are plenty of examples of unsustainable appropriation of CPRs (see for instance (Myers, Hutchings, & Barrowman, 1997; Ostrom, 1990)), Hardin's prediction is challenged by evidence from field research suggesting that CPR users are able to self-organise using institutions for collective action (De Moor, 2013b; Janssen, Holahan, Lee, & Ostrom, 2010). In addition, an extensive body of research suggests more complex behaviour than predicted by rational choice theory (Axelrod & Hamilton, 1981; Chaudhuri, 2011; Cherry et al., 2005; De Oliveira, Croson, & Eckel, 2009; Levati, Sutter, & van der Heijden, 2007; Ostrom, 1990). With examples of both successful and failed CPRs, it is interesting and important to investigate the role that economic and sociocultural heterogeneity in communities surrounding CPRs play in the success or failure of a CPR.

Empirically analysing the influence of heterogeneity in real-life CPR settings can be a challenge due to the number of confounding factors that influence success and failure; one can never be entirely sure that one variable or a set of variables caused an outcome (Ostrom, 2006). This can be solved to a large extent by using laboratory experiments. While laboratory experiments score lower on external validity than field experiments, they score high on internal validity: they allow one to test causality by measuring the impact of an isolated variable or set of variables repeatedly, in the same controlled setting - something that is not possible in field research (Ostrom, 2006; Meinzen-Dick et al., 2016).

For the current study, subjects first played an Investment Game [IG] to measure general trust and trustworthiness and then played a CPR game as introduced by Janssen, Holahan and Ostrom (2010), to measure behaviour in a CPR setting under different levels of heterogeneity. The CPR game mimics a fishing ground which the subjects can appropriate in return for money in groups of four under different conditions of economic and sociocultural heterogeneity. Economic heterogeneity is introduced as unequal endowments of players, and sociocultural heterogeneity by means of a Minimal Group Experiment [MGE]. An MGE is a method to create artificial identities based on a trivial criterion (see amongst others (Tajfel, 1970; Tajfel, Billig, Bundy, & Flament, 1971; Aksoy, 2015; Masella, Meier, & Zahn, 2014)). An extensive explanation of the MGE used in this paper is given in the section on experimental treatments.

Given the increasing depletion of CPRs world-wide and the rising levels of sociocultural and economic heterogeneity, the subject of heterogeneity and sustainable cooperation is gaining importance. The results of this study may be relevant not only for classic resources such as fishing grounds, but also for the growing number of contemporary commons such as food cooperatives and green energy initiatives (De Moor, 2013a, 2013b, 2018).

The paper is structured as follows. First, existing literature on the research topic will be explored and hypotheses based on the literature are derived. Second, the experimental proceedings, games and treatments will be described. Third, descriptive plots, non-parametric test and multilevel regression are employed to analyse the data. Lastly, expectations are revisited, the findings are discussed and a conclusion is formulated.

2 Existing literature

2.1 Heterogeneity and Cooperation

Experimental research looking into the effects of economic and sociocultural heterogeneity on cooperation suggests that asymmetrical endowments - i.e. an unequal division of money or points to spend between players in a group - lead to unequal contributions, unequal payoffs, and Pareto suboptimal outcomes (Chan, Mestelman, Moir, & Muller, 1999). Furthermore, it is argued that economic inequality leads to an increase of transaction costs (Zak & Knack, 2001) and diversification of interests among individuals, which makes cooperation less likely to happen (Shanmugaratnam, 1996; Adhikari & Lovett, 2006; Bardhan, 2000). For Public Good games it was found that heterogeneity in endowments indeed leads to a lower contribution to the public good (Cherry et al., 2005; Ledyard, 1993; Levati et al., 2007). This may be caused by an 'anticipated reciprocity' effect: a situation in which subjects with a lower endowment expect the subjects with higher endowments to invest more, since they have more means available to invest, while subjects with higher endowments do not in fact do so (Cherry et al., 2005).

Olson (1965) suggests an opposite effect of economic heterogeneity: he argues that when groups are sufficiently small, and inequality sufficiently large, economic inequality leads to inequality of incentives, which makes the rich incentivised enough to bear the burden of cooperation by themselves. However, Bardhan and Dayton-Johnson (2002) argue that this will only hold if there are "non-convexities" in the CPR, such as maintenance of the CPR, restraints on appropriation or large start-up costs. Most case-study literature still suggests a negative effect of economic heterogeneity (Easter & Palanisami, 1986; Jayaraman, 1981), despite the theoretical possibility as sketched by Olson.

Theory on the relation between sociocultural heterogeneity and cooperation suggests that individuals are more likely to cooperate with others from their ingroup: individuals with whom they share strong, multi-stranded relationships and common interests (C. J. Anderson & Paskeviciute, 2006; Becker & Ostrom, 1995; Bowles & Gintis, 2002, 2002; Boyd & Richerson, 1985; Ellickson, 1991; Jones, 2004; Nettle & Dunbar, 1997; Ostrom et al., 1992, 1992; Portes & Landolt, 2000; Putnam, 2000; Singleton, 2001; Varughese & Ostrom, 2001). Several case studies show that heterogeneity between CPR appropriators in terms of ethnicity, use of the resource, and view of the resource can be cause for conflict and hampers the development of regulation (R. N. Johnson & Libecap, 1982; Ostrom, 1990). Experimental research shows that (induced) group identity leads to positive behaviour towards ingroup members relative to outgroup members (Chen & Li, 2009) and to the prioritising of group interest over individual interests (Eckel & Grossman, 2005). Timilsina, Kotani and Kamijo (2017) show in their research on sustainability of CPRs that subjects from urban areas show less prosocial and sustainable behaviour in a CPR game than subjects from rural areas. They suggest that subjects from urban areas are less prosocial as they come from a more heterogeneous and anonymous environment, whereas subjects from rural areas are more homogeneous and have a long tradition of necessary mutual cooperation. Habyarimana, Humphreys, Posner and Weinstein (2007) suggest that people with the same ethnicity cooperate due to an increased "findability" in the ingroup through norms and tight social networks, and thus a higher probability of being punished for defection. Their research, identifying subjects as specific player types, suggests that homogeneity increases cooperation levels even for player types that are least likely to cooperate. Next to this, research shows that people have strong expectations of cooperation when interacting with ingroup members as opposed to outgroup members, which makes them more likely to cooperate themselves (Brewer & Kramer, 1986; Yamagishi & Kiyonari, 2000). However, Yamagishi and Kiyonari (2000) show that in order for people to have these higher expectations of cooperation and to act upon it, it is necessary for players to (1) know the ingroup or outgroup identity of the other players; and (2) to know that the other players are aware that everyone knows everyone's identity.

There is also research illustrating that sociocultural heterogeneity does not always have a negative impact on cooperation. Gehrig, Schlüter and Hammerstein (2019) for instance, show in their study of fishermen from a small-scale fishery in Zanzibar that heterogeneous groups of fishermen from different villages do not cooperate less than homogeneous groups, despite a history of conflict between the villages. They argue that the effect of sociocultural heterogeneity on cooperation may be dependent on the institutional scope in the economic domain. In addition, Varughese and Ostrom (2001) argue that heterogeneity does not influence cooperation when the right institutional arrangements are in place. However, the ease with which institutional arrangements can be set in place may depend on the type of heterogeneity. Bazzi, Gaduh, Rothenberg and Wong (2019) show in their study of a population resettlement program in Indonesia that in the context of polarisation (a situation with a few larger groups with different sociocultural backgrounds) public goods provision is reduced, the likelihood of ethnic conflict is increased and economic development is hampered. In the context of fractionalisation (a situation with many smaller groups) these negative effects of sociocultural heterogeneity are not found.

2.2 Trust

To get a better understanding on how heterogeneity affects cooperation, trust is considered to be a mediating variable. There is extensive evidence that heterogeneity reduces trust (Alesina & La Ferrara, 2002; Barr, 1999; Coleman, 1994; Glaeser, Laibson, Scheinkman, & Soutter, 2000, 1999), while higher trust yields higher levels of cooperation (Alesina & La Ferrara, 2000; Knack & Keefer, 1997; La Porta et al., 1997; Seabright, 1993). This implies that individuals trust others with a similar identity - for instance religion, ethnicity, culture, social identity or something else - more than others with a different identity (Alesina & La Ferrara, 2002; Bouckaert & Dhaene, 2004; Delhey & Newton, 2005; Knack & Keefer, 1997; Putnam, 2007; You, 2012; Zak & Knack, 2001).

In the particular case that is studied here - a fishing ground - trust is necessary to maintain cooperation. Real fishermen do not know how much fish the other fishermen are catching during a day out fishing at sea, and will only see or hear about each other's catch when all the ships have returned. In the same way, players in the experiment do not know what the others are doing during the appropriation stage and only receive information about this at the end of the period. Like fishermen, players will have to trust each other to behave cooperatively during the appropriation stage due to a lack of mutual monitoring.

2.3 Hypotheses

Based on the majority of the discussed literature, the following hypothesis is deduced with regard to the direct effect of heterogeneity on cooperation in CPRs:

Hypothesis 1 *(a) Economic and (b) sociocultural heterogeneity have a negative direct effect on cooperation over time and (c) the coincidence of economic and sociocultural heterogeneity has an even stronger negative direct effect on cooperation over time*

The following hypotheses are deduced with regard to the indirect effect of heterogeneity on cooperation in CPRs, through trust:

Hypothesis 2 *(a) Economic and (b) sociocultural heterogeneity have a negative effect on trust and (c) the coincidence of economic and sociocultural heterogeneity has an even stronger negative effect on trust.*

Hypothesis 3 *Trust has a positive effect on cooperation over time*

3 Data and Methods

3.1 Experimental Sessions

A computerised laboratory experiment was designed and programmed in z-tree (Fischbacher, 2007). A total of 344 subjects of age 18 and older participated in the experiment, which was conducted at the Centre for Experimental Social Sciences [CESS] at Nuffield College, University of Oxford between October 2018 and November 2019, and at the Experimental Laboratory for Sociology and Economics [ELSE] at Utrecht University in April 2019. The subjects for both laboratories were recruited from the Online Recruitment System for Economic Experiments [ORSEE] (Greiner, 2004). After a pre-test with 16 Oxford students, the experiment was held in 13 sessions at CESS containing 248 subjects, and 5 sessions at ELSE containing 96 subjects. Sessions contained 16, 20 or 24 subjects. 81% of the subjects were students, from varying disciplines and years/stages. 60% of the subjects were female, and the average age was 26. This research, including the pre-test, has obtained ethics clearance from the Research Ethics Committee of Department of Sociology (DREC) at the University of Oxford (Ref. SOC_R2_001_C1A_18_30), the CESS ethics committee (Ref. LE_0044) and was covered by the ethical approval (Ref. FETC17-028, Buskens) of the ethical committee of the Faculty of the Social and Behavioural Sciences at Utrecht University. Written consent was obtained from all subjects in the study, including the pre-test, before the start of each experimental session. The data was anonymised before the analyses.

The laboratories are very similar in physical setup: a room with 25 to 30 computers, separated by privacy dividers, with a designated area for the experimenter computer. The experimental procedures, including having participants wait in a waiting room, dividing subjects randomly over computers, and handing out instructions with help of a research assistant, were formalised in the exact same way for sessions in the UK and the Netherlands.

The sequence of the experiment is as follows. When subjects enter the lab, they are given general written instructions in English for the first part of the experiment, which entails (1) a one-shot Investment Game; (2) a basic, practise version of the Fishing Game without any treatments for 3 periods; (3) a Minimal Group Experiment; (4) a binary other-other Dictator Game; and (5) a quiz to strengthen group bonds; and lastly (6) two other one-shot rounds of the Investment Game, once with an ingroup member and once with an outgroup member. An extensive explanation of each of these parts is provided in the upcoming sections. After completing the first part of the experiment, subjects receive instructions for the second part of the experiment: the Fishing Game with heterogeneity treatments. Subjects receive instructions specific to their treatment; economic heterogeneity [EH], sociocultural heterogeneity [SH], economic and sociocultural heterogeneity [EHSH] and the control treatment with no heterogeneity [NH]. The general and treatment-specific instructions can be found in Appendix A and Appendix B respectively. Completing the experiment took 50 to 70 minutes, of which 20 to 30 minutes were spent on the games before the Fishing Game. Figure 1 shows a schematic overview of the separate parts of the experiment. Subjects played for real money (GBP in the UK and EUR in the Netherlands) under an exchange rate of 500 units = 1 GBP/EUR. The average earning was 15.11 GBP/EUR.

Figure 1: Sequence of the experiment

		Practise		*MGE*				
IG 1	⟶	*Fishing Game*	⟶	*Quiz*	⟶	*IG 2*	⟶	*Fishing Game*
		× *3*		*DG*				

3.2 The Investment Game

The game that is used to measure trust before the main experiment is a variation of an Investment Game, as designed by Berg, Dickhaut and McCabe (1995). The Investment Game [IG], also called the Trust Game, is the most frequently used game to study trust (Evans & Revelle, 2008).

The current version of the game is played as follows. There are two roles: the sending (or trusting) and the receiving (or honouring) role. Both players first adopt the sending role, and are given an endowment of 10 points. Both players are given the choice of sending points to another player, ranging from 0 to 10 points. This amount will be tripled once before it reaches the other player. Next, both players are put in the receiving role; they are asked how many of the points received by a sending player they would send back, for every possible amount of points received. This amount ranges from 0 to 30 points in increments of 3. 30 points would be the maximum amount to be received by the receiving player, since the maximum amount of points that the sending player can send is 10, and $3 \times 10 = 30$. Making players choose how many points to return for every possible received amount is called the strategy method (Bahry & Wilson, 2006; N. D. Johnson & Mislin, 2011). This method provides the advantage to the researcher of having data on trust and trustworthiness for all subjects, as the player 2 decision can be made separately from another subject's player 1 decision. After playing the game in each of the roles, the subjects are randomly assigned the role for which they will receive their payoff. They are matched to another player with the other role. Their previous actions decide their final payoff. The material utility functions for the players are as follows: For player 1, the sender/trustor, the general material utility payoff function is:

$$U_i = E_i - S_{ij} + R_{ji}$$

Where E_i is the initial endowment of sender i, S_{ij} is the amount of points sent from the sender i to the receiver j, and R_{ji} is the amount of points returned from the receiver to the sender. For player 2, the receiver/trustee, the general material utility function is:

$$U_j = E_j + 3 \times S_{ij} - R_{ji}$$

Where E_j is the initial endowment of receiver j, S_{ij} is the amount of points sent from the sender i to the receiver j that is multiplied by 3 by the experimenter, and R_{ji} is the returned amount from the receiver to the sender. In the current game, $E = 10$ for both players. The two trust variables, operationalised following Johnson and Mislin (2011) will be measured as follows:

$$Trust = \frac{number\ of\ points\ sent\ by\ i}{endowment\ of\ i} = \frac{S_{ij}}{Ei}$$

$$Trustworthiness = \frac{number\ of\ points\ returned\ to\ i\ by\ j}{number\ of\ points\ available\ to\ return\ to\ i\ by\ j} = \frac{R_{ji}}{E_j + 3 \times S_{ij}}$$

A graphic representation of an interaction between two matched players in the Investment Game is presented in Appendix C. Half of the subjects will be paid for the sending role, and half for the receiving role in each Investment Game. Trustworthiness for all subjects will be calculated as the average trustworthiness over the 10 decisions every subject makes as the receiving player, as facilitated by using the strategy method. There are many variations of the Investment Game. A list and explanation of the specific characteristics of the Investment Game used in this experiment can be found in Appendix D.

3.3 The Fishing Game

The game to be played by participants of the experiment is a CPR game. While it is common to measure cooperation, trust and heterogeneity in games such as Public Good [PG] games (see for instance Aksoy, 2019), there are fundamental differences between CPRs and PGs that should be taken into account when looking specifically at CPR situations. Two characteristic features of a CPR situation are that exclusion of the collective good is infeasible - for instance, it is very costly to fence off part of an ocean - and that subtractability is high - the resource is finite and can run out (Ostrom, 1990; Ostrom et al., 1992). Table 1 shows the classification of different types of goods as shown by Ostrom, Walker and Gardner (1992).[1]

Table 1: A classification of goods (Ostrom et al., 1992, p.7)

		Subtractability	
		Low	High
Exclusion	Difficult	Public Goods	Common-Pool Resources
	Easy	Toll Goods	Private Goods

The CPR in the current game is a fishing ground. In the game, there are four appropriators that use the CPR, who will play the game with each other for the entire session. All subjects first practise the basic CPR game without treatments for three periods, without any consequences for their payoff - just to get to know the game. The real game with treatments is played for 40 periods. A time span of 40 periods is long enough for subjects to see the resource fall into decay if they overexploit it systematically, and there is enough time for subjects to adjust their investments to regrow the resource again.

[1]This classification may be too simple, as it does not take into account CPRs that are not open-access. Nevertheless, it provides a good overview of the differences between different types of goods, and highlights why CPRs should be studied separately from PGs.

3.3.1 Appropriation of the resource

At the beginning of each period t, the appropriators all receive an endowment E of units to invest in appropriation of the resource, R. Since appropriation of the CPR is a costly activity - e.g. it takes time and requires maintenance of the boat and fishing nets - the appropriation effort a, where $0 \leq a \leq E$, represents the amount of effort an appropriator can invest in appropriation of the CPR. The actors can choose how much they want to invest in appropriation of the resource each period. All appropriators make their appropriation decision at the same time, without knowing what the other appropriators do in that period. They see how many fish there are in the lake and how many fish they receive per invested unit a. The appropriators all receive the same return $\left(\frac{4}{R_0} R_{t-1}\right)$ per appropriation effort unit of a. The material utility function for the appropriators per period is as follows:

$$U_{it} = \left(\frac{4}{R_0} R_{t-1}\right) a_{it} + (E_i - a_{it})$$

U_{it} is the total material utility of an appropriator i at timepoint t. In the function, a_{it} is the invested appropriation effort of appropriator i at timepoint t, and E_i is the endowment of appropriator i, which is the same every period. R_0 is the original resource size of the CPR (i.e. the maximum number of fish in the lake) for which $R_0 = 600$ is taken. R_{t-1} is the resource size at time $t-1$. The profit per invested appropriation effort unit of a is thus dependent on the current size of the resource, relative to its original size. If $R_{t-1} = R_0$, which is the case in the first period of the game, the return is $4 - 1 = 3$ units per invested unit of a. When $R_{t-1} < R_0$, the return will be lower than 3 units. The amount of appropriators' endowment not used for fishing is reflected by $(E_i - a_{it})$; players will thus keep the part of the endowment that they did not invest in appropriation as profit for that period.

At the end of the period, the players see how much they invested themselves, their profit from investing, and how much was invested in appropriation of the resource in total as a group. At the beginning of the next period, they also see how much each individual player in their group invested in previous periods.

3.3.2 Resource Renewal

Just like real natural resources, the resource in the game has a renewal rate. The renewal rate per period is modelled as follows:

$$R_t = \min\left(600, 1.25\left(R_{t-1} - \left(\frac{R_{t-1}}{R_0}\right)\sum_{i=1}^{4} a_{it}\right)\right)$$

Here, 1.25 is the renewal rate of the resource and R_t is the resource size at timepoint t. The amount of fish in the lake is thus multiplied by 1.25 after each period. The maximum resource size is $R_t = 600$; this is the maximum amount of fish in the lake and the resource cannot grow beyond this size. The sum of appropriation effort of all four appropriators is indicated by $\sum_{t=1}^{4} a_{it}$.

3.3.3 Overexploitation

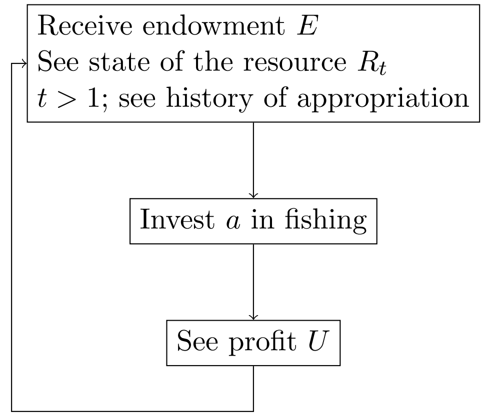
The CPR is overexploited - that is, the pool of fish in the lake is smaller than in the previous period - when $R_t < R_{t-1}$, so when the resource size in timepoint t is smaller than in the previous timepoint. This happens if $\sum_{t=1}^{4} a_{it} > 120$ because this is the limit of sustainable appropriation based on $R_0 - \frac{R_0}{1.25}$. The CPR is thus overexploited when the four appropriators have invested on average 30 units in appropriation effort per person $\left(600 - \frac{600}{1.25} = 120\right)$. Investing stops being profitable if $R_t = \frac{R_0}{4}$, so if the resource size decreased to 25% of the original resource size ($R_t = 150$), because:

$$U_{it} = \left(\frac{4}{600}150\right) a_{it} + (E_i - a_{it}) = E_i$$

When this happens, any amount the appropriator invests in appropriation of the resource will result in a return of exactly that amount, and the profit consisting of the return plus the leftover endowment will thus result in $U_{it} = E_i$. For example, if the appropriator has $E_i = 50$ and $a_{it} = 50$, the return will be $50 + 0 = 50$; if the appropriator invests 10 the return will be $10 + 40 = 50$ etc. When the resource size drops below 25% of the original size, appropriators make loss by investing in appropriation. Only when the size of the resource increases again will the multiplication of the invested unit of a increase and fishing will become relatively more profitable. Graphs visualising the development of the resource size under different levels of appropriation over time, and the decreasing marginal profits of overexploitation are shown in Appendix E and F respectively.

In real life, fishermen may not notice the decline of the resource size within a day's time. However, having limited time for a laboratory experiment, the game unfolds as if the process of depletion and renewal was sped up. With a total number of 40 periods the experiment covers enough time to capture long-term behaviour. Figure 2 schematically visualises the different stages in a period of the Fishing Game.

Figure 2: The different stages in a Fishing Game period for a player



3.3.4 Trust

Trust is measured at three points in the experimental session: (1) by the one-shot Investment Game with a random other subject at the very beginning of the experimental session, before the MGE and the main game; (2) after the MGE when subjects play the one-shot Investment Game once with an ingroup member and once with an outgroup member; and (3) by asking questions on trust in a post-experimental survey. The one-shot Investment Game with a stranger will be used to measure general trust. Even if this type of trust does not resemble the mutual trust necessary for repeated games (such as the current CPR game) exactly, it is still useful as an indicator of general trustfulness of subjects before they enter the main game.

3.4 Experimental Treatments

3.4.1 Sociocultural Heterogeneity: the MGE

To test the effect of sociocultural heterogeneity on cooperation, an MGE is used to create artificial identities which are based on a trivial criterion (Aksoy, 2015; Kahn, 2019; Tajfel, 1970; Tajfel et al., 1971; Yamagishi & Kiyonari, 2000). Following the approach of amongst others Tajfel, Billig, Bundy and Flament (1971), Masella, Meier and Zahn (2014), Aksoy (2015, 2019) and Kahn (2019), the subjects are shown five paintings by two artists, Paul Klee and Wassily Kandinsky, after which they are asked to express their preference of either picture, resulting in a score of 0 to 5 for Klee-preference. Based on the median preference of the particular experimental session, subjects are assigned to the Klee or Kandinksy group. Tajfel et al. (1971), in one of the first published studies using the MGE, divide subjects randomly over groups, regardless of their Klee or Kandinsky preferences. Even random allocation led to subjects trying to maximise ingroup outcomes. However, following Aksoy (2015), Kahn (2019) and specifically using the method of Masella et al. (2014), subjects in this study were divided on the actual outcomes of their choices. This approach was taken for several reasons. Firstly, this was done to avoid deception of subjects. Secondly, letting subjects go through a process where they are divided into groups based on a real characteristic, namely preference for Klee or Kandinsky, could add to the feeling of belonging to a group. Thirdly, in the rare case a subject would have a profound preference for either painting, knowing which painter painted which painting, allocating them by chance in the wrong group would decrease the power of the experiment.

After grouping subjects into Klees and Kandinskys, this study follows Aksoy (2015) and Kahn (2019) by enhancing group identities with a quiz and an other-other Dictator Game. In the quiz, players have to guess the painter (Klee or Kandinsky) of three paintings. High group performance is profitable: if more than half of the answers of the ingroup are right and/or if the ingroup has more right answers than the other group, players from that group get extra points. The extra points from this part of the experiment will be shown at the end of the CPR game, in order to avoid that low group performance in the quiz influences behaviour in the CPR game (Aksoy, 2015). Next, subjects play three periods of a binary other-other Dictator Game, as described by amongst others Aksoy and Weesie (2012) and Bilancini, Boncinelli, Capraro, Celadin and Di Paolo (2020). In this game, players face three scenarios in which they have to divide points between a Klee and a Kandinsky player (an ingroup and an outgroup member). In each of the three scenarios, they can opt to divide points equally or unequally between both other players. The purpose of this game is to make players aware of their group membership. Each experimental session, one scenario is randomly picked to be a paid interaction in which the choice that players make influences the amount of points that will be sent to a Klee and a Kandinsky player. Subjects know that any one of the three scenarios will be paid. The three scenarios with the available options in the other-other DG are provided in Appendix G.

An alternative way to induce sociocultural heterogeneity would be to use natural identities based on for instance gender, religion or ethnicity (Bouckaert & Dhaene, 2002; Fershtman & Gneezy, 2001). However, it is not necessarily known to what extent, if at all, a subject identifies with their natural identity. Next to that, it is unpredictable how natural identities will respond to experimental manipulations, and there are many other factors that may vary with natural identity that may influence behaviour (Aksoy, 2015; Chen & Li, 2009; Kahn, 2019). Induced identities on the other hand, are fully controllable and unambiguous, allowing for a bigger confidence that any behavioural differences between subjects are indeed caused by the treatment itself (Aksoy, 2015). Even though the groups are based on an artificial criterion, plenty of research shows that the feeling of belonging to a group, no matter on what basis categorisation takes place, is enough to create social identity (Aksoy, 2015; Billig & Tajfel, 1973; Chen & Li, 2009; Singleton, 2001; Tajfel et al., 1971; Yamagishi & Kiyonari, 2000).[2]

It was checked and confirmed that being a Klee or a Kandinsky itself did not significantly affect the outcomes of interest, that is, no underlying behaviour was associated with becoming a Klee or Kandinsky.

3.4.2 Economic Heterogeneity

Economic heterogeneity is induced by varying the endowment E_i that players receive at the start of each period. Under economic homogeneity, all appropriators receive $E_i = 50$ to invest in appropriation. Under economic heterogeneity, however, two appropriators receive $E_i = 40$ and two appropriators receive $E_i = 60$ (See (Cherry et al., 2005) for a similar operationalisation of economic heterogeneity based on variations in endowment). The total endowment of the group is 200 for all groups in the experiment.

3.4.3 Four Combinations

The four treatments that are applied in the experiment are shown in table 2. Subjects know their own endowment and the endowment of others in their group; just as they know their own preference identity (Klee or Kandinsky) and the preference identity of others in their group. They see all this information in a box on the screen every period.

Randomisation of subjects across groups in the main game was organised as follows. First, a rank order was created with subjects ranked on how many Kandinsky paintings they preferred out of five paintings. To prevent subjects sharing a rank, a random number between 0 and 1 was added to their rank, and the list was ordered again. From this ordered list, the bottom half was declared a Klee, and the top half Kandinsky. Groups were then assembled according to the treatment for that group; homogeneous for the EH and NH treatments (all Klees or Kandinskys) or heterogeneous for the SH and EHSH treatments (two Klees and two Kandinskys). Groups are assigned to treatments

[2] A side note here is that increased cooperative behaviour towards ingroup members may be 'neutralized' in sequential games, where expectations of reciprocity among ingroup members are replaced by information on the actual cooperation of the group members, as shown by Yamagishi & Kiyonari (2000). In the current game, players make their decisions simultaneously. However, as the game is played over 40 periods, previous behaviour of group members is likely to affect decisions more than expectations of reciprocity after the first period.

manually, depending on the number of subjects in a session and the total number of subjects in each treatment from earlier experiments

Note that in the EHSH treatment economic heterogeneity is lined up with sociocultural heterogeneity; that is, two members of the same identity group receive $E_i = 60$ and the two other members, who are both members of the other identity group, receive $E_i = 40$. In the EH treatment, two randomly chosen players receive $E_i = 40$ and the other two receive $E_i = 60$. This design does not include a treatment where economic and sociocultural heterogeneity are not lined up: economic heterogeneity is only found within and between groups, not both. This was done for two reasons. Firstly, by only varying heterogeneity within and between groups, the experimental design is kept simpler; adding a fifth treatment would result in fewer subjects in each treatment, or the need for a larger sample size to retain statistical power. Secondly, lining up economic and sociocultural heterogeneity enables one to distil whether it is economic or sociocultural heterogeneity that plays a role in certain conflicts between appropriators, such as the conflicts between Japanese and Chinese fishermen between 1920 and 1930 and after World War II: two groups who differed greatly in culture and in fishing assets (Keyuan, 2003; Muscolino, 2008). However, this does not mean that there are no cases where economic and sociocultural heterogeneity are not lined up. An interesting experiment that varies the overlap between economic and sociocultural heterogeneity is Aksoy (2019).

Table 2: Overview of treatments

	Treatment	Operationalisation
EH	Economic heterogeneity Sociocultural homogeneity	Different endowments Same preference identities
SH	Economic homogeneity Sociocultural heterogeneity	Same endowments Different preference identities
EHSH	Economic heterogeneity Sociocultural heterogeneity	Different endowments Different preference identities
NH	Economic homogeneity Sociocultural homogeneity	Same endowments Same preference identities

3.5 Analytical Strategy

3.5.1 Functions

A multilevel regression framework is deployed to test the hypotheses outlined above. For the macro-outcome resource size, a two-level multilevel model will be fitted with period-level outcomes (level 1) and random intercepts for groups (level 2). Individual characteristics will be aggregated to the group level - i.e. the group mean of general trust from the IG, sex, age, experience with game theory, etc. will be taken. The model is represented in the following function:

$$
\begin{aligned}
y_{tj} = \alpha_j &+ \sum_{k=1} \beta_k x_{jk} \\
&+ \sum_{\tau=1} \psi_\tau z_{j\tau} + \omega g_j \\
&+ \phi_1 t + \phi_2 t^2 \\
&+ \sum_{\tau=1} \theta_\tau (z_{j\tau} \times t) + \sum_{\tau=1} \lambda_\tau (z_{j\tau} \times t^2) + \xi (g_j \times t) \\
&+ e_{tj};
\end{aligned}
$$

with $\alpha_j \sim N(\mu^\alpha, \sigma^2_\alpha)$ and $e_{tj} \sim N(0, \sigma^2)$. α_j indicates the intercept for groups. There are t periods for j groups; k control variables x with coefficient β; τ treatments z with coefficients ψ. g_j represents average general trust as measured by the IG per group j with coefficient ω. Finally, an interaction of treatments with period and the quadratic term of period with respectively coefficients θ and λ, and an interaction of average general trust with period with coefficient ξ are included.

For the micro-outcome individual appropriation effort, a three-level multilevel model will be fitted with period-level outcomes (level 1) and random intercepts for individuals (level 2) and groups (level 3), as represented in the following function:

$$
\begin{aligned}
y_{tij} = \Psi_i + \alpha_j &+ \sum_{k=1} \beta_k x_{ijk} \\
&+ \sum_{\tau=1} \psi_\tau z_{ij\tau} + \omega g_{ij} \\
&+ \phi_1 t + \phi_2 t^2 \\
&+ \sum_{\tau=1} \theta_\tau (z_{ij\tau} \times t) + \sum_{\tau=1} \lambda_\tau (z_{ij\tau} \times t^2) + \xi (g_{ij} \times t) \\
&+ e_{tij};
\end{aligned}
$$

with $\Psi_i \sim N(\mu^\Psi, \sigma^2_\Psi)$, $\alpha_j \sim N(\mu^\alpha, \sigma^2_\alpha)$ and $e_{tij} \sim N(0, \sigma^2)$. Ψ indicates the intercept for individuals, and α indicates the intercept for groups. There are t periods for i individuals in j groups; k control variables x with coefficient β; τ treatments z with coefficient ψ. g_{ij} represents individual general trust as measured by the IG for person i in group j with coefficient ω. An interaction of treatments and period and the quadratic term of period with respectively coefficients θ and λ, and an interaction of individual general trust with period with coefficient ξ are included.

3.5.2 Controls

The macro-model on resource size controls for within-group levels of average general trust as measured by the IG, average age, average number of real-life acquaintances in the experimental session, average experience with game theory, percentage of students, percentage of women, and whether a session took place in the Netherlands (1) or not (0). The micro-model on appropriation effort controls for the group means as listed above, plus the individual measures of general IG trust, age, sex (male 0, female 1), number of acquaintances, experience with game theory and being a student. All of the controls are present in the models, but only the ones that impact the dependent variable significantly will be reported in the tables. In addition, the micro-model controls for resource size at period $t-1$ to tease out how much of the individual behaviour is due to the actual treatment instead of the resource size in the previous period; one can expect a general tendency of individuals to appropriate more when the resource size is bigger, and less when the resource size is smaller. The macro-model on resource size will not control for this, for two reasons. Firstly, resource size is a direct and absolute measure of success at the macro level. Controlling for resource size in the previous period would change the interpretation of the dependent variable into periodic change in resource size, which is unintuitive as a measure of success. Secondly, as change in resource size is potentially affected by the treatment, controlling for resource size in the previous period could create endogeneity, which would complicate the interpretation of treatment effects from the model.

Instead of controlling for lagged resource size, period by treatment interactions are introduced up to a second order polynomial to account for the explicitly dynamic nature of the treatment effects. A critic may hold that such a model specification may be ad-hoc or otherwise mis-specified; the response can be found in Appendix H and I, showing that non-parametric regression splines fitted to the purged residuals using Generalised Additive Models (Wood, 2006, 2017) come to similar conclusions regarding the nature of the dynamic functional forms of the treatments.

While it is common in analyses of experimental data to control for endgame effects, this is not the case in the current analyses. Endgame effects are found when participants behave in a purely selfish and profit optimising way near the end of the game, as they know that the interaction will end and thus there will be no consequences of defection in the future (Andreoni, 1988; González, Güth, & Levati, 2005). In the current game, however, there is no clear endgame behaviour visible, as subjects did not know how many periods of the game they would have to play. As González, Güth and Levati (2005) show, not informing participants when the experimental interaction ends does not alter behaviour in the game but does reduce the frequency of endgame effects. In addition, even though the experiment consists of many parts and experimental sessions took a significant amount of time, no sign of exhaustion by players is visible - that is, behaviour throughout the game seems constant. An effect can be expected for these first few periods of the game: subjects may not know the game well enough to understand the consequences of their behaviour until after the first couple of periods. However, in the current game the initial drop of the resource size is not necessarily an artefact of participants misunderstanding the game but rather a behavioural pattern common in CPR games (see for instance (Janssen et al., 2010) and (Hey, Neugebauer, & Sadrieh, 2009)) as well as a result of the withdrawal and renewal functions in the game. Thus, as this is a process that is not an unnatural behavioural response to the game but a process that can be expected to be found in any CPR, the models will not control for startgame effects.

4 Results

4.1 Descriptive Plots

Figure 3 shows an interesting difference in resource size over time between the treatments. The first thing that catches the eye is the steep drop of resource size in the first ten to fifteen periods. When the resource is at its fullest, all groups in all treatments seem to overappropriate the resource. This trend is very similar to the trend shown in the CPR game by Janssen, Holahan, Lee and Ostrom (Janssen et al., 2010), under treatments of no communication and punishment and costly punishment. A steep initial drop in resource size is also visible in the first 10 periods of the CPR fishing experiment by Hey, Neugebauer and Sadrieh (Hey et al., 2009), in a treatment where information on resource growth and stock size are available.

Looking at differences between treatments, it stands out that the EH treatment seems to do better - that is, has a higher resource size and thus a higher profit per invested unit of appropriation - throughout the game than the other treatments, including the NH treatment. Strikingly, this only holds for EH under sociocultural homogeneity, and not for the EHSH treatment, in which the resource size keeps decreasing throughout the game and ends up being lower than the NH treatment. Given the curve visible in the graph, treatment effects may vary over time, suggesting an interaction with the quadratic term of time.

Figure 4 shows a behavioural pattern consistent with Figure 3; the EH treatment starts off with and keeps up a decreasing appropriation effort throughout the game. The EHSH treatment decreases too, although with a smaller slope, resulting in overexploitation and a lower resource size as is visible in Figure 3. In all treatments, the appropriation effort stabilises around 30 units of a, which is the cooperative amount to invest in the resource per period per player.

To get a more detailed idea of how groups performed in the various treatments, Figure 5 shows the resource size in each group per treatment. This graph shows that all treatments have well and poorly performing groups. However, it is clearly visible that the EH treatment has the highest concentration of groups that maintain a resource size above 400 throughout the game. The EHSH treatment has the highest concentration of groups that have a resource size below 300 throughout the game.

Figure 3: Smoothed average Resource Size per treatment over time

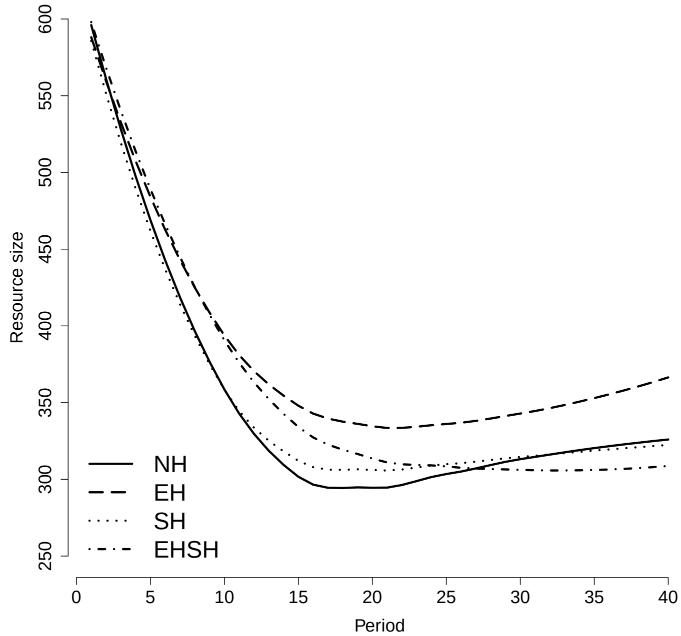


Figure 4: Smoothed average Appropriation Effort per treatment over time

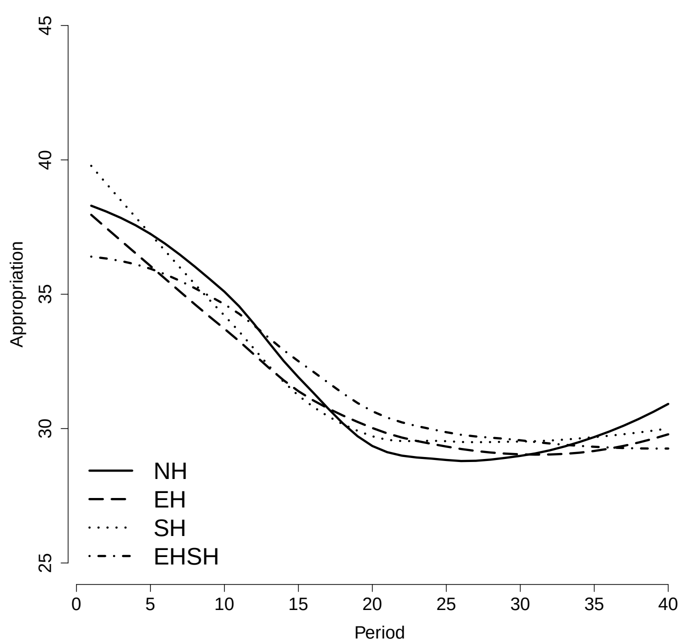


Figure 5: Resource Size per group per treatment

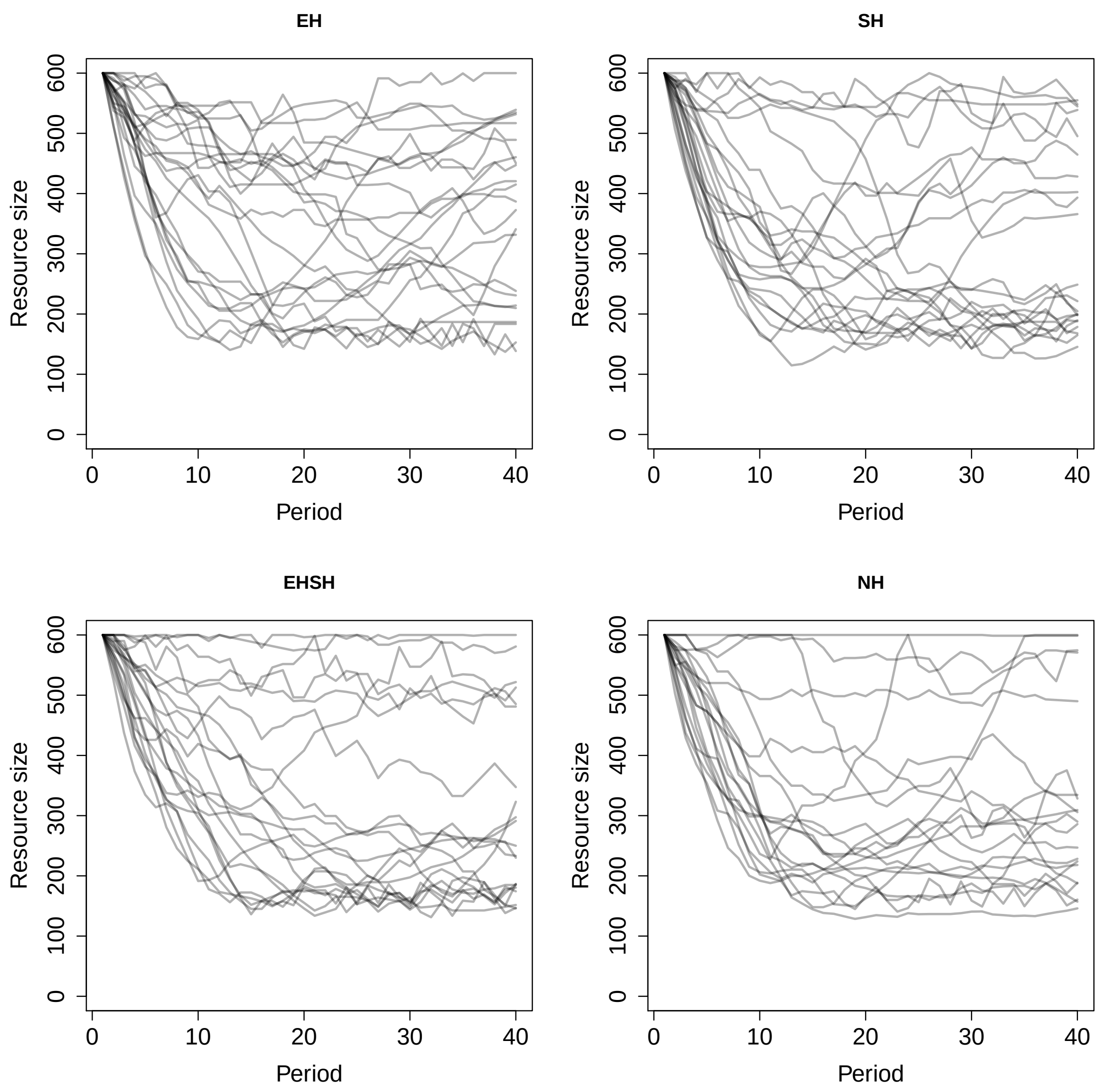


Figure 6 shows boxplots of general, ingroup and outgroup trust as measured by the general IG, the ingroup IG and the outgroup IG, converted to a measure between 0 and 1.[3] The boxplots show that while the trusting behaviour is similar in the general IG and the ingroup IG, it is generally lower for the outgroup IG. The latter illustrates at least partially the implications of the MGE; subjects treat outgroup members differently from ingroup members, even if group membership is based on an artificial criterion.

Similar to Figure 6, the boxplots in Figure 7 show a generally lower level of trustworthiness

[3]Each section of the box represents a quarter of the observations, and the middle line is the median.

towards outgroup members than ingroup members, while general trustworthiness is similar to the ingroup IG trustworthiness levels.

Based on these descriptive plots, some interesting areas to investigate further include (a) the difference in effects between treatments over time; (b) a potential quadratic relation between treatment effects and time; and (c) the effect of general trust measured with the Investment Game on main-game behaviour of individuals in the different treatments. Results will be analysed separately for the macro- and the micro-level.

Figure 6: Trust of players in general (left), ingroup (centre) and outgroup (right) players as displayed in the IG

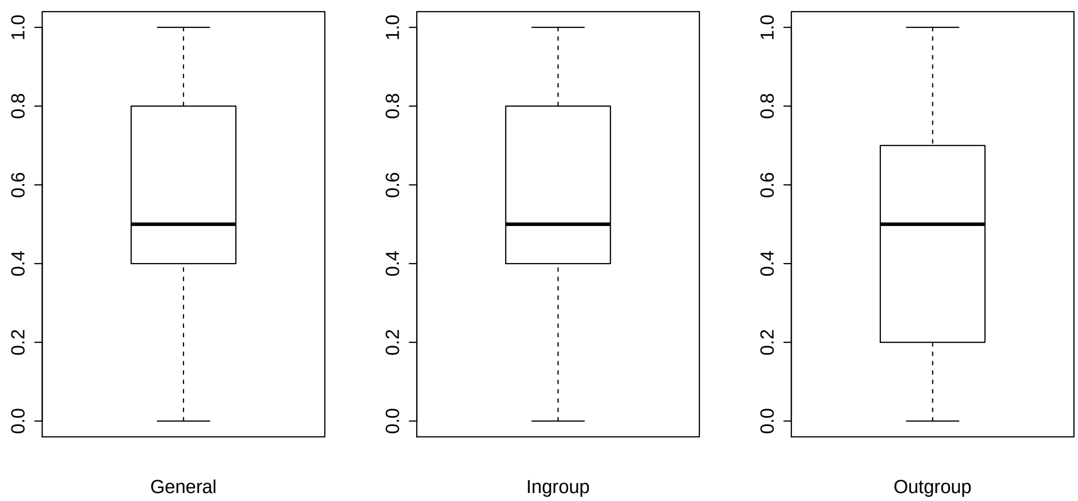
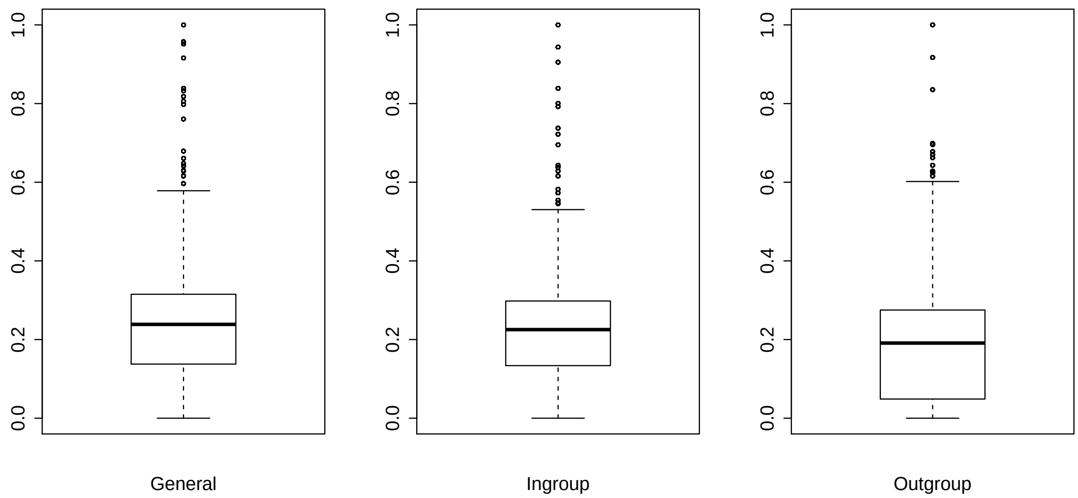


Figure 7: Trustworthiness of players towards general (left), ingroup (centre) and outgroup (right) players as displayed in the IG



4.2 Non-Parametric Tests

A Kruskal-Wallis test (Kruskal & Wallis, 1952) is used to compare the means of resource size and appropriation effort between the four treatment groups. The test concludes that there is significant evidence that the group means of resource size are not equal (X^2 = 27.21; df = 3; $p < 0.001$). Regarding appropriation effort, there is no evidence that the group means are not equal.

To analyse the differences in resource size between specific treatments, Mann-Whitney-Wilcoxon tests are performed for every pair of treatments. The distribution of resource size for EH is found to be significantly different from SH (W = 1233, $p < 0.001$), EHSH (W = 1124, $p < 0.001$) and NH (W = 1237, $p < 0.001$). The other treatments do not differ significantly from each other according to the test. However, the trends of resource size and appropriation over time may still differ between treatments, as is apparent from the descriptive plots. Whether this is the case will be investigated using interactions in the multilevel regressions.

4.3 Resource Size Results

Table 3 shows the two-level multilevel regression on resource size. Model 3 is the model including treatments interacted with the linear and quadratic term of period, trust interacted with period, and all the group characteristic control variables.

The main effects of the treatments, to be interpreted as the treatment effect in period $t = 0$, are not significant and are in fact not very meaningful for interpretation on their own.

Model 3 shows a significant positive interaction effect of EH with time (B = 3.06, p = 0.011), indicating that the slope of EH on resource size is significantly higher each period compared to NH. There is also a negative effect of EH interacted with the quadratic term of period (B = −0.06, p = 0.027), indicating that the positive slope of EH on resource size by period will flatten out over the course of the game. This is a surprising but interesting result, contradicting hypothesis 1a, stating a negative effect of economic heterogeneity on cooperation (and thus resource size on the macro-level) over time. Instead, taken together with the negative main effect of EH, results show a more complex relation of the treatment effect over time, starting with a negative effect becoming positive, and then flattening out.

There is a marginally significant positive difference in slope of SH on resource size relative to NH over time (B = 2.11, p = 0.083) and a marginally significant negative interaction effect of SH with the quadratic term of period (B = −0.05, p = 0.094). Taken together with the negative main effect of SH, this means that relative to NH, SH starts with a lower resource size, but has a larger slope than NH, which flattens out over time.

Model 3 shows a positive interaction of EHSH with period on resource size (B = 1.58, p = 0.201), but this effect is not significant. What is significant, however, is the interaction of EHSH with the quadratic term of period (B = −0.07, p = 0.0119). This indicates that the positive effect of EHSH on resource size per period relative to NH will decrease each period, until the slope becomes smaller than the slope of NH - and thus EHSH performs worse - around period 23. The main effect of period is now to be interpreted as the effect of NH over time. The model shows a significantly negative linear effect (B = −23.48, $p < 0.001$), and a positive quadratic effect (B = 0.44, p = < 0.001), indicating that the slope for NH is lower than the other treatments, but that this difference becomes smaller over time.

When changing the reference category in the multilevel model, it shows that the treatments do not differ significantly from each other. That is, EH and EHSH differ significantly from NH, but not from each other or from SH. When taking EHSH as a reference category, the interaction of EH with the linear term of period is not significant (B = 1.49, p = 0.211). However, note that the p-value is low; this reflects a high probability that subjects in EH performed better in terms of resource size over time than the subjects in EHSH.

To visualise the discussed differences in slopes between treatments, Figure 8 shows a graph of treatment effects fitted on the purged residuals of a model with all control variables. This shows the predicted resource size over time per treatment, while controlling for all relevant control variables.

When put together, these results support hypothesis 1c on the negative effect of economic and sociocultural heterogeneity on cooperation over time. The hypothesis stated specifically a stronger negative effect of the combination of economic and sociocultural heterogeneity than either heterogeneity type separately. While technically true, an effect of economic heterogeneity in the opposite direction and a negligible effect of sociocultural heterogeneity were not anticipated. No evidence was thus found for hypotheses 1a and 1b.

The average level of trust in the group - as measured by taking the group mean of general trust displayed in the Investment Game at the beginning of the experiment - has a significant positive interaction with period ($B = 1.81$, $p = 0.006$) meaning that higher average trust in the group will yield higher resource size each period. This supports hypothesis 3 on the positive effect of trust on cooperation over time. Controlling for the maximum individual level of general trust in the group, the interaction between average level of trust and period is still significant, indicating that it is not just one high trust player in the group that facilitates good outcomes for the group, but that more players with higher trust will lead to better results for the group.

As for the significant control variables, the models show that the subjects in the Netherlands managed to keep up higher levels of the resource size ($B = 88.93$, $p = 0.005$), which is an interesting finding indicating that even though the subject pools from Oxford and Utrecht contain international students and residents of approximately the same age range, the location of the experimental sessions (or perhaps the country of residence of subjects) matters. A marginally significant and positive effect is found for a higher percentage of females in the group ($B = 94.10$, $p = 0.063$).

Figure 8: Predicted treatment effects on Resource Size with multilevel regression coefficients

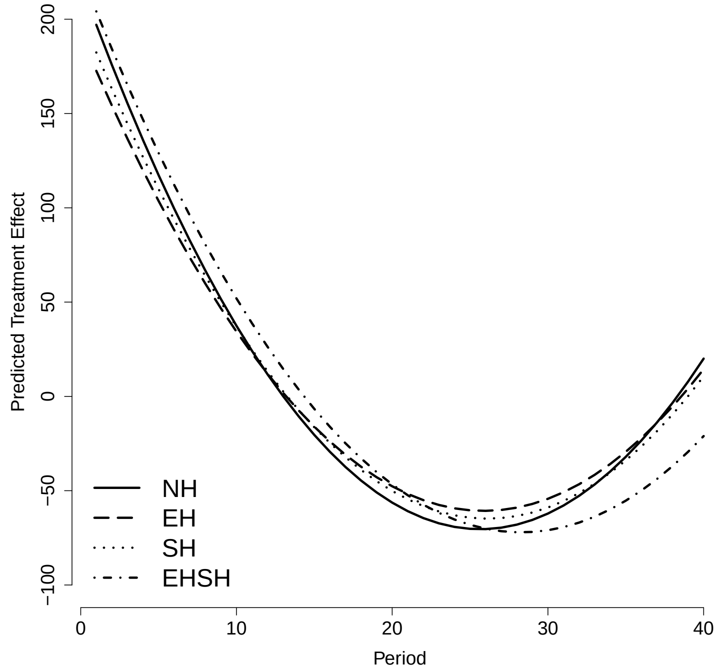


Table 3: Two-level multilevel regression on resource size with random intercepts for groups

	(1)	(2)	(3)
EH	21.13	16.15	−1.92
	(36.15)	(35.07)	(35.78)
EH × Period	0.50	0.483	3.06*
	(0.36)	(0.36)	(1.20)
EH × Period^2			−0.06*
			(0.03)
SH	−1.65	−9.76	−23.58
	(36.53)	(35.37)	(36.08)
SH × Period	0.14	0.14	2.11†
	(0.36)	(0.36)	(1.22)
SH × Period^2			−0.05†
			(0.03)
EHSH	35.10	21.95	2.27
	(36.94)	(36.23)	(36.94)
EHSH × Period	−1.24***	−1.24*	1.58
	(0.36)	(0.36)	(1.23)
EHSH × Period^2			−0.07*
			(0.03)
Period	−4.44***	−5.45***	−23.48***
	(0.26)	(0.51)	(0.95)
Period^2			0.44***
			(0.02)
General Trust [GT]		106.00	106.00
		(88.26)	(87.79)
GT × Period		1.81*	1.81**
		(0.80)	(0.66)
Controls			
Netherlands		88.93**	88.93**
		(30.55)	(30.55)
% Female		94.10†	94.10†
		(49.84)	(49.84)
Constant	439.85***	471.41**	597.64***
	(26.44)	(165.86)	(165.86)
Observations	3,440	3,440	3,440
Groups	86	86	86
Log Likelihood	−20,323.720	−20,283.180	−19,659.490
Akaike Inf. Crit.	40,667.450	40,602.360	39,362.980
Bayesian Inf. Crit.	40,728.860	40,712.850	39,498.000

Standard errors in parentheses.

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

4.4 Appropriation Effort Results

Table 4 shows the three-level multilevel regression on the micro-level variable appropriation effort. None of the models show a significant main effect of the treatments, but as these effects are interpreted as treatment effects at period $t = 0$, these coefficients are not very meaningful

Model 3 is the complete model including treatments interacted with the linear and quadratic term of period, trust interacted with period, and control variables. The model shows a significant positive effect of EHSH on appropriation per period relative to NH (B = 0.29, p = 0.011) but a negative effect when interacted with the quadratic term of period (B = −0.01, p = 0.020). Taken together with the negative main effect (B = −2.52), this suggests that the difference in slopes between EHSH and NH on appropriation increases and finally flattens out. Subjects in EHSH thus appropriate more for a large part of the game, until appropriation becomes more similar to NH.

No significant effects of the other treatments are visible, but it is worth noting that for EH the p-values of the main effect (p = 0.198), interaction with linear period (p = 0.186) and interaction with the quadratic term of period (p = 0.238) are close to 0.2, which reflects a non-significant but relatively high probability that subjects in EH treatment behaved more cooperatively over time than subjects in NH, as was found in the macro-model. The main effect of period is now to be interpreted as the effect of NH over time. The model shows a negative slope over time (B = −0.52, p < 0.001) which increases each period (B = 0.01, p < 0.001).

To give a visualisation of the differences in slopes between treatments, Figure 9 shows a graph of treatment effects fitted on the residuals of a model with all control variables. This shows the predicted resource size over time per treatment, while controlling for all relevant control variables. The results provide modest evidence in the opposite direction of hypothesis 1a, suggesting for the individual level a positive instead of a negative effect of economic heterogeneity under sociocultural homogeneity on cooperation over time. A surprising but interesting result that will be reflected on later.

It is worth noting the possibility that one would need more statistical power to detect significant differences on the micro-level. However, even small changes in behaviour on the micro-level can lead to big effects at the macro-level. The lack of significant findings on the micro-level thus does not mean that the effects do not play a role, in particular because the differences in behaviour between treatments found on the micro-level in table 4 do support the differences that were found in table 3 on the macro-level.

Regarding trust from the IG, model 3 shows a significant negative interaction effect of trust with time on appropriation effort (B $= -0.09$, p $= 0.002$). This suggests that higher levels of general trust result in lower levels of individual appropriation every period and thus higher levels of individual cooperation over time - after all, a lower appropriation effort yields higher resource size and higher returns for every player in the group. This supports hypothesis 3, stating the positive effect of trust on cooperation over time.

Regarding significant control variables, resource size in $t-1$ (B $= 0.01$, p < 0.001), and the sum of appropriation of other players in $t-1$ (B $= 0.04$, p < 0.001) have positive effects on appropriation effort. Female subjects appropriate marginally less (B $= -1.99$, p $= 0.073$). Model 2 shows that Dutch subjects appropriate marginally less (B $= -2.01$, p $= 0.081$), but this effect disappears in model 3.

Figure 9: Predicted treatment effects on Appropriation Effort using multilevel regression coefficients

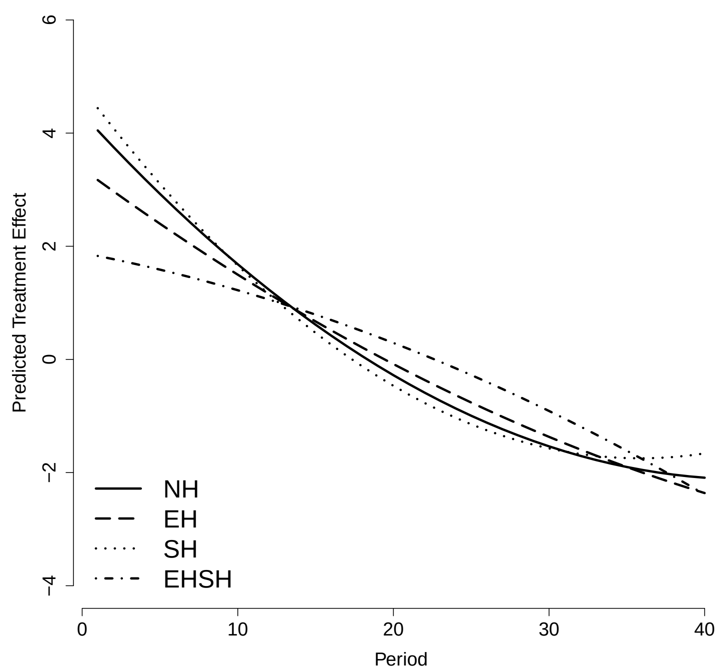


Table 4: Three-level multilevel regression on appropriation effort with random intercepts for subjects and groups

	(1)	(2)	(3)
EH	−0.91	−1.22	−2.10
	(1.29)	(1.43)	(1.62)
EH × Period	0.02	0.02	0.15
	(0.03)	(0.03)	(0.11)
EH × Period^2			−0.00
			(0.00)
SH	−0.09	0.14	0.37
	(1.30)	(1.45)	(1.64)
SH × Period	0.00	0.00	−0.03
	(0.03)	(0.03)	(0.11)
SH × Period^2			0.00
			(0.00)
EHSH	−0.55	−0.70	−2.52
	(1.32)	(1.48)	(1.67)
EHSH × Period	0.02	0.04	0.29*
	(0.03)	(0.03)	(0.11)
EHSH × Period^2			−0.01*
			(0.00)
Period	−0.24***	−0.10***	−0.52***
	(0.02)	(0.03)	(0.09)
Period^2			0.01***
			(0.00)
General Trust [GT]		−1.69	−1.73
		(1.85)	(1.81)
GT × Period		−0.10**	−0.10**
		(0.03)	(0.03)
Controls			
Resource Size t-1		0.02***	0.01***
		(0.00)	(0.00)
Sum Appropriation Others t-1		0.04***	0.04***
		(0.00)	(0.00)
Netherlands		−2.09†	−1.63
		(1.18)	(1.15)
Female		−2.01†	−1.99†
		(1.13)	(1.11)
Constant	36.91***	24.94***	30.80**
	(0.94)	(6.50)	(6.42)
Observations	13,760	13,299	13,299
Subjects	344	341	341
Groups	86	86	86
Log Likelihood	−54,226.350	−52,376.450	−52,370.950
Akaike Inf. Crit.	108,474.700	104,804.900	104,801.900
Bayesian Inf. Crit.	108,557.500	104,999.700	105,026.700

Standard errors in parentheses.
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*

4.5 Post-Experimental Trust Results

First of all, Figure 10 shows a descriptive plot of trust as measured in the post-experimental survey with the statement “I trusted the other players in my group”, referring to the Fishing Game, hereafter called trust in other players. The variable is measured on a 7-point Likert scale ranging from ‘completely disagree’ (0) to ‘completely agree’ (6). It shows that in especially the EH treatment the trust question is answered more positively by a higher percentage of subjects, and for the NH treatment this is lower. Figure 11 shows a descriptive plot of a statement from the post-experimental survey stating “The other players in my group were trustworthy”, hereafter called subjective trustworthiness of other players, and measured on the same 7-point Likert scale. It shows slightly lower scores for the SH treatment and the NH treatment.

An ordinal logistic regression on the two mentioned trust questions from the post-experimental survey can be found in Appendix J. No statistical evidence is found for hypotheses 2a, 2b or 2c on the negative effect of heterogeneity on trust. Instead it seems that the final individual profit at the end of the experiment has a strong positive influence on how the survey questions on trust were answered.

Figure 10: Trust in other players by treatment

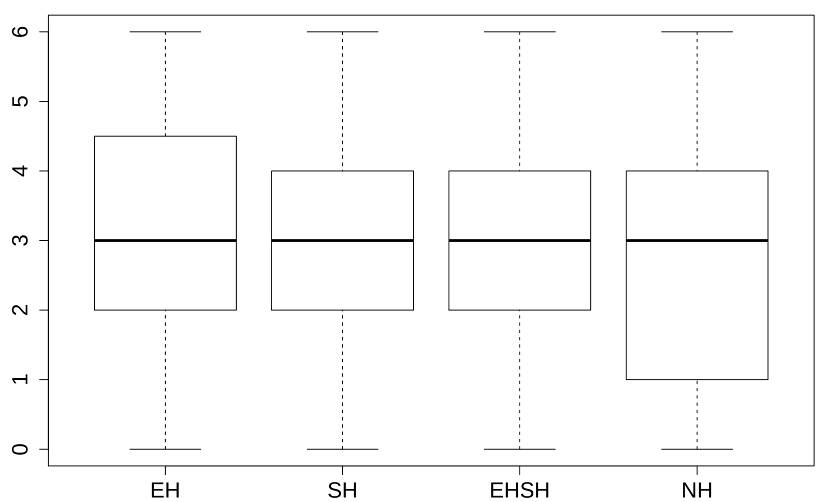
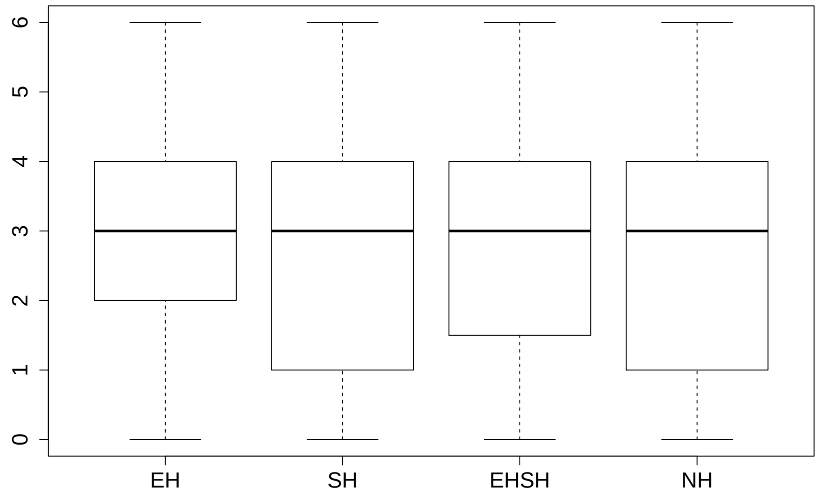


Figure 11: Subjective trustworthiness other players by treatment



4.6 Revisiting Expectations

Table 3 shows that economic heterogeneity affects collective action and resource size in a positive way compared to homogeneity. This is in stark contrast with hypothesis 1a, stating a negative effect of economic heterogeneity. As not only a non-effect but a significant effect in the opposite direction in the macro-model, it is worth revisiting the literature for possible explanations.

4.6.1 The Olson-Effect

Despite the majority of research suggesting a negative effect of heterogeneity on cooperation, the positive effect of heterogeneity is theorised by the economist Mancur Olson in his book *The logic of collective action: public goods and the theory of groups*(1965) describing what is known as the 'Olson-effect':

> In smaller groups marked by considerable degrees of inequality – that is, in groups of members of unequal "size" or extent of interest in the collective good – there is the greatest likelihood that a collective good will be provided; for the greater the interest in the collective good of any single member, the greater the likelihood that that member will get such a significant proportion of the total benefit from the collective good that he will gain from seeing that the good is provided, even if he has to pay all of the cost

himself (Olson, 1965, p. 34)

Even though Olson does not directly mention a positive effect of economic heterogeneity on cooperation, he does describe a theoretical mechanism of the rich bearing the costs of cooperation for the poor by overinvesting in cooperation. In the context of the current CPR experiment, the group was small enough so that subjects with higher endowments may have invested less than they could have, to provide space for the two other subjects with lower endowments to invest in the resource for profit. The cost for not investing in the resource, and thus not receiving profit from appropriation, is lower for the higher endowed subjects, as everyone can keep the endowment that was not invested, which is higher for them to begin with.

To explore the possibilities of the Olson-effect in the current experiment, Figure 12 shows a plot of the appropriating behaviour of the high and low endowed subjects in the EH and EHSH treatments. It shows that in the EH treatment, the investments in appropriation for the higher endowed subjects are lower than the investments from higher endowed subjects in the EHSH treatment. For both treatments, the lower endowed subjects have on average about the same appropriation over time, with the ones in EH higher from the 16th period on.

Figure 13 shows that the lower endowed subjects in the EH treatment can make more profit than the lower endowed subjects in the EHSH treatment, from about period 10, while higher endowed subjects in EH still make more profit than higher endowed subjects in EHSH. It is still the case that the higher endowed in both treatments overappropriate on average, but an unpaired t-test points out that the higher endowed appropriate less in the EH ($M = 34.830$, $SD = 17.116$) than in the EHSH ($M = 36.390$, $SD = 17.922$) treatment ($t\ (3518) = -2.642$, $p = 0.004$). Taken together these results provide evidence for the Olson-effect in EH, but not in EHSH.

Figure 12: Smoothed average Appropriation of higher ($E = 60$) and lower ($E = 40$) endowed players in economic heterogeneity [EH] and economic and sociocultural heterogeneity [EHSH] treatment (smoothed line)

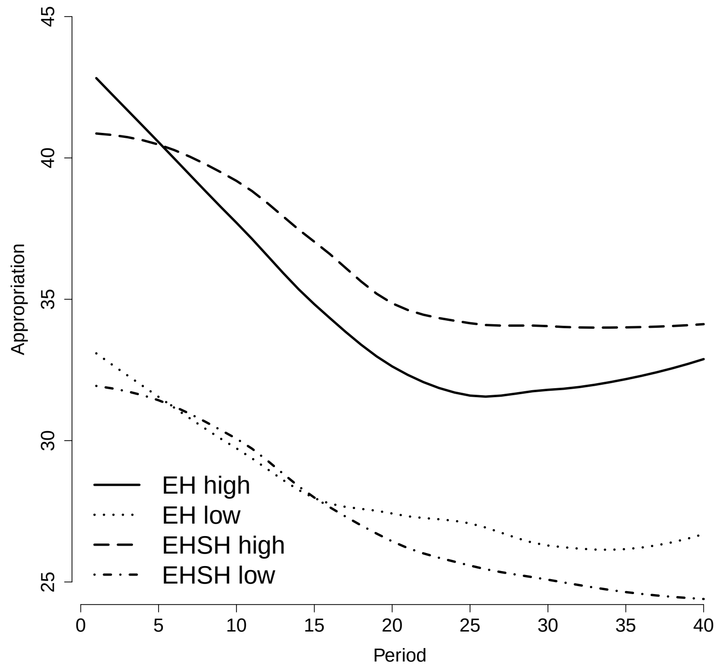
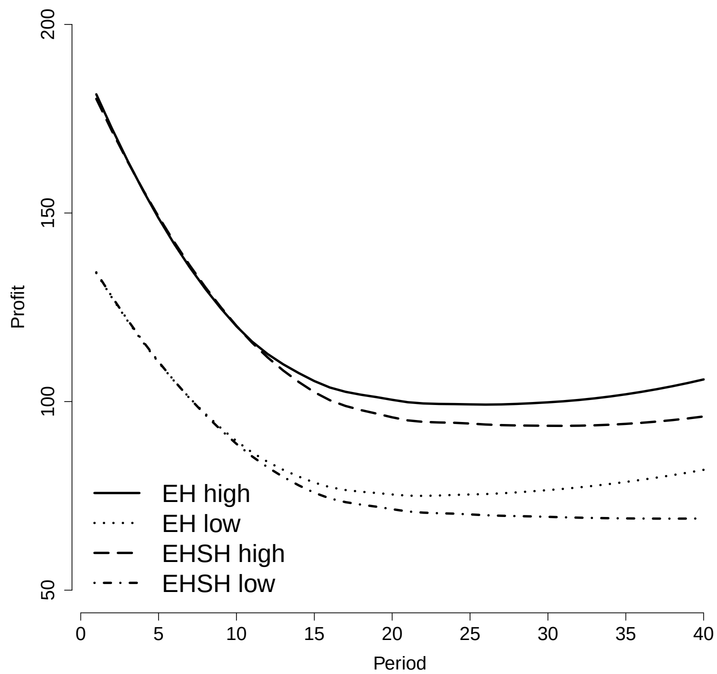


Figure 13: Smoothed average Profit of higher ($E = 60$) and lower ($E = 40$) endowed players in economic heterogeneity [EH] and economic and sociocultural heterogeneity [EHSH] treatment



4.6.2 Ingroup Favouritism and Conditional Reciprocity

A closer look can be taken at the effect of the MGE on in-game behaviour. Even though trust itself may not play a role in levels of cooperation, the difference in outcomes of the IG with ingroup and outgroup members could indicate why less cooperative behaviour takes place when economic heterogeneity is combined with sociocultural heterogeneity. Consistent with the descriptive plots of Figure 6 and Figure 7, a paired samples t-test comparing the average trust in the general IG (i.e. playing with a random other player before the MGE) with average trust in the outgroup IG (i.e. playing with an outgroup member after the MGE) shows that there is a significant difference in average trust between a general (M = 0.559, SD = 0.310) and an outgroup (M = 0.455, SD = 0.333) interaction ($t\ (343) = -8.023$, $p < 0.001$). The average trust in the ingroup (M = 0.573. SD = 0.320) and outgroup (M = 0.455, SD = 0.333) IG interaction is also significant ($t\ (343) = 10.010$, $p < 0.001$). These results show that even with a division that is as artificial as painting preferences of painters in the same art discipline, group identities are strong enough to behave differently in different group compositions of ingroup and outgroup members. In their meta-study, Balliet, Wu and De Dreu (2014) support the finding that people are more cooperative with ingroup, compared to outgroup, members.

The current results regarding trust indicate derogation towards the outgroup rather than favouritism towards the ingroup, since the difference in behaviour towards a general other and an ingroup member is not significant. In a mixed-design experiment using Dictator Games, Bilancini et al. (2020) show that ingroup favouritism is stronger when group are based on moral preferences rather than non-moral preferences. This finding provides another reason for future research to vary the operationalisation of sociocultural heterogeneity.

Another potential explanation for cooperative behaviour in EH is conditional reciprocity. Numerous studies, both experimental and in the field, have shown that people are conditional cooperators: they cooperate when others cooperate as well (see amongst others Fehr & Fischbacher, 2004; Herrmann & Thöni, 2009; Fischbacher, Gächter, & Fehr, 2001; Chaudhuri & Paichayontvijit, 2006; Ahmed, 2011; Frey & Meier, 2004). In the IG results of the current study, conditional reciprocity is visible: controlling for individual characteristics and location of the experiment, player 2 in the general IG sends a significantly higher percentage of their total points back to player 1, the higher the percentage of the points sent by player 1 of their endowment ($B = 0.57$, $p = < 0.001$). Similarly, the significant positive effect of lagged sum of appropriation of others in table 4 means that a lower appropriation of other players results in a lower appropriation of the player, which can be thought of as a form of reciprocal cooperation. This behaviour can also be related to informational effects; a phenomenon that describes how individuals will better comply with norms or rules if they see a greater number of other individuals complying as well (Krupka & Weber, 2009). Lastly, Chen & Li (2009) show that subjects that are matched with ingroup members display more charity when they have a higher payoff, and show less signs of envy if they have a lower payoff. This suggest a level of goodwill that could have lead to the Olson-effect and ultimately the success in the EH treatment.

However, none of the behavioural theories above explain the difference between EH and EHSH behaviour on their own. The answer may lie in a cross between ingroup favouritism, conditional reciprocity and the Olson-effect.

5 Discussion

The aim of this paper is to study the impact of economic and sociocultural heterogeneity and the coincidence of the two, through trust on cooperation on the micro- and macro-level in common-pool resources. Using a CPR game in the laboratory allowed for the effects of economic and sociocultural heterogeneity and trust to be disentangled and enabled establishing the causal direction of effects. Existing literature predominantly suggests negative effects of heterogeneity on trust and on cooperation, and positive effects of trust on societal outcomes.

The results show that under the coincidence of economic and sociocultural heterogeneity, groups struggle to converge to a sustainable appropriation of the common-pool resource over time. Surprisingly, the economic heterogeneity treatment is the first to converge to cooperative levels of appropriation. It manages to hold the highest resource size over the 40 periods of the game and is the most successful of all four treatment groups, including the homogeneous control group, over time. A striking conclusion here is thus that it may be the presence or absence of sociocultural heterogeneity in CPR settings that makes economic heterogeneity perform respectively worse or better than full homogeneity. The results contribute to the current literature by providing a possible explanation for the emergence of aversion to economic inequality, which may not have a natural origin per se, but could have a sociocultural origin instead. Sociocultural heterogeneity under economic homogeneity, however, differs only marginally from full homogeneity on the macro-level. Regarding trust, it is found that over time higher average general trust within a group increases resource size, and individual general trust decreases appropriation effort - trust thus increases cooperation on both the micro- and macro-level. In addition, the post-MGE Investment Game results showed that subjects acted more trusting towards ingroup members than towards outgroup members, and less trusting towards outgroup members than to a random other person in the pre-MGE Investment Game. However, no evidence for the mediating role of trust between heterogeneity and cooperation in CPRs was found.

The results support literature suggesting positive effects of economic heterogeneity (Olson, 1965) or U-shaped relations between CPR performance and economic inequality (see Bardhan, 2000; Dayton-Johnson & Bardhan, 2002). Olson (1965) suggests that economic heterogeneity may have a positive effect on cooperation, provided that the rich act as catalysts for cooperation by bearing the cost of collective action just a little more than the poor. The results show that subjects with high endowments in the economic heterogeneity treatment invest less on average than subjects with a high endowment in the combination treatment. These results are not unthinkable if one places them in the context of CPRs: fishermen who come from the same sociocultural background, speaking the same language and with a similar view on the resource could be more likely to cooperate with each other, despite economic heterogeneity, than with an unfamiliar actor - such as a large fishing company with a big fleet - that is unlike them on both sociocultural background and economic means. The key here could be a conflict of interests or incompatibility arising at the moment that two groups are unequal in economic means to appropriate a resource without a sociocultural bond to bridge that inequality gap. However, as Bazzi et al. (2019) argue, the emergence of coordination depends on whether heterogeneity is shaped by many smaller groups, or a few bigger groups; smaller groups are more prone to find common ground, whereas bigger groups are more prone to ingroup antagonism. The results underline the importance of understanding the influence of various types of heterogeneity, and their interaction, on CPR outcomes.

Some critical comments can be made about this study. A well-known criticism of laboratory experiments using mainly students as their subjects is that they are not representative of situations in the real world, while the results are sometimes presented as real-world outcomes. However, if the aim of the research is to investigate relationships between human behaviour and social, biological or economic contextual variables, experiments are a good way of doing so, regardless of the subject pool (Anderies et al., 2011; Falk & Zehnder, 2013; Falk & Heckman, 2009; Levitt & List, 2007; Ostrom, 2006). To point out causality and to show the effect of a treatment the only assumption necessary is appropriate randomisation, which the laboratory setup provides (Levitt & List, 2009). In addition, a survey-experiment conducted with a representative sample of a city's population by Exadaktylos, Espín and Brañas-Garza (2013) points out that students are indeed appropriate subjects to study human behaviour with laboratory experiments. The external validity of experiments can be secured as long as the environment under which the results are generated capture essential characteristics of the real-world version of the phenomenon that is being researched (Fehr, Fischbacher, von Rosenbladt, Schupp, & Wagner, 2003). In the current paper, a CPR experiment was conducted which contained key aspects of the way CPRs, and in particular fisheries, work. A first step improvement on this study could be made by using real forms of identity, as real-life heterogeneous communities using CPRs also have to deal with real-life sentiments towards real ingroup and outgroup members. For instance, gender or nationality of subjects could be used to operationalise sociocultural heterogeneity. This could also serve as an extra test for and comparison with using the MGE to investigate whether subjects behave differently in CPR games if they are grouped by a natural rather than a more artificial characteristic. Lastly, future research could investigate whether the group size of different preference or identity groups influences the outcome of the game, as Bazzi et al. (2019) suggest.

For future CPR experiments it would also be interesting to add communication and/or punishment between players (see for instance Janssen et al., 2010) or to add a type of risk to overexploitation that is separate from decreasing income (see for instance Bednarik, Linnerooth-Bayer, Magnuszewski and Dieckmann (2019) where overharvesting trees increases the chance of flood damage). Adding elements like this can change behaviour drastically, and can create a more realistic setting. A bolder improvement on this study could be made by setting up an artefactual field experiment, better known as a lab-in-field experiment: a controlled environment where artefactual games (such as the Investment Game or the Fishing Game) are played, but with a subject pool that is more like the population of interest. In the current context, this could be a group of actual fishermen.

With the use of detailed and heavily contextualised games, comes a more detailed - and thus limited - interpretation of the results; the results of this study are valuable for common-pool resources, and especially resources with structures similar to fishing grounds. With the information about the resource size (fish stock) available for players to see at the beginning of every new period, the results may not hold in situations where the total allowable catch cannot be correctly measured because the fish population dynamics is unknown (Hey et al., 2009). In addition, whereas players could see the history of other players' actions, this may not always be the case (see for instance Lacomba, Lagos, & Perote, 2017). Future experiments could vary the amount and accuracy of information about resource growth and stock size, or information on other players' actions, as it is found to influence players' appropriation behaviour (Hey et al., 2009; Lacomba et al., 2017; Neugebauer, Perote, Schmidt, & Loos, 2009). Findings may be different for other resource types, such as irrigation systems, where resource renewal is partially dependent on the weather, appropriation is sequential, and farmers already know if someone took more water than allowed before they make their own decision of how much water to take.

The level of detail in the game is necessary to fully understand the different mechanisms at work in different CPRs; games that are too generalised will not provide directed results. However, hypotheses were not formulated based on resource-specific characteristics, so it may well be that the found results would apply to a wider range of CPRs. The flexibility for researchers to adjust a game to represent any type of CPR is a very valuable asset of experimental research, and one that should be deployed more often in social science.

6 Conclusion

As far as one should base policy advice on laboratory results alone, the main recommendation is perhaps that management of CPRs cannot be a 'one size fits all' solution, but instead that sustainable cooperation in CPRs can be achieved under a flexible management that is adapted to the level and the type(s) of heterogeneity found in a CPR user community. Laboratory experiments are important to tease out the mechanisms at work in social phenomenons. The mechanisms for which this paper provide evidence should be further studied in real-life contexts, first through lab-in-field experiments, and then via large-scale randomised control trials, to ensure they are externally valid instruments of policy.

Understanding cooperative behaviour and trust under different conditions of heterogeneity is a core question within social sciences. The application of this question to CPR situations is vital especially in a time of increasing depletion of these resources, manifested in for instance overfishing, deforestation and unsustainable use of fresh water. It is crucial to understand the behaviour of humans in these contexts to prevent overexploitation of resources and to promote cooperation between different actors involved. In addition, the growing number of modern commons such as citizen initiatives for food, green energy and infrastructure provide new incentives to investigate human behaviour in and around CPRs (De Moor, 2013a, 2013b, 2018). The investigation of relations between heterogeneity, trust and cooperation in common-pool resources is not only important to advance insights within the social sciences, but also demonstrates the importance of social science research for present-day problems.

References

Adams, J. S. (1965). Inequity In Social Exchange. *Advances in Experimental Social Psychology*, *2*, 267–299. doi: 10.1016/S0065-2601(08)60108-2

Adams, J. S., & Freedman, S. (1976). Equity Theory Revisited: Comments and Annotated Bibliography. *Advances in Experimental Social Psychology*, *9*, 43–90. doi: 10.1016/S0065-2601(08)60058-1

Adhikari, D. B., & Lovett, J. C. (2006). Institutions and collective action: Does heterogeneity matter in community-based resource management? *The Journal of Development Studies*, *42*(3), 426–445. Retrieved 2020-06-12, from `https://doi.org/10.1080/00220380600576201` (Publisher: Routledge _eprint: https://doi.org/10.1080/00220380600576201) doi: 10.1080/00220380600576201

Ahmed, A. (2011). Conditional reciprocity in the investment game. *The Social Science Journal*, *48*(2), 404–408. Retrieved 2020-06-10, from `https://doi.org/10.1016/j.soscij.2010.11.005` (Publisher: Routledge _eprint: https://doi.org/10.1016/j.soscij.2010.11.005) doi: 10.1016/j.soscij.2010.11.005

Aksoy, O. (2015). Effects of Heterogeneity and Homophily on Cooperation. *Social Psychology Quarterly*, *78*(4), 324–344. doi: 10.1177/0190272515612403

Aksoy, O. (2019). Crosscutting circles in a social dilemma: Effects of social identity and inequality on cooperation. *Social Science Research*, *82*, 148–163. doi: 10.1016/j.ssresearch.2019.04.009

Aksoy, O., & Weesie, J. (2012). Beliefs about the social orientations of others: A parametric test of the triangle, false consensus, and cone hypotheses. *Journal of Experimental Social Psychology*, *48*(1), 45–54. doi: 10.1016/j.jesp.2011.07.009

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904.

Alesina, A., & La Ferrara, E. (2002). Who trusts others? *Journal of Public Economics*, *85*(2), 207–234. doi: 10.1016/S0047-2727(01)00084-6

Anderies, J. M., Janssen, M. A., Bousquet, F., Cardenas, J.-C., Castillo, D., Lopez, M.-C., . . . Wutich, A. (2011). The challenge of understanding decisions in experimental studies of common pool resource governance. *Ecological Economics*, *70*(9), 1571–1579. doi: 10.1016/j.ecolecon.2011.01.011

Anderson, C. J., & Paskeviciute, A. (2006). How Ethnic and Linguistic Heterogeneity Influence the Prospects for Civil Society: A Comparative Study of Citizenship Behavior. *The Journal of Politics*, *68*(4), 783–802. doi: 10.1111/j.1468-2508.2006.00470.x

Anderson, L. R., Mellor, J. M., & Milyo, J. (2006). Induced heterogeneity in trust experiments. *Experimental Economics*, *9*(3), 223–235. doi: 10.1007/s10683-006-9124-2

Andersson, K., & Agrawal, A. (2011). Inequalities, institutions, and forest commons. *Global Environmental Change*, *21*(3), 866–875. doi: 10.1016/j.gloenvcha.2011.03.004

Andreoni, J. (1988). Why free ride?: Strategies and learning in public goods experiments. *Journal of Public Economics*, *37*(3), 291–304. doi: 10.1016/0047-2727(88)90043-6

Axelrod, R., & Hamilton, W. D. (1981). The Evolution of Cooperation. *Science*, *211*(4489), 1390–1396.

Bahry, D., L., & Wilson, R., K. (2006). Confusion or fairness in the field? Rejections in the ultimatum game under the strategy method. *Journal of Economic Behavior & Organization*, *60*(1), 37–54. doi: 10.1016/j.jebo.2004.07.005

Balliet, D., Wu, J., & De Dreu, C. K. W. (2014). Ingroup favoritism in cooperation: A meta-analysis. *Psychological Bulletin*, *140*(6), 1556–1581. Retrieved 2020-06-10, from `http://doi.apa.org/getdoi.cfm?doi=10.1037/a0037737` doi: 10.1037/a0037737

Bardhan, P. (2000). Irrigation and Cooperation: An Empirical Analysis of 48 Irrigation Communities in South India. *Economic Development and Cultural Change*, *48*(4), 847–865. doi: 10.1086/452480

Bardhan, P., & Dayton-Johnson, J. (2002). Unequal irrigators: Heterogeneity and commons management in large-scale multi-variate research. In E. Ostrom, T. Dietz, N. Dolsak, P. C. Stern, S. Stonich, & E. U. Weber (Eds.), *The Drama of the Commons* (pp. 87–112). Washington, D. C.: National Academy Press.

Barr, A. (1999). *Familiarity and trust: An experimental investigation* (CSAE Working Paper Series No. 1999-23). Centre for the Study of African Economies, University of Oxford.

Bazzi, S., Gaduh, A., Rothenberg, A. D., & Wong, M. (2019). Unity in Diversity? How Intergroup Contact Can Foster Nation Building. *American Economic Review*, *109*(11), 3978–4025. Retrieved 2020-06-12, from

Becker, C. D., & Ostrom, E. (1995). Human Ecology and Resource Sustainability: The Importance of Institutional Diversity. *Annual Review of Ecology and Systematics*, *26*, 113–133.

Bednarik, P., Linnerooth-Bayer, J., Magnuszewski, P., & Dieckmann, U. (2019). A Game of Common-pool Resource Management: Effects of Communication, Risky Environment and Worldviews. *Ecological Economics*, *156*, 287–292. Retrieved 2020-06-09, from http://www.sciencedirect.com/science/article/pii/S0921800918302647 doi: 10.1016/j.ecolecon.2018.10.004

Berg, J., Dickhaut, J., & McCabe, K. (1995). Trust, Reciprocity, and Social History. *Games and Economic Behavior*, *10*(1), 122–142. doi: 10.1006/game.1995.1027

Bilancini, E., Boncinelli, L., Capraro, V., Celadin, T., & Di Paolo, R. (2020). "Do the Right Thing" for Whom? An Experiment on Ingroup Favouritism, Group Assorting and Moral Suasion. *arXiv:2002.12464 [physics, q-bio]*. Retrieved 2020-06-11, from http://arxiv.org/abs/2002.12464 (arXiv: 2002.12464)

Billig, M. G., & Tajfel, H. (1973). Social categorization and similarity in intergroup behaviour. *European Journal of Social Psychology*, *3*(1), 27–52. doi: 10.1002/ejsp.2420030103

Bottom, W. P. (1998). Negotiator Risk: Sources of Uncertainty and the Impact of Reference Points on Negotiated Agreements. *Organizational Behavior and Human Decision Processes*, *76*(2), 89–112. doi: 10.1006/obhd.1998.2800

Bottom, W. P., Holloway, J., Miller, G. J., Mislin, A., & Whitford, A. (2006). Building a Pathway to Cooperation: Negotiation and Social Exchange between Principal and Agent. *Administrative Science Quarterly*, *51*(1), 29–58.

Bouckaert, J., & Dhaene, G. (2002). *Inter-ethnic trust and reciprocity: Results of an experiment with small business entrepreneurs* (Tech. Rep. No. 2002022). University of Antwerp, Faculty of Applied Economics.

Bouckaert, J., & Dhaene, G. (2004). Inter-ethnic trust and reciprocity: Results of an experiment with small businessmen. *European Journal of Political Economy*, *20*(4), 869–886. doi: 10.1016/j.ejpoleco.2003.08.006

Bowles, S., & Gintis, H. (2002). Social Capital and Community Governance. *The Economic Journal*, *112*(483), F419-F436.

Boyd, R., & Richerson, P. J. (1985). *Culture and the evolutionary process.* Chicago: University of Chicaco Press.

Brandts, J., & Charness, G. (2000). Hot vs. cold: Sequential responses and preference stability in experimental games. *Experimental Economics*, *2*(3), 227–238. doi: 10.1007/BF01669197

Brewer, M. B., & Kramer, R. M. (1986). Choice behavior in social dilemmas: Effects of social identity, group size, and decision framing. *Journal of Personality and Social Psychology*, *50*(3), 543–549. doi: 10.1037/0022-3514.50.3.543

Burks, S., Carpenter, J., & Goette, L. (2009). Performance pay and worker cooperation: Evidence from an artefactual field experiment. *Journal of Economic Behavior & Organization*, *70*(3), 458–469. doi: 10.1016/j.jebo.2008.02.012

Burks, S., V., Carpenter, J., P., & Verhoogen, E. (2003). Playing both roles in the trust game. *Journal of Economic Behavior & Organization*, *51*(2), 195–216. doi: 10.1016/S0167-2681(02)00093-8

Chan, K. S., Mestelman, S., Moir, R., & Muller, R. A. (1999). Heterogeneity and the voluntary provision of public goods. *Experimental Economics*, *2*(1), 5–30. doi: 10.1007/BF01669132

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

Chaudhuri, A., & Paichayontvijit, T. (2006). Conditional cooperation and voluntary contributions to a public good. *Economics Bulletin*, 1–14.

Chen, Y., & Li, S. X. (2009). Group Identity and Social Preferences. *The American Economic Review*, *99*(1), 431–457.

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. doi: 10.1016/j.jebo.2003.11.010

Coleman, J. S. (1994). *Foundations of social theory.* Cambridge, MA: Harvard University Press.

Dayton-Johnson, J., & Bardhan, P. (2002). Inequality and Conservation on the Local Commons: A Theoretical Exercise. *The Economic Journal*, *112*(481), 577–602.

Delhey, J., & Newton, K. (2005). Predicting Cross-National Levels of Social Trust: Global Pattern or Nordic Exceptionalism? *European Sociological Review*, *21*(4), 311–327.

De Moor, T. (2013a). De herontdekking van het Collectief.

De Moor, T. (2013b). *Homo Cooperans: Institutions for collective action and the compassionate society* [Inaugural Lecture].

De Moor, T. (2018). De toekomst van bewonersoverlegorganisaties.

De Oliveira, A., Croson, R. T. A., & Eckel, C. C. (2009). One Bad Apple: Uncertainty and Heterogeneity in Public Good Provision. *SSRN Electronic Journal*. doi: 10.2139/ssrn.1883766

Easter, K. W., & Palanisami, K. (1986). *Tank Irrigation in India and Thailand: An Example of Common Property Resource Management.* Minneapolis: Department of Agricultural and Applied Economics Staff, University of Minnesota.

Eckel, C. C., & Grossman, P. J. (2005). Managing diversity by creating team identity. *Journal of Economic Behavior & Organization*, *58*(3), 371–392. doi: 10.1016/j.jebo.2004.01.003

Ellickson, R. C. (1991). *Order without Law: How Neighbors Settle Disputes.* Harvard University Press.

Evans, A. M., & Revelle, W. (2008). Survey and behavioral measurements of interpersonal trust. *Journal of Research in Personality*, *42*(6), 1585–1593. doi: 10.1016/j.jrp.2008.07.011

Exadaktylos, F., Espín, A. M., & Brañas-Garza, P. (2013). Experimental subjects are not different. *Scientific Reports*, *3*, 1213. doi: 10.1038/srep01213

Falk, A., & Heckman, J. J. (2009). *Lab Experiments Are a Major Source of Knowledge in the Social Sciences — Science.* https://science.sciencemag.org/content/326/5952/535.

Falk, A., & Zehnder, C. (2013). A city-wide experiment on trust discrimination. *Journal of Public Economics*, *100*, 15–27. doi: 10.1016/j.jpubeco.2013.01.005

Fehr, E., & Fischbacher, U. (2004). Social norms and human cooperation. *Trends in Cognitive Sciences*, *8*(4), 185–190. Retrieved 2020-06-10, from `http://www.sciencedirect.com/science/article/pii/S1364661304000506` doi: 10.1016/j.tics.2004.02.007

Fehr, E., Fischbacher, U., von Rosenbladt, B., Schupp, J., & Wagner, G. G. (2003). *A Nation-Wide Laboratory: Examining Trust and Trustworthiness by Integrating Behavioral Experiments into Representative Survey* (SSRN Scholarly Paper No. ID 385120). Rochester, NY: Social Science Research Network.

Fershtman, C., & Gneezy, U. (2001). Discrimination in a Segmented Society: An Experimental Approach. *The Quarterly Journal of Economics*, *116*(1), 351–377.

Fischbacher, U. (2007). Z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178. doi: 10.1007/s10683-006-9159-4

Fischbacher, U., Gächter, S., & Fehr, E. (2001). Are people conditionally cooperative? Evidence from a public goods experiment. *Economics Letters*, *71*(3), 397–404. Retrieved 2020-06-10, from `http://www.sciencedirect.com/science/article/pii/S0165176501003949` doi: 10.1016/S0165-1765(01)00394-9

Flache, A., & Mäs, M. (2008). Why do faultlines matter? A computational model of how strong demographic faultlines undermine team cohesion. *Simulation Modelling Practice and Theory*, *16*(2), 175–191. doi: 10.1016/j.simpat.2007.11.020

Frey, B. S., & Meier, S. (2004). Social Comparisons and Pro-social Behavior: Testing "Conditional

Cooperation" in a Field Experiment. *American Economic Review*, *94*(5), 1717–1722. Retrieved 2020-06-10, from https://pubs.aeaweb.org/doi/10.1257/0002828043052187 doi: 10.1257/0002828043052187

Fukuyama, F. (1995). *Trust: The social virtues and the creation of prosperity.* New York: Free Press.

Gehrig, S., Schlüter, A., & Hammerstein, P. (2019). Sociocultural heterogeneity in a common pool resource dilemma. *PLOS ONE*, *14*(1), e0210561. doi: 10.1371/journal.pone.0210561

Glaeser, E. L., Laibson, D., Scheinkman, J. A., & Soutter, C. L. (1999). *What is Social Capital? The Determinants of Trust and Trustworthiness* (Working Paper No. 7216). National Bureau of Economic Research. doi: 10.3386/w7216

Glaeser, E. L., Laibson, D. I., Scheinkman, J. A., & Soutter, C. L. (2000). Measuring Trust. *The Quarterly Journal of Economics*, *115*(3), 811–846. doi: 10.1162/003355300554926

González, L. G., Güth, W., & Levati, M. V. (2005). When does the game end? Public goods experiments with non-definite and non-commonly known time horizons. *Economics Letters*, *88*(2), 221–226. doi: 10.1016/j.econlet.2005.02.010

Gouldner, A. W. (1960). The Norm of Reciprocity: A Preliminary Statement. *American Sociological Review*, *25*(2), 161–178. doi: 10.2307/2092623

Greiner, B. (2004). The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics. , 67.

Güth, W., Huck, S., & Müller, W. (2001). The Relevance of Equal Splits in Ultimatum Games. *Games and Economic Behavior*, *37*(1), 161–169. doi: 10.1006/game.2000.0829

Habyarimana, J., Humphreys, M., Posner, D. N., & Weinstein, J. M. (2007). Why Does Ethnic Diversity Undermine Public Goods Provision? *American Political Science Review*, *101*(4), 709–725. doi: 10.1017/S0003055407070499

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(3859), 1243–1248.

Herrmann, B., & Thöni, C. (2009). Measuring conditional cooperation: a replication study in Russia. *Experimental Economics*, *12*(1), 87–92. Retrieved 2020-06-10, from https://doi.org/10.1007/s10683-008-9197-1 doi: 10.1007/s10683-008-9197-1

Hey, J. D., Neugebauer, T., & Sadrieh, A. (2009). An Experimental Analysis of Optimal Renewable Resource Management: The Fishery. *Environmental and Resource Economics*, *44*(2), 263. Retrieved 2020-06-11, from https://doi.org/10.1007/s10640-009-9285-5 doi: 10.1007/s10640-009-9285-5

International Migration report 2019 (Tech. Rep.). (2019). Department of Economic and Social Affairs, United Nations.

Janssen, M. A., Holahan, R., Lee, A., & Ostrom, E. (2010). Lab Experiments for the Study of Social-Ecological Systems. *Science*, *328*(5978), 613–617. doi: 10.1126/science.1183532

Jayaraman, T. K. (1981). Farmers' Organisations in Surface Irrigation Projects: Two Empirical Studies from Gujarat. *Economic and Political Weekly*, *16*(39), A89-A98.

Johnson, N. D., & Mislin, A. A. (2011). Trust games: A meta-analysis. *Journal of Economic Psychology*, *32*(5), 865–889. doi: 10.1016/j.joep.2011.05.007

Johnson, R. N., & Libecap, G. D. (1982). Contracting Problems and Regulation: The Case of the Fishery. *The American Economic Review*, *72*(5), 1005–1022.

Jones, E. C. (2004). Wealth-Based Trust and the Development of Collective Action. *World Development*, *32*(4), 691–711. doi: 10.1016/j.worlddev.2003.10.009

Kahn, K. (2019). *Crime and equality, or crime and punishment?* (Ph.D.). University of Oxford.

Keller, R. T. (2001). Cross-Functional Project Groups in Research and New Product Development: Diversity, Communications, Job Stress, and Outcomes. *The Academy of Management Journal*, *44*(3), 547–555. doi: 10.2307/3069369

Keyuan, Z. (2003). Sino-Japanese joint fishery management in the East China Sea. *Marine Policy*, *27*(2), 125–142. Retrieved 2020-06-09, from `http://www.sciencedirect.com/science/article/pii/S0308597X02000866` doi: 10.1016/S0308-597X(02)00086-6

Knack, S., & Keefer, P. (1997). Does Social Capital Have an Economic Payoff? A Cross-Country Investigation. *The Quarterly Journal of Economics*, *112*(4), 1251–1288.

Kölle, F. (2015). Heterogeneity and cooperation: The role of capability and valuation on public goods provision. *Journal of Economic Behavior & Organization*, *109*, 120–134. doi: 10.1016/j.jebo.2014.11.009

Krupka, E., & Weber, R. A. (2009). The focusing and informational effects of norms on pro-social behavior. *Journal of Economic Psychology*, *30*(3), 307–320. Retrieved 2020-06-10, from `http://www.sciencedirect.com/science/article/pii/S0167487008001128` doi: 10.1016/j.joep.2008.11.005

Kruskal, W. H., & Wallis, W. A. (1952). Use of Ranks in One-Criterion Variance Analysis. *Journal of the American Statistical Association*, *47*(260), 583–621. Retrieved 2020-05-30, from `https://www.jstor.org/stable/2280779` (Publisher: [American Statistical Association, Taylor & Francis, Ltd.]) doi: 10.2307/2280779

Lacomba, J. A., Lagos, F., & Perote, J. (2017). The Lazarillo's game: Sharing resources with asymmetric conditions. *PLoS ONE*, *12*(7). Retrieved 2020-06-11, from `https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5509147/` (Publisher: Public Library of Science) doi: 10.1371/journal.pone.0180421

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1997). Trust in Large Organizations. *The American Economic Review*, *87*(2), 333–338.

Ledyard, J. O. (1993). *Public Goods: A Survey of Experimental Research.* Division of the Humanities and Social Sciences, California Institute of Technology.

Levati, M. V., Sutter, M., & van der Heijden, E. (2007). Leading by Example in a Public Goods Experiment with Heterogeneity and Incomplete Information. *Journal of Conflict Resolution*, *51*(5), 793–818. doi: 10.1177/0022002707302796

Levitt, S. D., & List, J. A. (2007). What Do Laboratory Experiments Measuring Social Preferences Reveal About the Real World? , 81.

Levitt, S. D., & List, J. A. (2009). Field experiments in economics: The past, the present, and the future. *European Economic Review*, *53*(1), 1–18. doi: 10.1016/j.euroecorev.2008.12.001

Masella, P., Meier, S., & Zahn, P. (2014). Incentives and group identity. *Games and Economic Behavior*, *86*, 12–25. doi: 10.1016/j.geb.2014.02.013

Meinzen-Dick, R., Chaturvedi, R., Domènech, L., Ghate, R., Janssen, M., Rollins, N., & Sandeep, K. (2016). Games for groundwater governance: Field experiments in Andhra Pradesh, India. *Ecology and Society*, *21*(3).

Muscolino, M. (2008). The Yellow Croaker War: Fishery Disputes between China and Japan, 1925–1935. *Environmental History*, *13*(2), 306–324. Retrieved 2020-06-09, from `https://academic.oup.com/envhis/article/13/2/306/619103` (Publisher: Oxford Academic) doi: 10.1093/envhis/13.2.306

Myers, R. A., Hutchings, J. A., & Barrowman, N. J. (1997). Why Do Fish Stocks Collapse? The Example of Cod in Atlantic Canada. *Ecological Applications*, *7*(1), 91–106. Retrieved 2020-06-06, from

Nettle, D., & Dunbar, R. I. M. (1997). Social Markers and the Evolution of Reciprocal Exchange. *Current Anthropology*, *38*(1), 93–99.

Neugebauer, T., Perote, J., Schmidt, U., & Loos, M. (2009). Selfish-biased conditional cooperation: On the decline of contributions in repeated public goods experiments. *Journal of Economic Psychology*, *30*(1), 52–60. Retrieved 2020-06-11, from http://www.sciencedirect.com/science/article/pii/S0167487008000780 doi: 10.1016/j.joep.2008.04.005

Olson, M. (1965). *The logic of collective action: Pubic goods and the theory of groups.* Cambridge, MA: Harvard University Press.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action.* Cambridge ; New York: Cambridge University Press.

Ostrom, E. (2006). The value-added of laboratory experiments for the study of institutions and common-pool resources. *Journal of Economic Behavior & Organization*, *61*(2), 149–163. Retrieved 2020-06-11, from http://www.sciencedirect.com/science/article/pii/S0167268106001041 doi: 10.1016/j.jebo.2005.02.008

Ostrom, E., Walker, J., & Gardner, R. (1992). Rules, Games and Common-Pool Resources. *The American Political Science Review*, *86*(2), 404–417. doi: 10.2307/1964229

Portes, A., & Landolt, P. (2000). Social Capital: Promise and Pitfalls of its Role in Development. *Journal of Latin American Studies*, *32*(2), 529–547.

Poteete, A. R., & Ostrom, E. (2004). Heterogeneity, group size and collective action: The role of institutions in forest management. *Development and change*, *35*(3), 435–461.

Putnam, R. D. (1993). *Making democracy work: Civic traditions in modern Italy.* Princeton, NJ: Princeton University Press.

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community.* New York: Simon & Schuster.

Putnam, R. D. (2007). E Pluribus Unum: Diversity and Community in the Twenty-first Century The 2006 Johan Skytte Prize Lecture. *Scandinavian Political Studies*, *30*(2), 137–174. doi: 10.1111/j.1467-9477.2007.00176.x

Roth, A. E. (1995). Bargaining experiments. In J. H. Kagel & A. E. Roth (Eds.), *Handbook of Experimental Economics* (pp. 253–348). Princeton, NJ: Princeton University Press.

Ruttan, L. M. (2008). Economic Heterogeneity and the Commons: Effects on Collective Action and Collective Goods Provisioning. *World Development*, *36*(5), 969–985. doi: 10.1016/j.worlddev.2007.05.005

Sanfey, A. G., Rilling, J. K., Aronson, J. A., Nystrom, L. E., & Cohen, J. D. (2003). The Neural Basis of Economic Decision-Making in the Ultimatum Game. *Science*, *300*(5626), 1755–1758.

Seabright, P. (1993). Managing Local Commons: Theoretical Issues in Incentive Design. *Journal of Economic Perspectives*, *7*(4), 113–134. Retrieved 2020-06-12, from https://www.aeaweb.org/articles?id=10.1257/jep.7.4.113 doi: 10.1257/jep.7.4.113

Shanmugaratnam, N. (1996). Nationalisation, Privatisation and the dilemmas of common property management in Western Rajasthan. *The Journal of Development Studies*, *33*(2), 163–187. doi: 10.1080/00220389608422461

Singleton, S. (2001). How distributional conflicts shape co-management institutions and collaborative environmental policy in the United States. In *"Economic Inequality, Collective Action and Environmental Sustainability" workshop.* Santa Fe Institute.

Tajfel, H. (1970). Experiments in Intergroup Discrimination. *Scientific American*, *223*(5), 96–103. Retrieved 2020-06-10, from https://www.jstor.org/stable/24927662 (Publisher: Scientific American, a division of Nature America, Inc.)

Tajfel, H., Billig, M. G., Bundy, R. P., & Flament, C. (1971). Social categorization and intergroup behaviour. *European Journal of Social Psychology*, *1*(2), 149–178. doi: 10.1002/ejsp.2420010202

Timilsina, R. R., Kotani, K., & Kamijo, Y. (2017). Sustainability of common pool resources. *PLoS ONE*, *12*(2). Retrieved 2020-06-09, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5315376/ doi: 10.1371/journal.pone.0170981

Uslaner, E. M. (2002). *The moral foundations of trust.* Cambridge: Cambridge University Press.

Varughese, G., & Ostrom, E. (2001). The Contested Role of Heterogeneity in Collective Action: Some Evidence from Community Forestry in Nepal. *World Development*, *29*(5), 747–765.

Vedeld, T. (2000). Village politics: Heterogeneity, leadership and collective action. *The Journal of Development Studies*, *36*(5), 105–134. doi: 10.1080/00220380008422648

Wood, S. N. (2006). Low-Rank Scale-Invariant Tensor Product Smooths for Generalized Additive Mixed Models. *Biometrics*, *62*(4), 1025–1036. Retrieved 2020-06-04, from https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1541-0420.2006.00574.x (_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1541-0420.2006.00574.x) doi: 10.1111/j.1541-0420.2006.00574.x

Wood, S. N. (2017). *Generalized Additive Models: An Introduction with R, Second Edition.* CRC Press.

Yamagishi, T., & Kiyonari, T. (2000). The Group as the Container of Generalized Reciprocity.

Social Psychology Quarterly, *63*(2), 116–132. doi: 10.2307/2695887

You, J.-s. (2012). Social Trust: Fairness Matters More Than Homogeneity: Social Trust: Fairness Matters. *Political Psychology*, *33*(5), 701–721. doi: 10.1111/j.1467-9221.2012.00893.x

Zak, P. J., & Knack, S. (2001). Trust and Growth. *The Economic Journal*, *111*(470), 295–321.

Appendix A

Instructions

Welcome to this experiment and thank you for coming. Please read the following instructions carefully. The instructions will state everything you need to know in order to participate in the experiment. If you have any questions, please raise your hand.

Earning money

You can earn money by means of earning points during the experiment. The number of points that you earn depends on your own choices. At the end of the experiment, the total number of points that you earn during the experiment will be exchanged at the rate of:

500 points = 1 GBP

The money you earn will be paid out in cash at the end of the experiment without other players

being able to see how much you earned. During the experiment you are not allowed to communicate

with other players. Please turn off your mobile phone and put it in your bag. Thank you very much.

The Trust Game

Before the main game, you will play a short game called the 'Trust Game'. In this game, you will be paired with another participant from this session, and you will face **two decision situations. You will only be paid for one of the two situations;** which one will be determined at random**.**

In the **first situation**, you are player 1. Both player 2 and you receive 10 points. **You**, as player 1, can choose to send none, some or all points to player 2. Once you have chosen the amount to send to player 2, this amount will be **tripled**: player 2 will receive three times the amount you sent. Player 2 will then decide how many of the points they received they will send **back to you**.

Example:

1. *Player 1 and player 2 both receive 10 points*
2. *Player 1 sends 5 points to player 2*
3. *Player 2 receives 5 x 3 = 15 points*
4. *Player 2 sends 7 points back to player 1*
5. *Player 2 has a total payoff of 10 + 15 - 7 = 18 points, and player 1 has a total payoff of 10 – 5 + 7 = 12 points.*

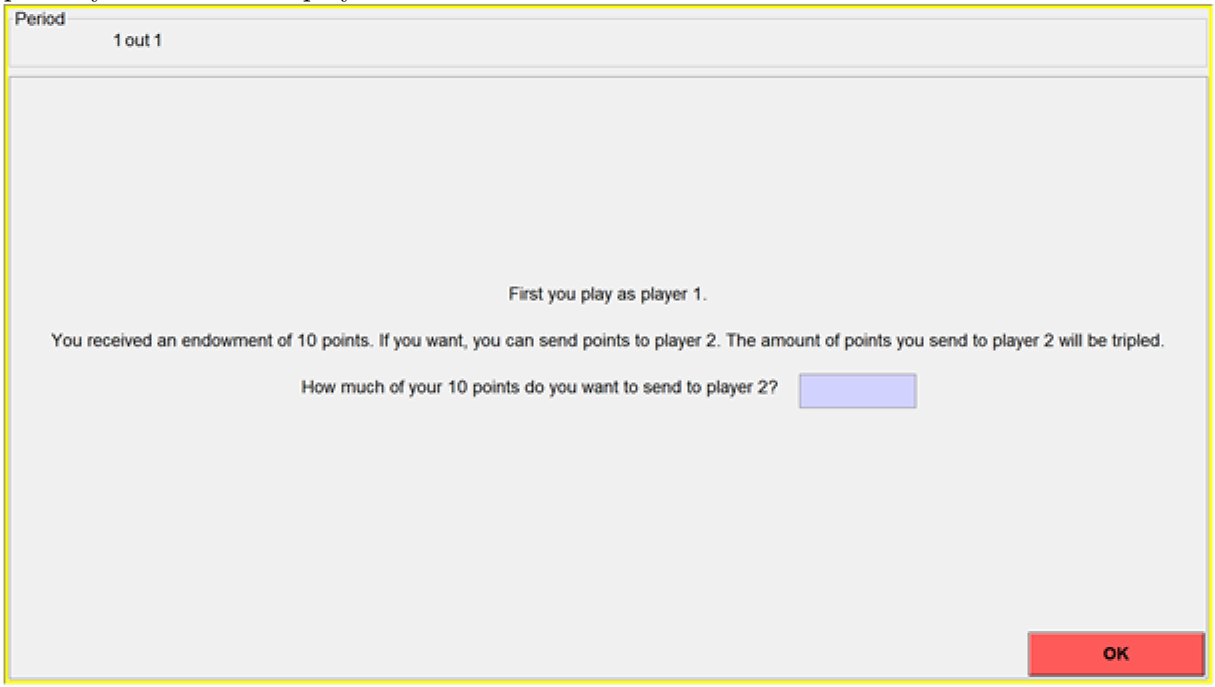
In this example, player 1 has made 7 – 5 = 2 points profit from sending points. However, you can also chose to send no points, and separately, player 2 can decide to send nothing back.

In the **second situation**, you are player 2 and another subject of this session is player 1. As player 2, you will start with 10 points. You will receive points from player 1 which will be tripled, and you decide if you want to send none, some or all of the points back to player 1.

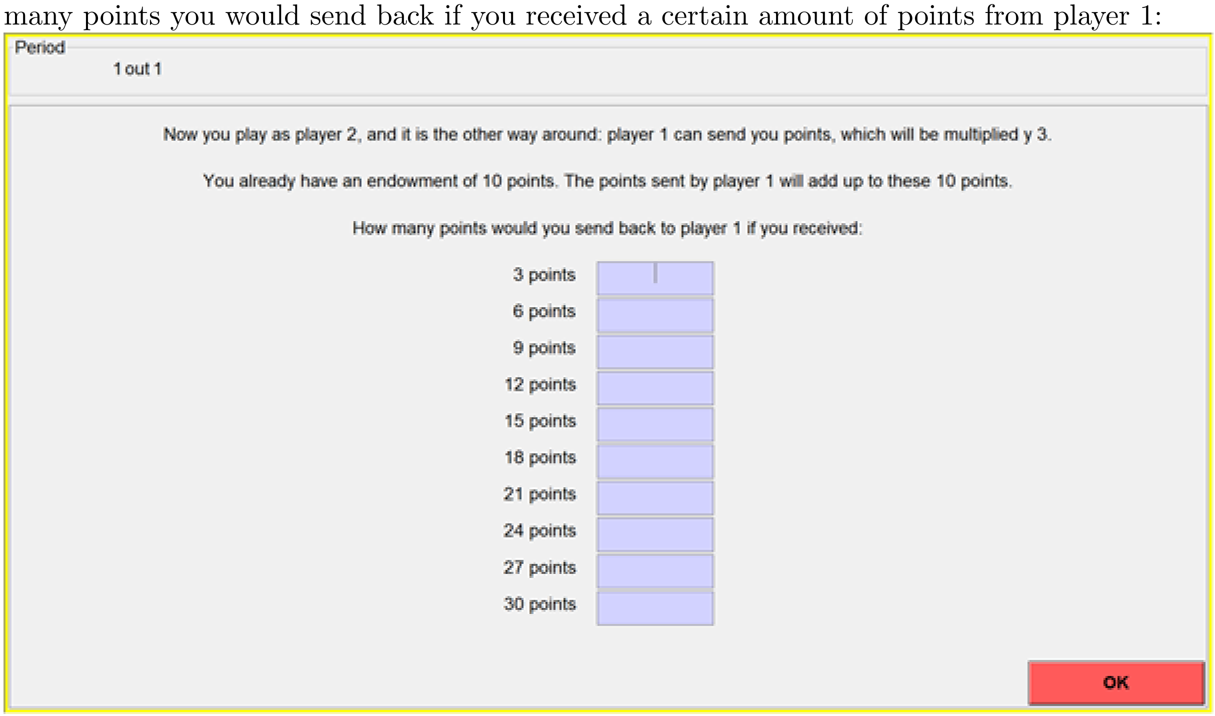
The total amount of points for **one of these situations** will be multiplied by **30** and added to your final payoff at the end of the experiment.

How it looks on your computer

Below, you see the first screen where you play as player 1 and have to choose if and how many points you will send to player 2.



Below, you see the second screen, where you play as player 2. Here, you have to decide how many points you would send back if you received a certain amount of points from player 1:



The fishing game

We will now describe the decision situation in which you are placed.

You will play **three rounds** of this game to practise.

You are placed in a group consisting of you and **three other players** in this laboratory, with whom you will interact. Every player receives a budget of **50 points** in each period.

Imagine you and the others in your group are living in a village at a lake and for food you depend on the fish in this lake. Every period, you are asked how many of your budget points, between **0 and 50**, you want to invest in fishing from the lake.

For every point you invest, you catch fish. How many fish you catch depends on the number of fish in the lake.

Initially, the lake contains **600 fish**. With 600 fish in the lake, you catch one fish with a value of **4 points**, for every point you invest. You, thus, gain 3 points for every invested point (4 profit minus 1 invested point). In general, your earnings depend on the number of fish in the lake and are equal to $\frac{\text{the number of fish in the lake}}{150}$ per invested point, see the following table:

Fish in the lake	Earnings per point invested	Gains (earnings – investment) per point invested
600	4	3
450	3	2
300	2	1
150	1	0

Example: imagine there are 400 fish in the lake and you invest 15 points. Then you keep 35 points from your budget and you earn $15\times\frac{400}{150} = 40$ points (= 10 fish) from your investment. You end this period then with 35 + 40 = 75 points. To make things a little easier, you can always see on the screen how many points you will earn per invested point.

Fishing reduces the number of fish in the lake, but the lake will also recover to some extent every period. The number of fish taken out of the lake equals $\frac{fish\ in\ the\ lake\ \times\ total\ points\ invested\ in\ fishing}{600}$. So, if there are 600 fish in the lake, for every point invested, one fish is taken out; if there are, e.g., only 300 fish in the lake, for every point invested only half a fish is taken out of the lake. After each period, the fish population recovers again with an increase of 25%, but the lake can never contain more than 600 fish. See the following table.

Starting amount of fish	Amount invested per subject	Amount invested by all subjects together	Number of fish caught	Amount before recovery	Amount after recovery
600	*50*	*200*	*200*	*400*	*500*
600	40	160	160	440	550
600	**30**	**120**	**120**	**480**	**600**
600	20	80	80	520	600
300	50	200	100	200	250
300	40	160	80	220	275
300	30	120	60	240	300
300	20	80	40	260	325

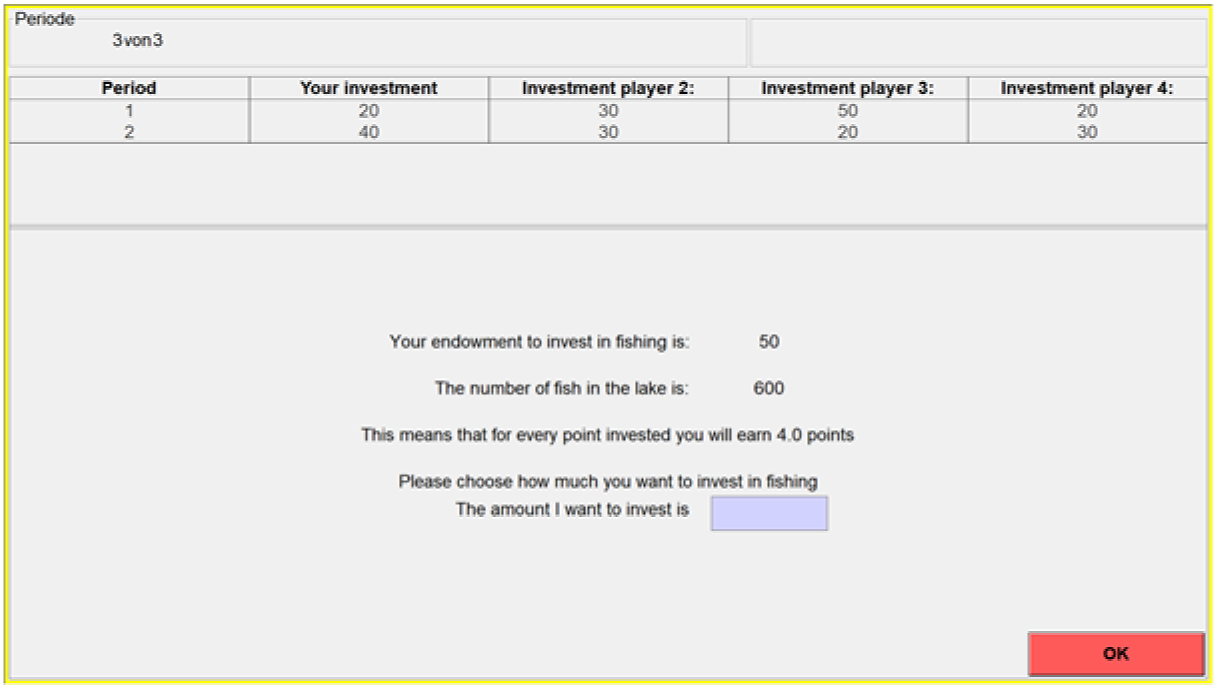
For example (see the row in **bold**), if all four players in your group invest **30** in fishing, your group will invest $4 \times 30 = 120$ in total. This will decrease the number of fish in the lake to 600 – 120 = 480. Due to increase of the fish in the lake, the number of fish in the lake will be $480 \times 1.25 = 600$ again in the next period. However, if all four players invest *50* (the row in *italics*), the number of fish in the lake will decrease with $4 \times 50 = 200$, which results in 600 – 200 = 400 fish. Due to the increase of the fish in the lake, the number of fish in the lake will be $400 \times 1.25 = 500$ in the next period. The number of fish in the lake, and with it the number of fish you can catch per invested point in fishing, will then decrease.

To summarize, some important properties of fishing need to be considered:

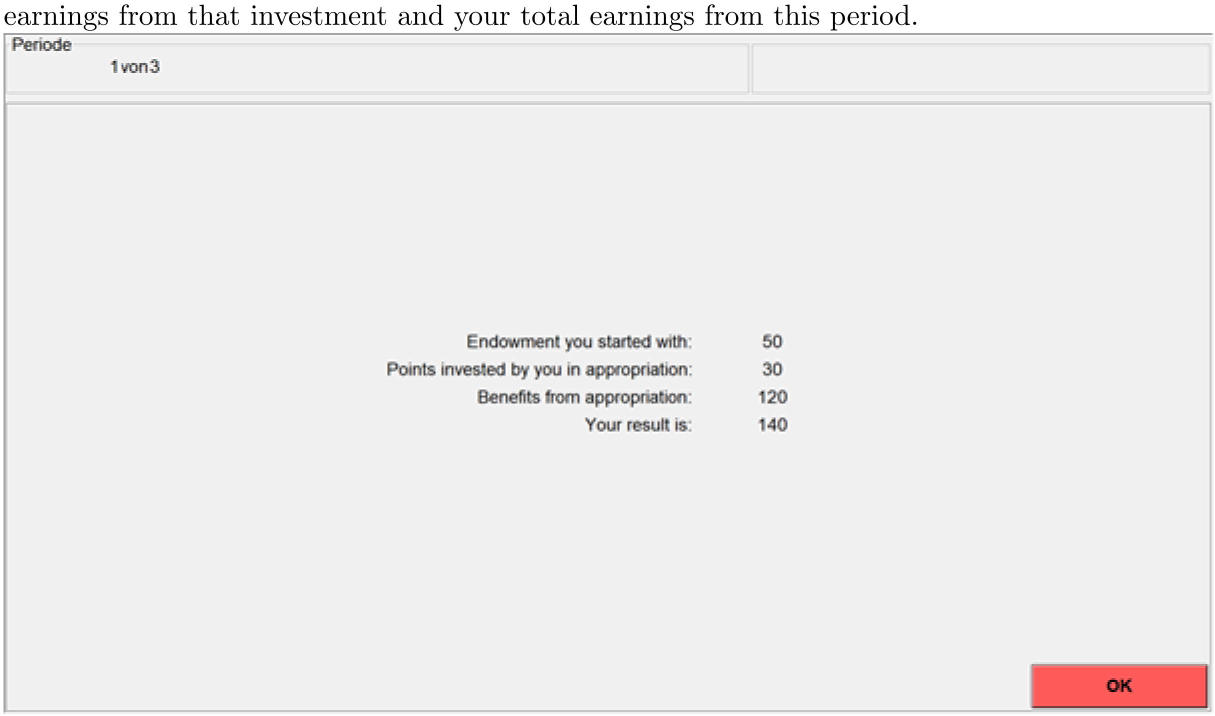
- **The more fish in the lake, the more points you earn with the same investment of points**
- **If everyone invests 30 (or less) in fishing, the number of fish in the lake remains the same (or increases to a maximum of 600) over time**
- **If everyone invests more than 30 in fishing (or the total investment in fishing is more than 120), the number of fish in the lake decreases over time.**

How it looks on your computer

Below, you see the screen in which you make a decision of how many points (0 to 50) you want to invest in fishing. On the top of the screen, you see how many points you and your group as a whole invested in fishing in the previous periods.



Below, you see the screen in which you can see your starting budget, invested points in fishing, earnings from that investment and your total earnings from this period.



Identities

In this part of the experiment, you will first be asked to express your preference for a few sets of paintings from the artists Paul Klee and Wassily Kandinsky. Based on your preferences, you will be labelled as part of the "Klees" or the "Kandinskys".

Quiz

Together with your allocated group (Klees or Kandinskys), you will play a short quiz in which you have to guess who the painter is for several paintings that are shown.
If your group has **more right answers** than the other group, everyone in your group will earn 100 extra points.
If the **majority of the answers in your group** is right, everyone in your group will earn 100 extra points.

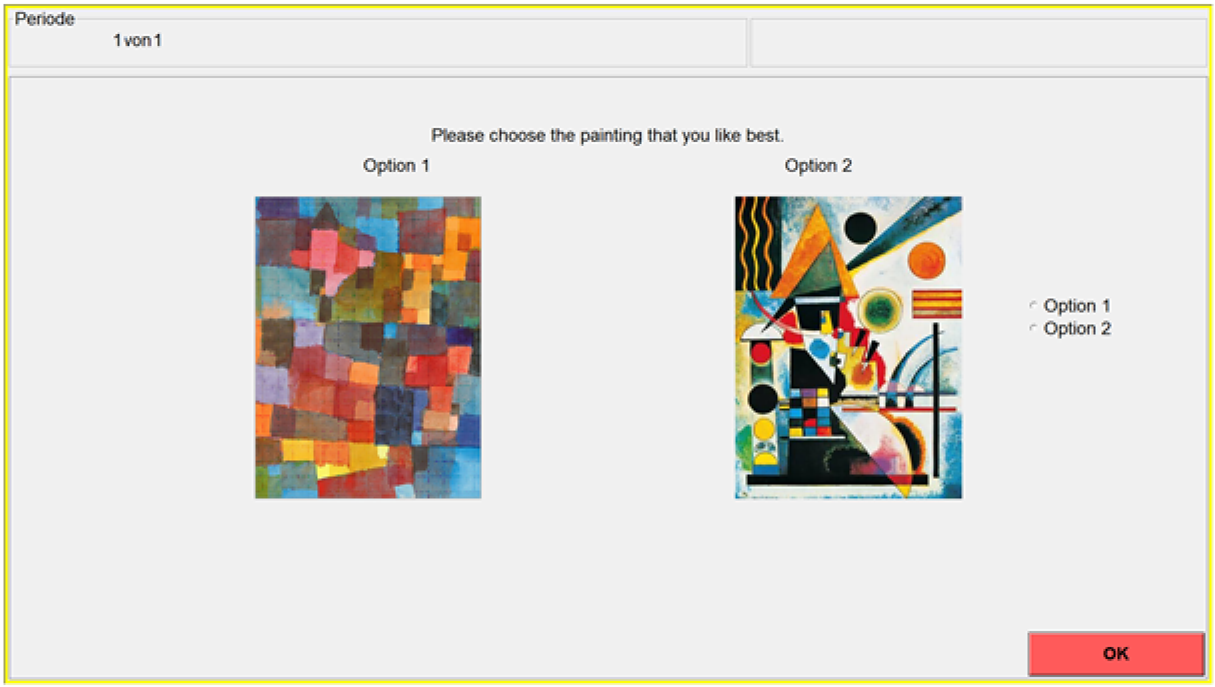
Division game

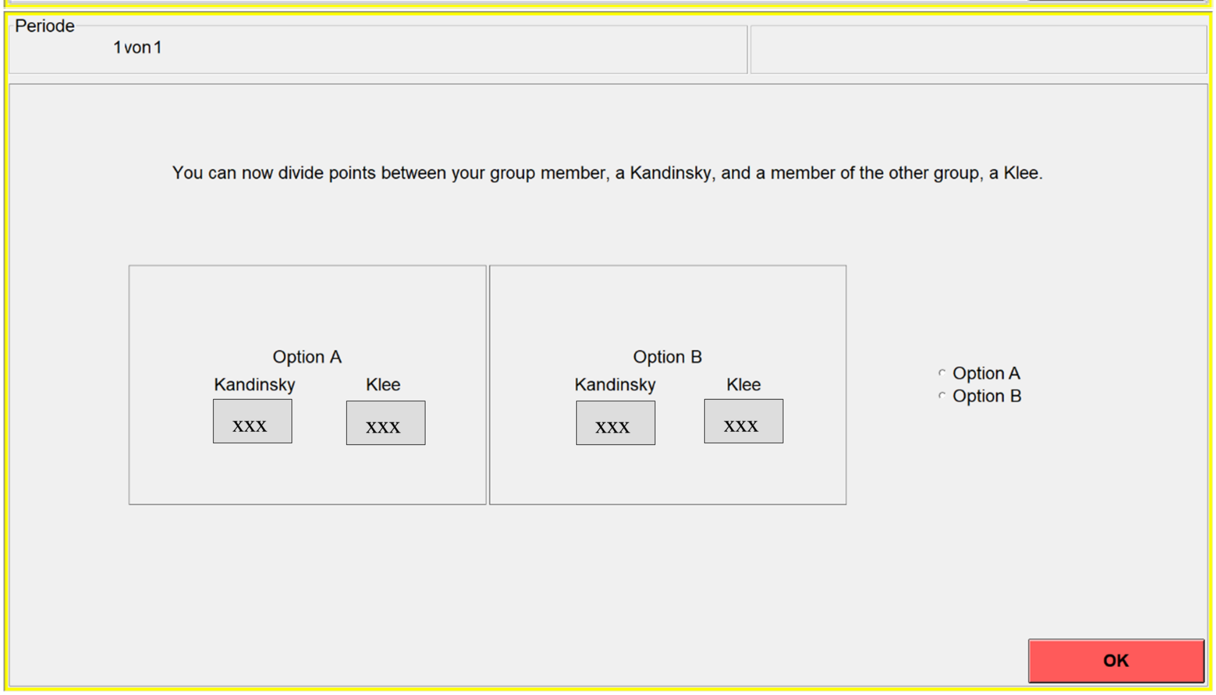
Before the fishing game continues, you play 3 short games in which you divide points between Klees and Kandinskys. One of these games will be randomly selected to be paid: the points will be added to a Kandinsky and a Klee.

Trust Game

After the quiz and the division game, you will play the trust game again: **once with a member of your group, and once with a member of the other group.**
All the extra points from this part of the experiment will be added to your total payoff at the end of the experiment.

How it looks on your computer





Appendix B

Inequality [EH]

When the Fishing Game starts, some of the players in your group have a **larger endowment** than others, which means they have the possibility to invest more points in fishing. You will be informed on the endowments of each player in your group. The situation will stay the same throughout **all periods** of the fishing game. Note that the renewal rate of the fish in the lake **stays the same**. So even though some players have more points to invest in fishing, investing more than **120** points in total as a group will lead to a **decrease** in both the number of fish in the lake and the returns per invested point.
Lastly, a questionnaire will be started after which you will receive your payment.

Different identities [SH]

When the Fishing Game starts, you are placed in a group consisting of you and three other players in the laboratory, with whom you will interact. Two of the players will be Klees and two will be Kandinskys. You will know how much each Klee and each Kandinsky invests in fishing.
Lastly, a questionnaire will be started after which you will receive your payment.

Different identities & Inequality [EHSH]

When the Fishing Game starts, some of the players in your group have a **larger endowment** than others, which means they have the possibility to invest more points in fishing. You will be informed on the endowments of each player in your group. The situation will stay the same throughout **all periods** of the fishing game. Two of the players will be Klees and two will be Kandinskys, and either the Klees or Kandinskys have a higher endowment than the other. You will know how much each Klee and each Kandinsky invests in fishing. Note that the renewal rate of the fish in the lake **stays the same**. So even though some players have more points to invest in fishing, investing more than **120** points in total as a group will lead to a **decrease** in both the number of fish in the lake and the returns per invested point.
Lastly, a questionnaire will be started after which you will receive your payment.

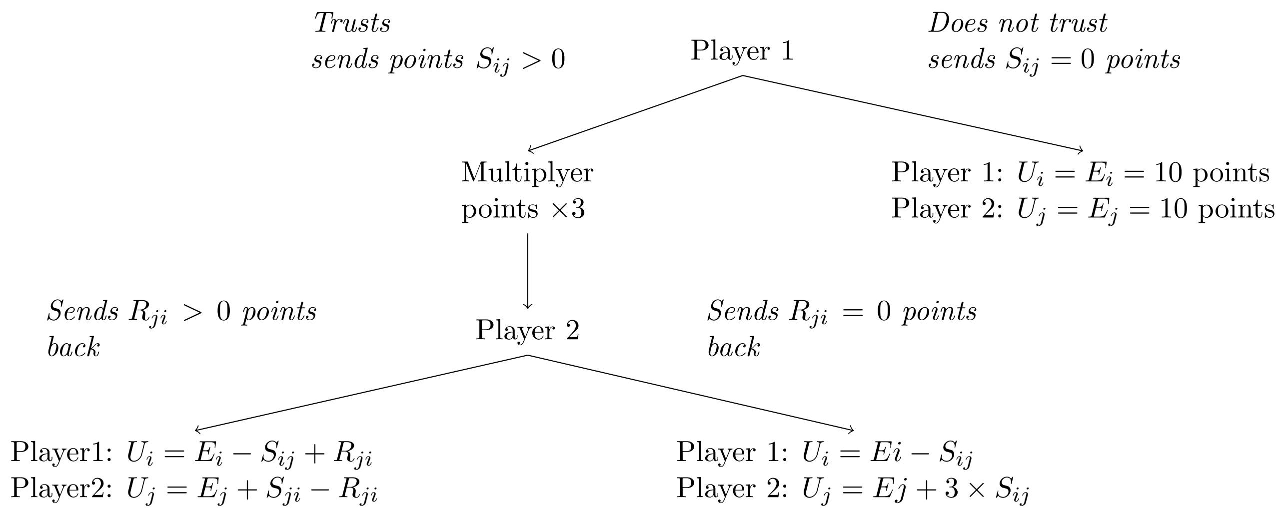
Same identities [NH]

When the Fishing Game starts, you are placed in a group consisting of you and three other players in the laboratory, with whom you will interact. You will be placed in a group with 3 players of your own group (all Klees or all Kandinskys). You will know how much each person invests in fishing.

Lastly, a questionnaire will be started after which you will receive your payment.

Appendix C

Figure 14: A graphic representation of the Investment Game as played in the current experiment



Appendix D

Characteristics of the Investment Game

There are many variations on the Investment Game. In this version of the game, choices were made with regard to the following characteristics.

(1) Players will play the role of sender as well as the role of receiver once. Burks, Carpenter and Verhoogen (S. Burks V., Carpenter, & Verhoogen, 2003) found that letting the players play both roles takes away a feeling of guilt that subjects in the sending role would otherwise experience towards the receivers, since the payoff would rely on only one interaction However, they also find that playing both roles reduces mutual trust and reciprocity. In this experiment, players play both roles but will be paid for only one. However, since subjects do not know for which interaction they will receive their payment, I do not expect the players' behaviour to be affected by feelings of guilt. An advantage of letting subjects play both roles is that more data on trusting and trustworthiness can be gathered, and different types of players - such as altruists, egoists and conditional co-operators - can be identified (see also (S. Burks, Carpenter, & Goette, 2009)).

(2) Real players are used instead of computerised counterparts. If subjects suspect or know that their counterpart in an interaction is computerised, they will behave differently in the sense that they will send less money to the receiver (Bottom, Holloway, Miller, Mislin, & Whitford, 2006; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). The meta-analysis of Johnson and Mislin (N. D. Johnson & Mislin, 2011), comprising 162 replications of the Investment Game, shows that playing against a real counterpart has a positive effect on trusting behaviour e.g. playing with a real person will yield higher amounts of points sent by the sender.

(3) A form of random payment is introduced, as stated earlier, in the sense that all subjects will be paid for one out of in total two interactions; they will be paid either for the sending or the receiving role. Random payment is in general suggested to yield more risk-averse behaviour from subjects, resulting in lower amount of points sent by the sender (Bottom, 1998). The meta-analysis of Johnson and Mislin (N. D. Johnson & Mislin, 2011) points out that there is indeed a negative effect of random payment on trust. However, this random payment is defined as only a subset of subjects receiving payment, while in the current experiment all subjects will be paid; the randomness lies in which role interaction will be paid. Based on the

latter, subjects are not expected to be influenced by random payment.

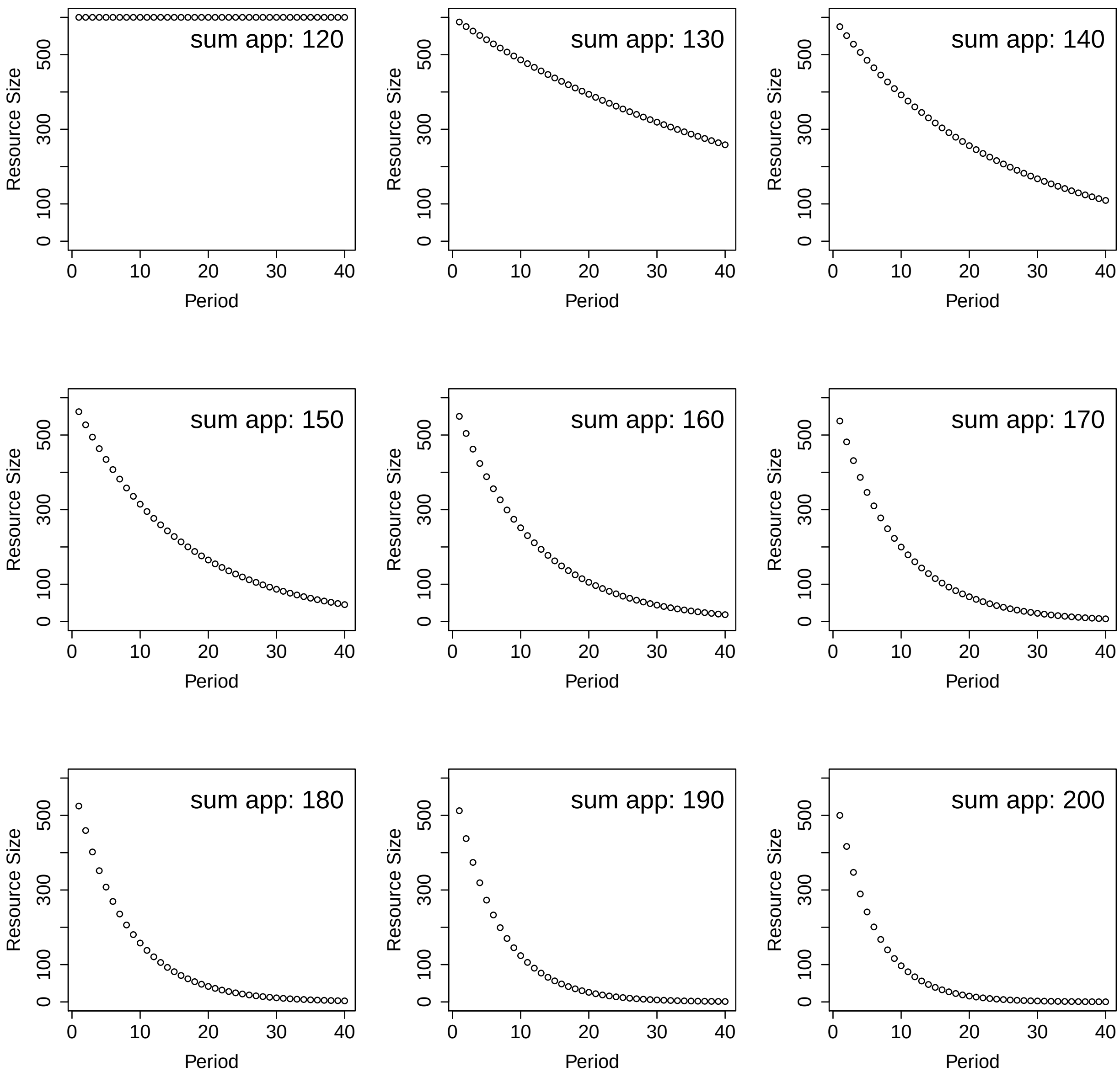
(4) The strategy method is used, meaning that all subjects in the receiving role interaction have to indicate how much they would return to the sender for every possible amount of points received (Bahry & Wilson, 2006). Some research suggests that providing this choice to subjects may alter their perception of the game (Güth, Huck, & Müller, 2001; Roth, 1995). The research, on the other hand, suggests that the strategy method has no influence of subjects' behaviour (Brandts & Charness, 2000). The meta-data analysis of Johnson and Mislin (N. D. Johnson & Mislin, 2011) found no significant effects of this method on trust or trustworthiness.

(5) Subjects in the receiving roles will receive an endowment. This will cancel out the possible effect that inequity may have on subjects. If only the sender starts with an endowment, this may cause the sender to send money to the receiver out of a feeling of injustice or guilt instead of trust (Adams, 1965; Adams & Freedman, 1976). If both players start with the same endowment, the act of sending money to the receiver can still increase the payoff for both players, and sending money while the other player has money already will be a more defined act of trust in the other player. The meta-analysis of Johnson Mislin (N. D. Johnson & Mislin, 2011) shows no persistent negative effect of receiver endowment (only one out of three models on trust shows a significant negative effects of receiver endowment).

(6) We will use anonymity amongst subjects. Subjects will not see each other's decisions, not do they know with whom they are matched for the payoff interaction. This will prevent reputation (Kreps, 1990) and/or reciprocity of kind acts (Gouldner, 1960) from having an effect on trust and trustworthiness, enabling us to measure trust and trustworthiness without the shadow of the future nor from the past. The meta-analysis of Johnson and Mislin (N. D. Johnson & Mislin, 2011) shows weak support of the suggestion that anonymity has a negative effect on trust.

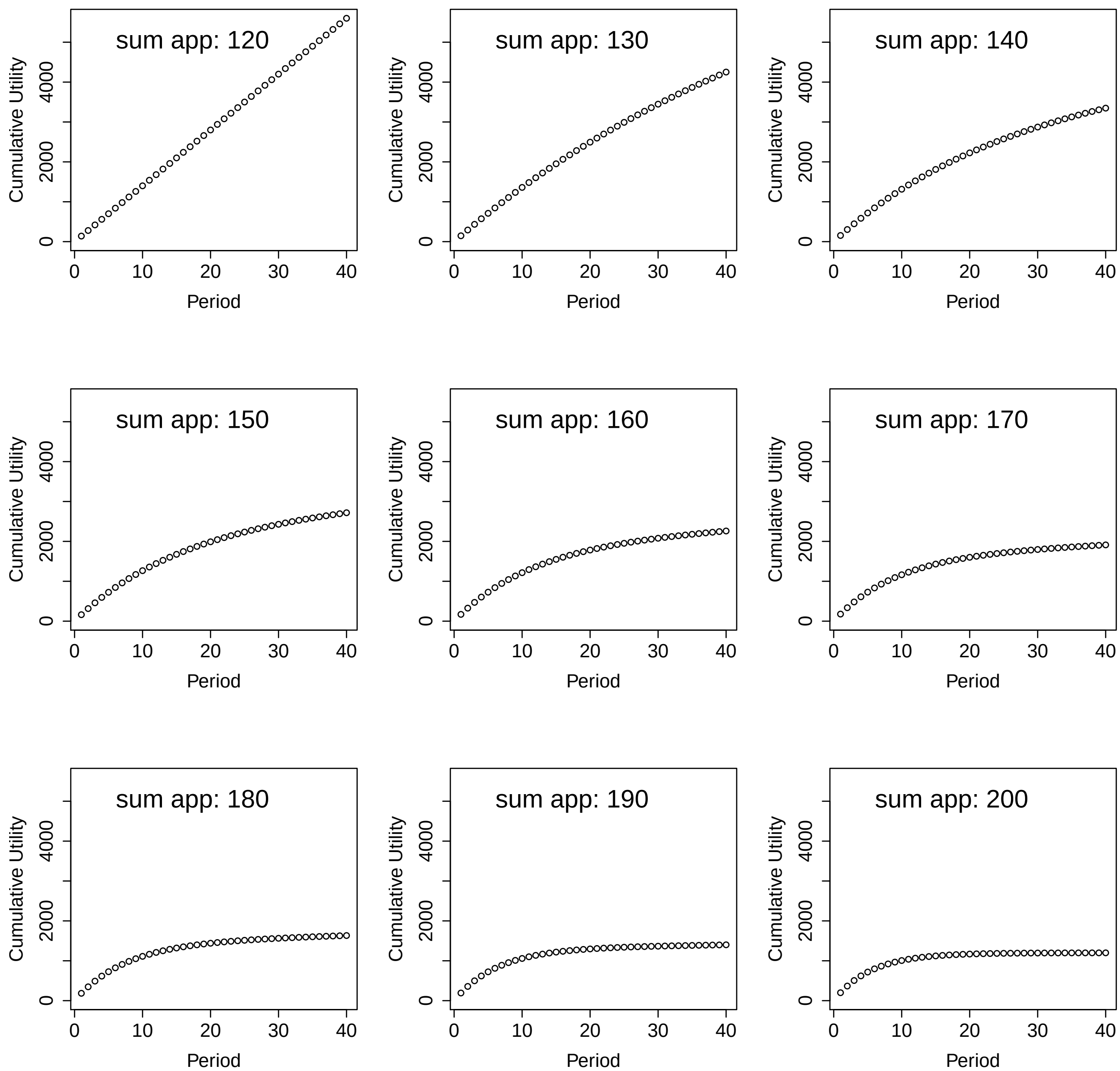
Appendix E

Figure 15: Resource Size under different group behaviour



Appendix F

Figure 16: Cumulative Profit under different group behaviour



Appendix G

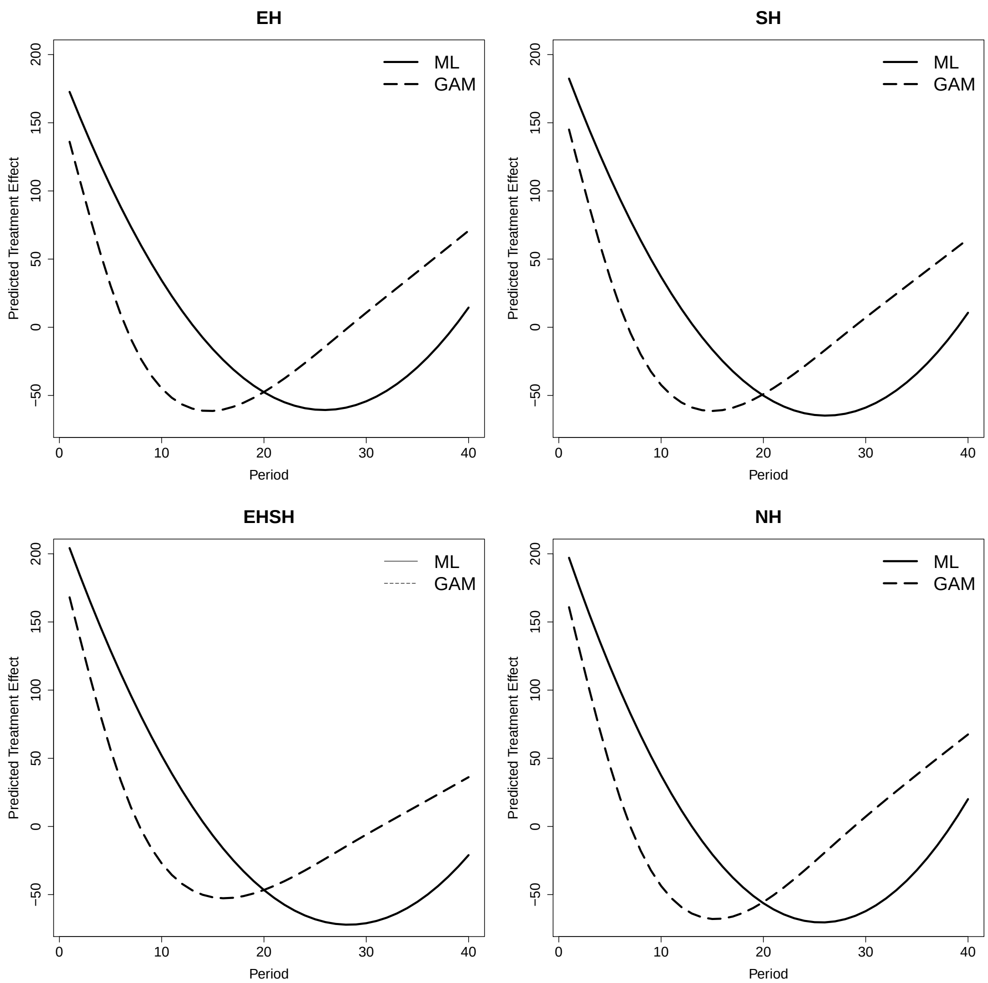
Table 5: Other-Other Dictator Game scenario 1 (A1, B1), 2 (A2, B2) and 3 (A3, B3)

	Option given for:					
	Klees & Kandinskys		Klees		Kandinskys	
	A1		B1		B1	
Scenario 1	Klee	Kandinsky	Klee	Kandinsky	Klee	Kandinsky
	330	330	345	355	355	345
	A2		B2		B2	
Scenario 2	Klee	Kandinsky	Klee	Kandinsky	Klee	Kandinsky
	420	420	440	445	445	440
	A3		B3		B3	
Scenario 3	Klee	Kandinsky	Klee	Kandinsky	Klee	Kandinsky
	320	320	300	280	280	300

Appendix H

Resource size treatment effect predictions of multilevel regression models [ML] including up to a second order polynomial of 'period' versus predictions from a Generalised Additive Models [GAM] with splines.

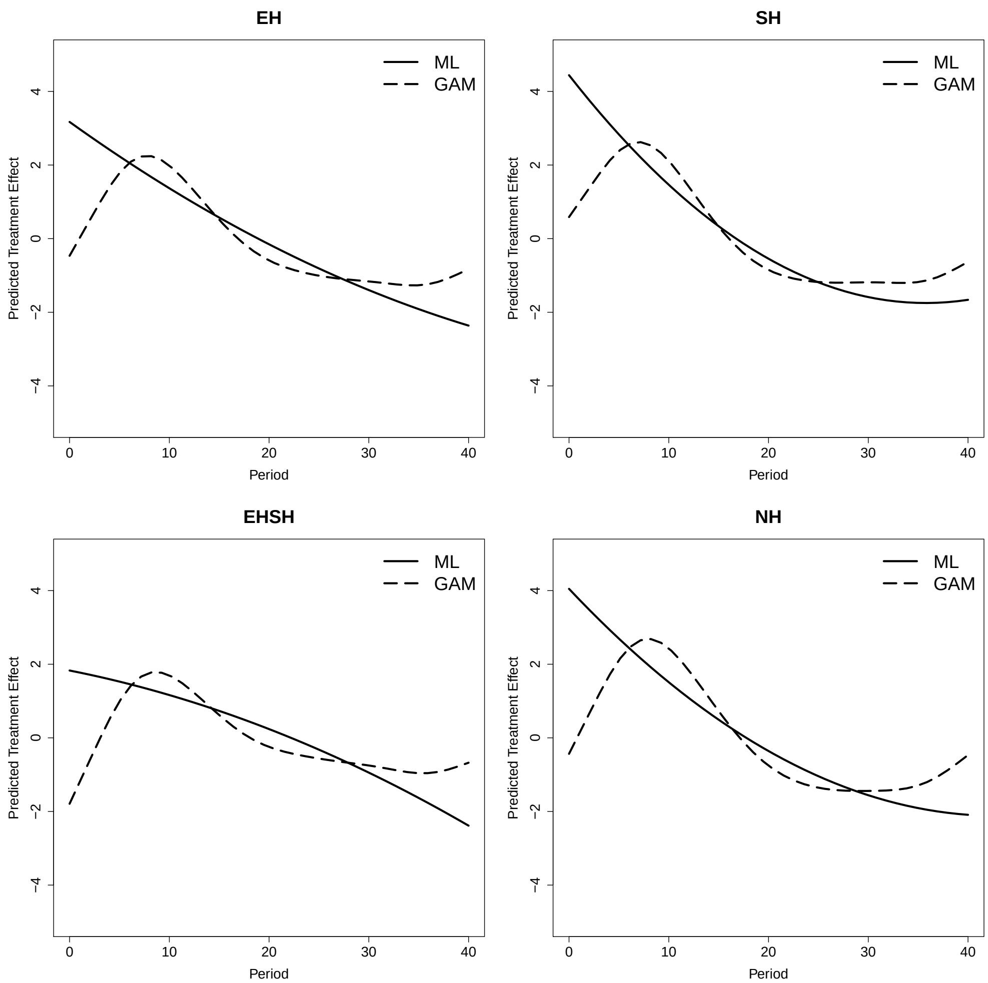
Figure 17: ML vs GAM with splines for Resource Size



Appendix I

Appropriation effort treatment effect predictions of multilevel regression models [ML] including up to a second order polynomial of 'period' versus predictions from a Generalised Additive Models [GAM] with splines.

Figure 18: ML vs GAM with splines for Appropriation Effort



Appendix J

Table 6: Ordinal Logistic Regression on post-experimental measures of trust (Odds Ratios)

	(1) Trust in other players	(2) Subjective trustworthiness of others
EH	1.67†	1.21
	(0.46)	(0.33)
SH	1.60†	1.13
	(0.45)	(0.32)
EHSH	1.67†	1.06
	(0.47)	(0.30)
Controls		
Final Profit	1.19***	1.39***
	(0.06)	(0.07)
Age	1.04**	1.02
	(0.01)	(0.01)
Friends	0.97	0.82†
	(0.01)	(0.09)
Game Theory Experience	1.10	0.88
	(0.23)	(0.19)
Female	1.63*	1.11
	(0.33)	(0.23)
Student	1.21	0.60
	(0.45)	(0.23)
Netherlands	1.12	1.26
	(0.25)	(0.29)
Observations	341	341

Standard errors in parentheses.
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*
N = 341 due to 3 missing responses on sex

Chapter IV: Using Player Types to Understand Cooperative Behaviour under Heterogeneity in CPRs: evidence from lab experiments and agent-based models

Fijnanda van Klingeren

Abstract

Experiments in behavioural social science have shown that people in common-pool resource [CPR] dilemmas do not act only according to rational choice. Three player types that are often found in experimental research are free-riders, conditional cooperators and unconditional cooperators. This study aims to use player type classification to explain cooperative outcomes of two CPR experiments on the effect of economic and sociocultural heterogeneity on cooperation, containing 344 subjects from the United Kingdom and the Netherlands and 144 subjects from India. A mixed method of multilevel regression, ordinal logistic regression, calculation of a linear conditional-contribution profile [LCP] and agent-based models [ABMs] is used to analyse, interpret and replicate experimental outcomes on the micro- and macro-level. Results suggest that economic heterogeneity and sociocultural heterogeneity on itself do not reduce cooperation in CPRs, and that economic heterogeneity under certain circumstances can even lead to more cooperation than under homogeneity. Through a combination of analytical tools this paper concludes that the effect of a combination of economic and sociocultural heterogeneity on cooperation in CPRs depends on incompatibility between groups, which affects perceived fairness of economic inequality and the level of conditional versus unconditional cooperation. Player type classification based on LCP scores shows that experimental data can be translated to and interpreted with player types, and that heterogeneity influences the player type distribution. Simple mixed ABMs informed by experimental data are shown to be capable of replicating large differences between treatments in experimental outcomes, suggesting ABMs can be a valuable tool in experimental research.

1 Introduction

Two key characteristics of common-pool resources [CPR] are their non-excludability and high subtractability: it is hard to exclude potential users from accessing CPRs, and the resource may run out after overuse (Ostrom, Walker, & Gardner, 1992). These characteristics make CPRs vulnerable to the 'Tragedy of the Commons' which is famously described by Hardin (1968) as a situation in which the CPR is locked into a system that provides each resource-user incentives to use the limited resource unlimitedly, which will lead to its inevitable decay. However, humans do not necessarily behave according to the predictions based on myopic rationality as hypothesised by Hardin - rather, they often tend to cooperate. Actors in cooperation dilemmas such as Public Good games are often divided into types such as free-riders, conditional cooperators or reciprocators and "normal" - or neutral, as they will be called in this paper - cooperators (see amongst others Dong, Zhang, & Tao, 2016; Fischbacher, Gächter, & Fehr, 2001; Fischbacher & Gächter, 2006; Gächter, 2006; Herrmann & Thöni, 2009; Janssen & Baggio, 2016; Kocher, Cherry, Kroll, Netzer, & Sutter, 2008; Kurzban & Houser, 2005; Zhang, An, & Dong, 2021). This paper starts with the analysis of two laboratory experiments: the experiment presented in Van Klingeren (2020) conducted in the United Kingdom and the Netherlands and a new experiment conducted in India. Both experiments investigate the relation between heterogeneity, trust and cooperation in CPR settings. Results from the experiments show that subjects cooperate to various degrees depending on the levels of economic and sociocultural heterogeneity and the combination of the two. In an effort to explain these differences, this paper builds on the player type classification approach by classifying subjects of experiments into cooperative types using a linear conditional-contribution profile [LCP] as described and applied by Kurzban & Houser (2005). Furthermore, agent-based models [ABMs] informed by the experimental data are deployed to measure the ability that mixed models of simple agents have to explain, replicate and eventually predict experimental outcomes. The aim of this paper is to use a combination of analytical tools understand differences in cooperative behaviour under heterogeneity in CPRs between the two experiments and in addition to explore the role that relatively new tools such as player type classification and simple ABMs can play in experimental research.

The experiments analysed in this paper focus on the effects of economic heterogeneity and sociocultural heterogeneity on cooperation. Economic heterogeneity is defined here as heterogeneity in wealth, assets or income, and sociocultural heterogeneity is defined as heterogeneity in language, ethnicity, religion or other cultural expressions (Baland & Platteau, 1996; Bardhan & Dayton-Johnson, 2002; Ruttan, 2006). A dominating argument in the literature is that economic heterogeneity will decrease cooperation by diversifying interests of the individuals involved: wealthy actors may have different interests than less wealthy actors (Shanmugaratnam, 1996). It was found in several Public Good experiments that heterogeneity in endowments indeed leads to a lower contribution to the public good (Cherry, Kroll, & Shogren, 2005; Levati, Sutter, & van der Heijden, 2007; Ledyard, 1993). On the other hand, there is research suggesting a positive effect of economic heterogeneity on cooperation: The economist Mancur Olson suggests in his book *The logic of collective action: public goods and the theory of groups* (1965) that under specific circumstances cooperation can be established in economically heterogeneous groups, in a situation in which the rich bear the cost of cooperation for the poor. Van Klingeren (2020) finds some evidence that this so-called 'Olson-effect' may hold for economic heterogeneity under sociocultural homogeneity. Regarding sociocultural heterogeneity, the main argument in existing literature states that individuals are more likely to cooperate with ingroup members: others that are similar to themselves and with whom they share multi-stranded relationships and common interests (Anderson & Paskeviciute, 2006; Becker & Ostrom, 1995; Bowles & Gintis, 2002; Boyd & Richerson, 1985; Ellickson, 1991; Gehrig, Schlüter, & Hammerstein, 2019; Jones, 2004; Nettle & Dunbar, 1997; Ostrom et al., 1992; Portes & Landolt, 2000; Putnam, 2000; Singleton, 2001; Varughese & Ostrom, 2001). There is experimental evidence that shows that the feeling of belonging to a group can lead to ingroup favouritism (Chen & Li, 2009; Van Klingeren, 2020). A variable that is commonly thought of as a mediator between heterogeneity and cooperation is trust. Literature suggests that individuals trust others that are like them, for instance with respect to ethnicity, culture, religion or something else (Alesina & La Ferrara, 2002; Barr, 1999; Bouckaert & Dhaene, 2004; Delhey & Newton, 2005; Knack & Keefer, 1997; Putnam, 2007; You, 2012; Zak & Knack, 2001). Trust in its turn has been broadly established to promote cooperation (Alesina & La Ferrara, 2000; Knack & Keefer, 1997; La Porta, Lopez-de-Silanes, Shleifer, & Vishny, 1997; Seabright, 1993; Van Klingeren, 2020; Van Klingeren & De Graaf, 2020).

The analytical strategy of this paper comprises statistical analyses of experimental data, player type classification through the construction of LCP scores and replicating experimental outcomes with ABMs. All three add to the understanding of cooperative behaviour in their own way. Firstly, the statistical analysis of the experimental data establishes significant differences between behaviour in different treatments, both on the macro- and micro-level. Secondly, player type classification is useful for identifying and visualising the emergence of different types of cooperative and defective behaviour in different treatments, and to express experimental outcomes as a result of player type distribution. It will provide a more granular insight on behavioural differences on the player-level. Thirdly, ABMs based on simple theoretical agents are used in accordance with the earlier established player type distribution from the data to replicate and explain experimental outcomes on the micro- and macro-level. Through testing of the fit of ABMs with the data, this paper investigates whether experimental data can be coded into simple ABMs and whether complex experimental outcomes can be understood in terms of simple behavioural rules. If it can, that opens up opportunities for future experimental research to manipulate ABMs to generate counterfactual data and to develop realistic and dynamic hypotheses on cooperation in CPRs before the experiment is conducted.

In the next section, the CPR experiments are discussed and the outcomes are presented. Subsequently, LCP scores of the subjects are computed and the player type distribution is compared within and between the two experiments. Next, the agents that are part of the ABMs are described, ABM predictions on cooperation are made based on hypothetical player type distributions, and informed ABM outcomes are matched against the experimental data. Between each section, an abridgement paragraph summarises the findings and introduces the next analytical step. Lastly, the overarching findings of this paper are discussed and a conclusion is presented.

2 The Experiments

To understand the relation between heterogeneity, trust and cooperation in CPRs, two laboratory experiments comprising several games were conducted. One experiment took place in the United Kingdom and the Netherlands (hereafter called the UKNL study) and the other experiment was conducted in India (hereafter called the IND study). Results of the UKNL study were published in Van Klingeren (2020), whereas the results from the IND study are presented in the current paper for the first time. The difference between the two experiments is the operationalisation of sociocultural heterogeneity: the UKNL study uses an artificial, induced identity through a Minimal Group Experiment [MGE] and the IND study uses a real identity, namely city of origin.

In the following paragraphs, details on the experimental sessions are described as well as the games that were played and the treatments that were applied. The outcomes of both experiments are presented using descriptive plots and statistical analyses.

2.1 Experimental Sessions

The UKNL and the IND study comprise experiments with an almost identical setup.[1] Both are computerised laboratory experiments and were designed and programmed in z-tree (Fischbacher, 2007). The UKNL study was conducted at the Centre for Experimental Social Sciences [CESS] at Nuffield College, University of Oxford and at the Experimental Laboratory for Sociology and Economics [ELSE] at Utrecht University. A total of 344 subjects of age 18 and older participated in the experiment that was held between October 2018 and November 2019. 81% of the subjects were students, from varying disciplines and years or stages. 60% of the subjects were female, and the average age was 26. After a pre-test with 16 Oxford students, the experiment was held in 13 sessions at CESS containing 248 subjects, and 5 sessions at ELSE containing 96 subjects. The IND study was conducted at the CESS Nuffield - FLAME laboratory at the FLAME University campus in Pune, India in November and December 2019. A total of 144 students of age 18 and older participated in the experiment, of whom 56 from Bangalore and 88 from Mumbai. 65% of the subjects was female, and the average age was 19. After two pilot sessions with respectively 8 and 16 subjects from Pune and Delhi, the experiment was held in 7 sessions. The average age between the UKNL and IND experiments differs - the implications this may pose for the results of this paper will be discussed later in the paper. Subjects played for real money. The average earnings for participation were 15.11 GBP/EUR and 550 INR respectively. Completing the experiment took 50 to 70 minutes. Every session included groups for all treatments, and every subject only participated in one treatment.

General written instructions in English were handed out to the subjects at the start of the experiment. The first part of the experiment comprised a (1) one-shot Investment Game [IG] (Berg, Dickhaut, & McCabe, 1995) to measure general trust; (2) a basic, practise version of the CPR game called 'the Fishing Game' without any treatments for three periods; and (3) a group division stage. For the UKNL study the group division was based on the MGE and for the IND study this was based on city of origin; Mumbai or Bangalore. In this stage, group bonds were strengthened through a short quiz in which group performance paid off. In addition, the UKNL study included a binary other-other Dictator Game [DG] and two one-shot IGs (once with an

[1]This research, including the pre-tests, has obtained ethics clearance from the Research Ethics Committee of Department of Sociology (DREC) at the University of Oxford (Ref. SOC_R2_001_C1A_18_30), the CESS ethics committee (Ref. LE_0044) covering both the UKNL and IND study, and the sessions in the Netherlands were in addition covered by the ethical approval (Ref. FETC17-028, Buskens) of the ethical committee of the Faculty of the Social and Behavioural Sciences at Utrecht University. Written consent was obtained from all subjects in the study, including the pre-test, before the start of each experimental session. The data were anonymised before the analyses.

ingroup member and once with an outgroup member) to strengthen and test group bonds. Due to time constraints, the other-other binary DG and the additional IGs were not included in the IND study. The IND study included a comprehension check after each period of the practise Fishing Game, as it was expected that the subjects were less experienced in the type of game than the subjects in the UKNL study. In the second part of the experiment, the subjects started the Fishing Game. Prior to the start of the second part, subjects received specific instructions corresponding to their treatment. Figure 1 and Figure 2 show the sequence of the UKNL and IND experimental stages respectively. The purpose of each stage will be expanded on in the following paragraphs.

Figure 1: Sequence of UKNL experiment (Based on Van Klingeren, 2020, p.6)

IG 1 ⟶ *Practise Fishing Game × 3* ⟶ *MGE Quiz DG* ⟶ *IG 2* ⟶ *Fishing Game*

Figure 2: Sequence of IND experiment

IG ⟶ *Practise Fishing Game × 3 incl. comprehension checks* ⟶ *Division Quiz* ⟶ *Fishing Game*

2.2 The Fishing Game: cooperation and heterogeneity

A detailed explanation of each stage of the Fishing Game including utility and regrowth functions can be found in Appendix A and in Van Klingeren (2020). The resource in both experiments is a fishing ground. In the game there are four resource users or 'appropriators' that use the CPR. They play the game with each other for the entire session. During the game, players can invest all or part of their endowment E in the extraction or 'appropriation' of fish from the resource (i.e. they go fishing) for profit every period t. The resource regrows after each period to a certain extent, but consistent overappropriation will reduce the resource size over time. Profit per invested unit in appropriation a depends on the size of the resource relative to its original size. Cooperation in the experiment is operationalised as the appropriation effort (lower is more cooperative[2]) and resource

[2]As can be learned from the experiment description in Appendix A, an appropriation of 30 units of a out of an endowment of $E = 40$, $E = 50$ or $E = 60$ is considered cooperative, as the resource can grow back to its original size after a total group appropriation of 120. Appropriation lower than $a = 30$ units is thus not necessarily more cooperative than an appropriation of $a = 30$. However, as the average appropriation is found to be above 30 in general and a lower appropriation helps regrowth of the resource size, lower appropriation is considered more cooperative when interpreting effects on appropriation level in the multilevel regressions

size (higher is more cooperative) and heterogeneity is operationalised with treatments of economic and/or sociocultural heterogeneity. The game lasts 40 periods in the UKNL study, and 30 periods in the IND study. To be able to compare the data from both experiments, only the first 30 periods of the UKNL study are taken into account in the comparative analyses. Subjects do not know how many periods they will play the game for in either experiment, which means that no endgame effects are expected (González, Güth, & Levati, 2005) and the first 30 periods are thus comparable between the two experiments.

2.3 Trust

Trust is measured at two points[3] in the experimental session: (1) by the one-shot IG with a random other subject at the very beginning of the experimental session before the main game, and (2) by asking questions on the extent of mutual trust felt during the main game in a post-experimental survey. The one-shot IG will be used to measure general trust; to get an idea on how trusting the participants are when they enter the experiment. Even if this type of trust does not resemble the mutual trust necessary for repeated games (such as the current CPR Game) it is still useful as indicator of general trustfulness and trustworthiness of subjects. See Appendix B for an extensive explanation of the IG as played in the experiment.

2.4 Experimental Treatments

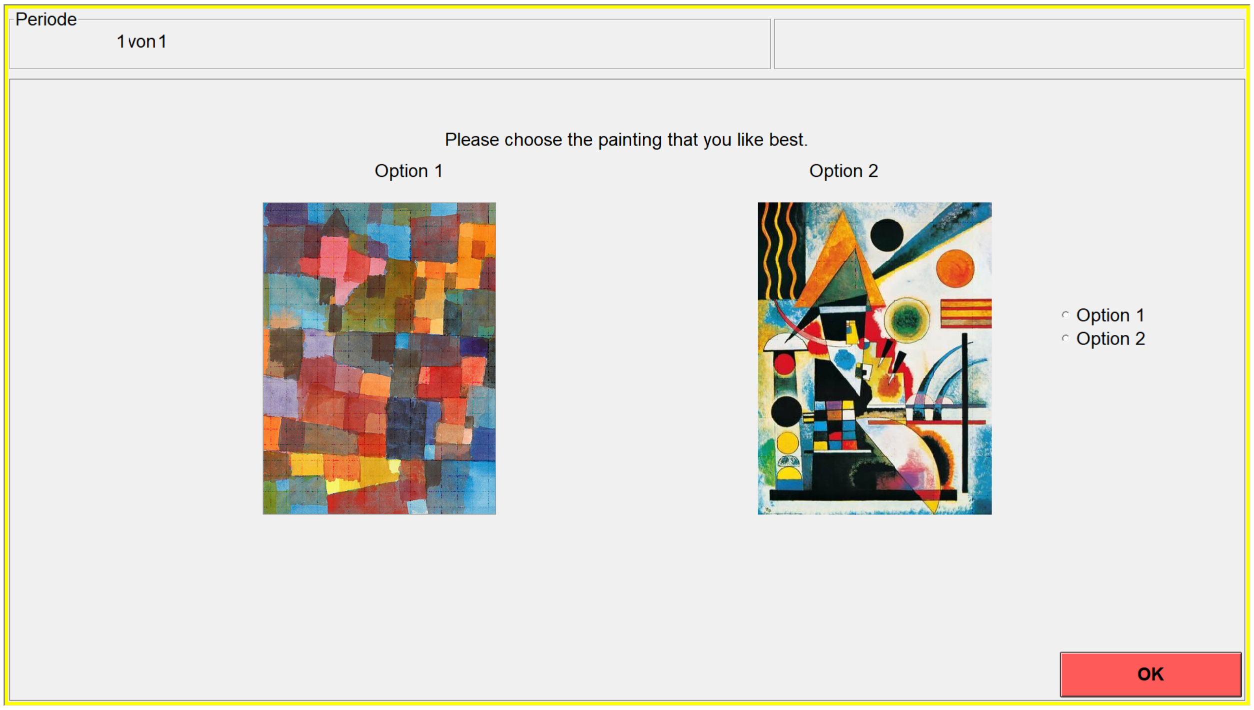
2.4.1 Sociocultural Heterogeneity: paintings and cities

In the UKNL study, a Minimal Group Experiment [MGE] was used to create artificial identities which are based on an intended trivial criterion (Tajfel, 1970; Tajfel, Billig, Bundy, & Flament, 1971; Aksoy, 2015; Chen & Li, 2009; Kahn, 2019; Yamagishi & Kiyonari, 2000). Following the approach of amongst others Tajfel, Billig, Bundy and Flament (1971), Aksoy (2015, 2019) and Kahn (2019), the subjects were shown five paintings by two artists, Paul Klee and Wassily Kandinsky, after which they were asked to express their preference of either picture, resulting in a score of 0 to 5 for Klee-preference. Based on the median preference of the particular experimental session, subjects are assigned to the Klee or Kandinsky group (following the method of Masella, Meier, & Zahn, 2014). See Figure 3 for an example of one of the decision screens in the MGE. To strengthen the group bonds, subjects play a quiz in which group performance pays off. In the quiz, three paintings

[3] As mentioned before, in the UKNL study trust is measured at three points in the experiment: with a general IG, an IG after the division in groups - once with an ingroup and once with an outgroup member - and at the post-experimental survey. Due to time constraints in the IND study, the second trust measurement was omitted.

were presented to the subjects, of which they had to guess whether it was painted by Klee or Kandinsky. After that, subjects player an other-other Dictator Game in which they had to divide points equally or unequally between an ingroup and an outgroup member. See Appendix C for the decision table of the other-other DG and Van Klingeren (2020) for a more extensive explanation of this stage.

Figure 3: Decision screen UKNL MGE



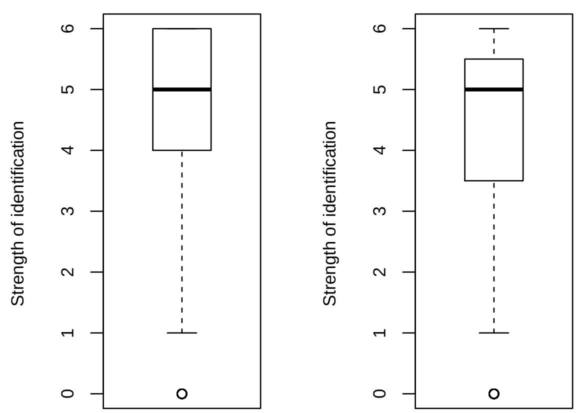
In the IND study, a real form of identity was used to operationalise sociocultural heterogeneity, namely city of origin. Subjects were selected based on whether they came originally from Mumbai or Bangalore. These two big Indian cities are viewed by some people as competing cosmopolitan cities with rivalry between the two. Numerous internet articles compare the two cities in terms of living costs, job opportunities, diversity and general quality of life. The rivalry between the two cities becomes especially clear when looking at reader comments at these articles, in which people fervently defend their city of origin as being the best city out of the two. To make sure participants of the IND study were really from Mumbai or Bangalore, subjects' home towns were checked during the sign up process, and they were asked to provide some type of proof of their affiliation with either city during the registration process.[4] To get an insight of how strongly subjects identify themselves

[4]Of course, we can never be 100% certain that someone who claims to identify strongly as a Mumbaikar based on

as Mumbaikars or Bangloreans, half of the subjects were asked a question in the post-experimental survey on how strongly they identify with their city of origin on a 7-point Likert-scale, and subjects were asked to write down why they identify as Mumbaikar or Bangalorean.[5] Figure 4 shows that subjects from both Bangalore and Mumbai reported similar levels of identification with their city of origin.

Figure 4: Reported strength of identification with city of origin

(a) Mumbai (b) Bangalore



From the answers to the open question of why subjects feel a connection to their city, it became quite clear that subjects felt passionate about their city, with some of the answers being: "*It's alive. It is always awake. It's familiar. I am comfortable there.*", "*I am extremely influenced by its culture, people and ways of life.*" and "*It plays a big role in what I am today*". Subjects also wrote things highlighting the effect that being from their city had on them: "*The city influenced the way I speak; my language and my tone*", "*This is the city that has taught and influenced my behaviour in all aspects*", "*The general distrust and quick pace of the city keeps me on my feet and resonates with how I feel about others around me*", "*[...] I've been socialized into the culture of the city*" and

their time spent there or coming out of the general area, but was not born there, really has the affiliation they say they have. However, Mumbaikars and Bangaloreans are randomly spread over treatments, so this should not influence treatment effects. A few students were not admitted to participate due to lack of or unconvincing "evidence" of their affiliation with either city.

[5]This measure was implemented halfway through the experimental sessions as an extra measure of identification, as more subjects that were not born in Mumbai or Bangalore wanted to participate in later sessions of the experiment.

"It is my home and when people meet me they know I'm from this city".

After dividing subjects into groups of Mumbaikars and Bangaloreans, subjects played a quiz in which group performance paid off to strengthen the feeling of belonging to a group. In the quiz, three sets of two geographical areas were presented and subjects had to choose which one was bigger. Unlike the UKNL study, subjects in the IND study did not play an other-other Dictator Game due to time constraints. However, as the heterogeneity is based on a real form of identity the additional other-other Dictator Game was not deemed a necessary addition to the group-strengthening process, as it was for the UKNL study.

2.4.2 Economic Heterogeneity

Economic heterogeneity is induced by varying the endowment E that players receive at the start of each period. Under economic homogeneity, all appropriators receive $E = 50$ to invest in appropriation. Under economic heterogeneity, however, two players receive $E = 40$ and two players receive $E = 60$ (see i.a. Cherry et al. (2005) for a similar operationalisation of economic heterogeneity based on variations in endowment). The total endowment of the group is 200 for all groups in all treatments.

2.4.3 Four Combinations

The four treatments that are applied in the experiment are (1) economic heterogeneity [EH], (2) sociocultural heterogeneity [SH], (3) economic and sociocultural heterogeneity [EHSH], and the control treatment (4) no heterogeneity [NH]. Table 1 shows the treatments and the number of subjects in each treatment for the UKNL and IND studies.[6] Subjects know their own endowment and the endowment of others in their group; just as they know their own group identity and the group identity of others in their group. They see all this information in a box on the screen every period. Note that in the EHSH treatment, economic heterogeneity is lined up with sociocultural heterogeneity; that is, two members of the same group receive $E = 60$ and the two other members, who are both members of the other group, receive $E = 40$. In the EH treatment, two randomly chosen players receive $E = 40$ and the other two receive $E = 60$.

[6] In the treatments without sociocultural heterogeneity - EH and NH - there is an unequal division of Mumbaikars and Bangaloreans due to the difficulty of recruitment of Bangaloreans, who were a minority at the FLAME University campus. However, a two-level multilevel regression on resource size with random effects for groups and a three-level multilevel regression on appropriation with random effects for groups and subjects show that being a Mumbaikar or Bangalorean does not significantly affect behaviour on respectively the macro-level ($B = -0.180$, $p = 0.971$) or the micro-level ($B = 1.828$, $p = 0.141$). For these treatments, the unequal division of Mumbaikars and Bangaloreans is thus no issue.

Table 1: Overview of treatments

	Treatment	Operationalisation	UKNL	IND Mumbai	Bangalore
1. EH	Economic heterogeneity Sociocultural homogeneity	Different endowments Same painter /city identity	N = 92	N = 24	N = 12
2. SH	Economic homogeneity Sociocultural heterogeneity	Same endowments Different painter / city identity	N = 88	N = 18	N = 18
3. EHSH	Economic heterogeneity Sociocultural heterogeneity	Different endowments Different painter / city identity	N = 84	N = 18	N = 18
4. NH	Economic homogeneity Sociocultural homogeneity	Same endowments Same painter /city identity	N = 80	N = 28	N = 8

2.5 Experimental Outcomes

As a first step to analyse the data, descriptive plots are generated showing the differences in behaviour between treatments and between the IND and UKNL studies. Next, two-level and three-level multilevel regressions are used to analyse the significance of differences in behaviour between treatments and the UKNL and IND data. Lastly, ordinal logistic regressions are used to analyse data on perceived trust and fairness from the post-experimental survey.

2.5.1 Descriptive Plots

Figure 5 and Figure 6 show the smoothed average resource size and smoothed average appropriation effort per treatment per period respectively. When comparing the descriptive plots between the IND and UKNL experiments it is visible that the patterns of appropriation effort and resource size over time are similar. A difference is that resource size in the UKNL study stabilises around period 15 already, while resource size in the IND study only seems to stabilise around period 25, nearer to the end of the game. However, this development of resource size over time is coherent with what is generally found in this type of game (see also Janssen, Holahan, Lee, & Ostrom, 2010; Hey, Neugebauer, & Sadrieh, 2009).[7] There is one treatment, however, that does not follow the expected pattern of resource size over time. Figure 5 shows that in the IND study, the EHSH treatment has the highest resource size over the entire game. The other three treatments have the same position relative to each other in the two experiments: EH performs best, then SH, closely followed by the

[7] To some extent this shape of resource size curve is also a function of the way the withdrawal and renewal of the resource is designed; the quick drop and then stabilisation fits a pattern in which the average appropriation is above the sustainable amount, but fairly consistent over time.

control treatment NH. Figure 6 shows an image complementary to Figure 5: in the IND study, EHSH has the lowest appropriation over time, NH the highest. In the UKNL study, EHSH has the highest appropriation effort for a large part of the game, and EH the lowest.

Figure 5: Smoothed average Resource Size per treatment per period

(a) UKNL (Van Klingeren, 2020, p.14) (b) IND

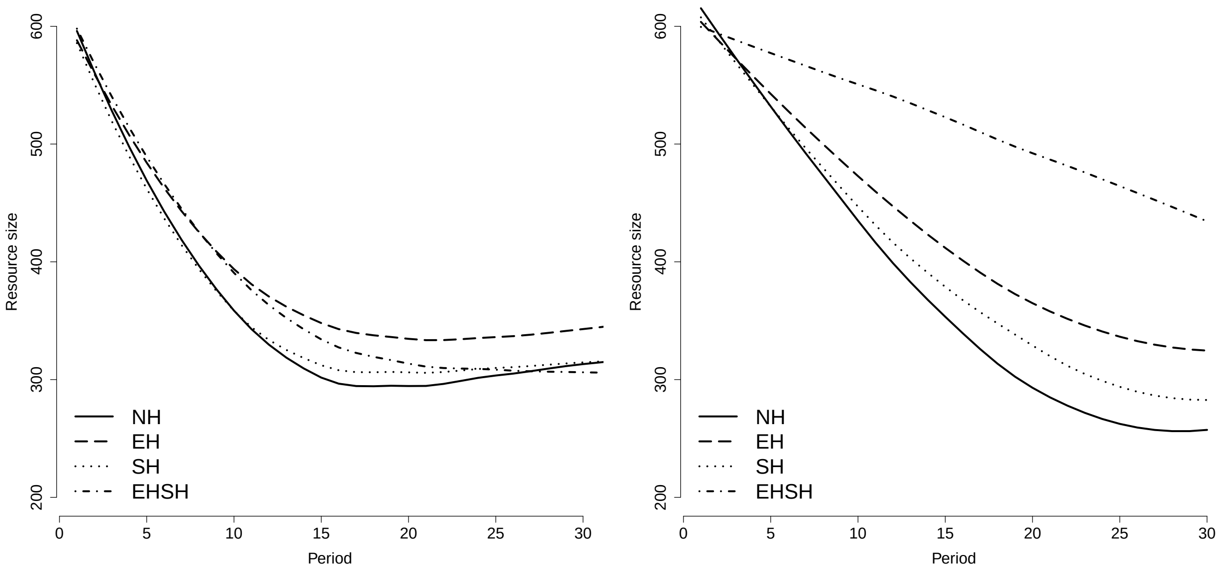
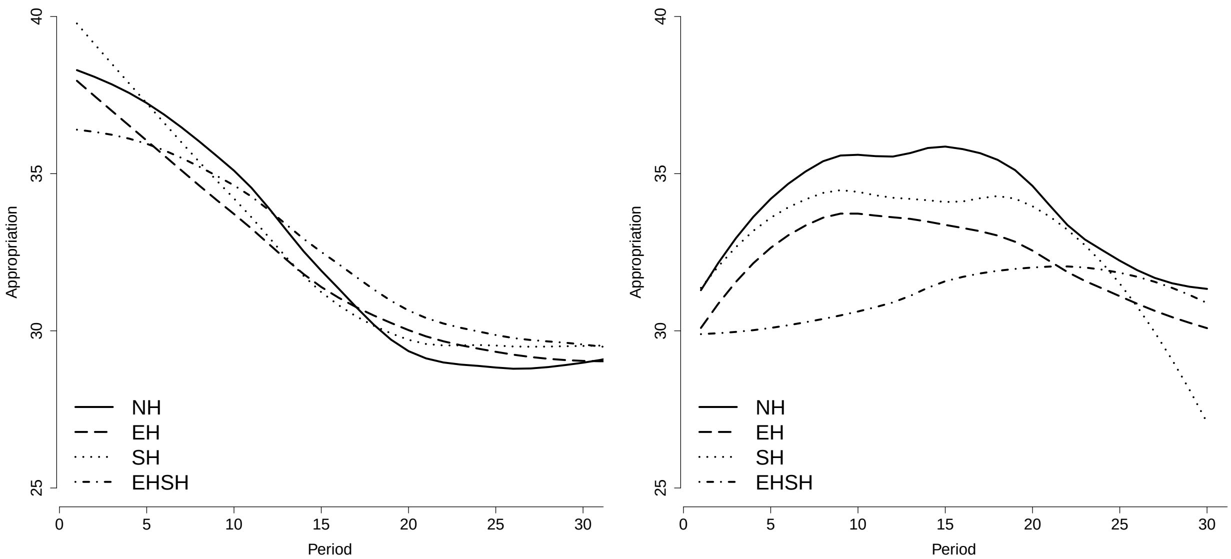


Figure 6: Smoothed average Appropriation Effort per treatment per period

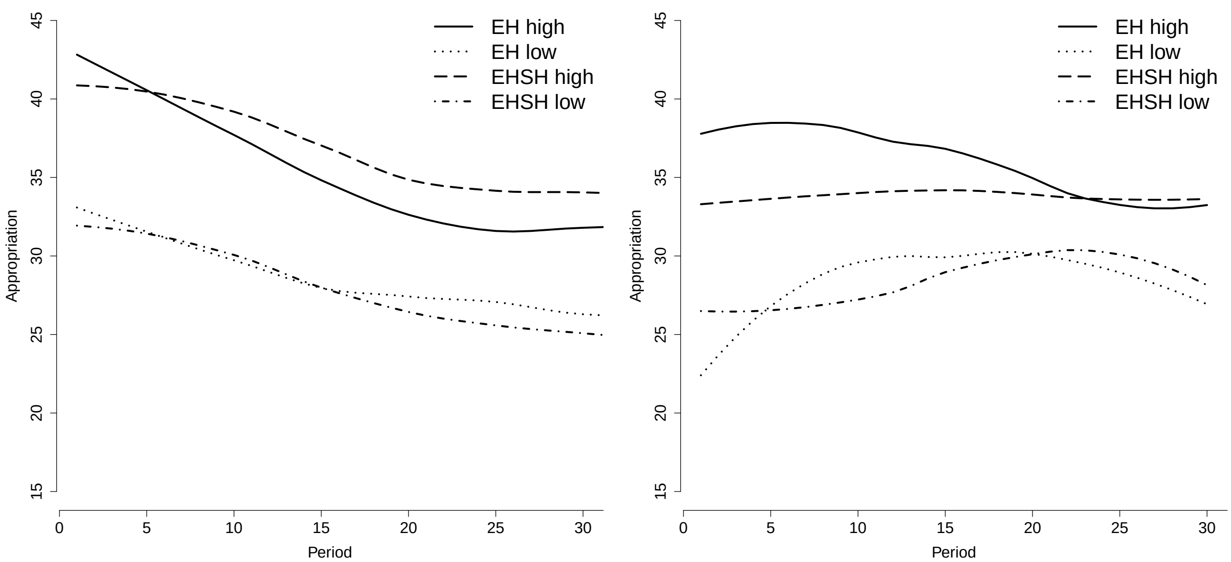
(a) UKNL (Van Klingeren, 2020, p.16) (b) IND



It is remarkable that the EHSH treatment performed so differently in the UKNL and the IND study, especially since the behaviour in the other three treatments is very similar between the two studies. The behaviour of subjects in the EH treatment in the IND study supports results from Van Klingeren (2020) with regard to the positive effect of economic heterogeneity on cooperation relative to homogeneity. The difference between the resource size of the EH and NH treatments seems to be even bigger in the IND study. The results of the EHSH treatment, however, contradict the result that the combination of economic and sociocultural heterogeneity has a negative effect on cooperation. In Van Klingeren (2020), the earlier mentioned Olson-effect (Olson, 1965) - a situation in which rich actors bear the burden of cooperation for the poor - is suggested as a potential explanation for the success of EH in the UKNL study. In this case, this would mean that players with higher endowments invest less in appropriation so that players with low endowments can invest more. To see whether this phenomenon plays a role in the experiments, Figure 7 shows the average appropriation effort for subjects with high and low endowments for the EH and EHSH treatments. Whereas the UKNL graph shows an Olson-effect in which the richer players under EH appropriate less relative to rich players in EHSH to give the poorer players room to appropriate more, we see the opposite in the IND data: rich players in the EHSH treatment invest less on average per period than rich players in the EH treatment. However, the poor players from the EH treatment invest more on average than the poor players in the EHSH treatment. Whereas the EH treatment in both studies shows that high and low endowed players make a "move to the middle" in which the rich invest less and the poor more over time - which is consistent with an Olson-effect - this is not the case for EHSH in the IND study.

Figure 7: Smoothed average Appropriation Effort with low (E = 40) and high (E = 60) endowment for EH and EHSH

(a) UKNL (Van Klingeren, 2020, p. 25) (b) IND



2.5.2 Analytical Strategy

To investigate statistical significance of the differences between treatments, two-level multilevel regression models on the macro-level outcome resource size with random intercepts for groups, and three-level multilevel regression models on the micro-level outcome appropriation effort with random intercepts for groups and subjects are conducted. To separate the effects between the UKNL and IND study, interaction effects for India [× IND] are added. Following Van Klingeren (2020), the macro-model on resource size controls for within-group levels of average general trust as measured by the IG, average age, average number of real-life acquaintances in the experimental session, average experience with game theory, percentage of students, percentage of women, and whether a session took place in the Netherlands (1) or not (0). The micro-model on appropriation effort controls for the group means as listed above, plus the individual measures of general IG trust, age, sex (female = 1), number of acquaintances, experience with game theory and being a student.

In addition, the models on appropriation effort control for resource size in period $t-1$ and the sum of appropriation of others in period $t-1$. The models on resource size do not control for lagged resource size, but both the micro- and macro-level models include period by treatment interactions up to a second order polynomial to account for the dynamic nature of the treatment effects. This approach has been proven appropriate by comparing non-parametric regression splines fitted to the purged residuals using Generalised Additive Models (Wood, 2006, 2017) with the prediction models from the multilevel regression as shown in Appendix D. Both model types come to very similar conclusions regarding the nature of the dynamic functional forms of the treatments for both the UKNL and IND study. See Van Klingeren (2020) for a more detailed description regarding the formal regression functions and modelling decisions for the multilevel models.

2.5.3 Resource Size Models

Table 2 shows a two-level multilevel regression on resource size for the entire sample. Model 3 shows that the EH treatment in the UKNL study performs significantly better relative to the NH treatment in terms of resource size every period (B = 5.84, $p < 0.001$), but with a significant negative effect of the interaction with the squared term of period (B = −0.16, $p < 0.001$), indicating that the positive effect of EH per period relative to NH decreases over time. The SH treatment too performs significantly better per period than NH in the UKNL study, however with a smaller effect size (B = 2.38, p = 0.006), and also with a negative interaction effect of SH with the squared term of period (B = −0.06, p= 0.037). The combination treatment EHSH has a significantly higher resource size over time relative to NH (B = 4.40, $p < 0.001$) for the UKNL treatment with a negative interaction effect of EHSH with the squared term of period (B = −0.17, $p < 0.001$). In the original analysis of the UKNL data, Van Klingeren (2020) finds no significant difference in resource size over time between the SH and NH, and finds that the EHSH treatment performs worst out of all treatments when taking into account the interaction with period and the squared term of period. The results in this analysis are similar, but slightly different as the last 10 periods of the game in the UKNL study are not taken into account, in order to have an unbiased comparison with the IND data.

When looking at the effects for the IND study, model 3 shows that the EH treatment does even better relative to the NH treatment than EH in the UKNL study (B = 6.74, $p< 0.001$). There is no significant difference between the performance of SH in the UKNL study and SH in the IND study relative to the NH treatment. The biggest change is the effect per period of the EHSH treatment relative to the NH treatment in the IND study, which is positive and very substantial (B = 14.74, p < 0.001). To visualise the above discussed effects, Figure 8 shows the predicted resource size based on the coefficients reported in model 3 of Table 2.

Figure 8: Predicted Resource Size per treatment per period

(a) UKNL (b) IND

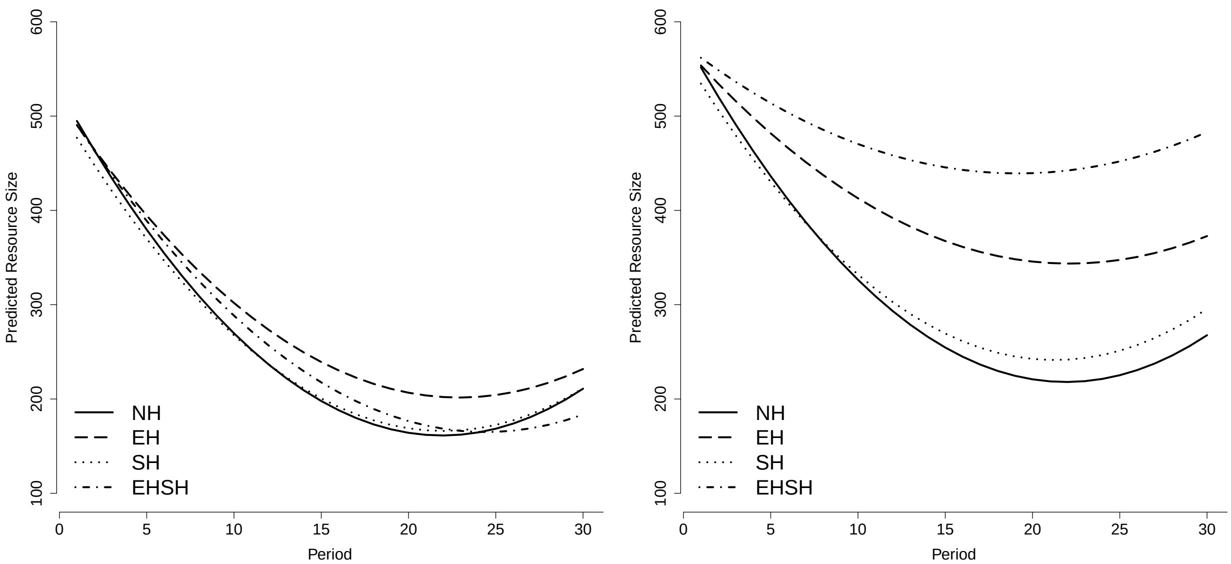


Table 2: Two-level multilevel regression on Resource Size with random intercepts for groups

	(1)	(2)	(3)
Economic Heterogeneity [EH]	19.12	16.27	−10.18
	(33.73)	(32.94)	(33.18)
EH × Period	0.90***	0.88**	5.84***
	(0.24)	(0.24)	(0.86)
EH × Period^2			−0.16***
			(0.03)
EH × IND	−16.68	−20.58	−42.23
	(61.96)	(65.15)	(65.61)
EH × IND × Period	2.04***	2.68***	6.74***
	(0.44)	(0.48)	(1.68)
EH × IND × Period^2			−0.13*
			(0.05)
Sociocultural Heterogeneity [SH]	−5.73	−10.91	−20.25
	(34.07)	(33.34)	(33.58)
SH × Period	0.64**	0.63**	2.38**
	(0.24)	(0.25)	(0.86)
SH × Period^2			−0.06*
			(0.03)
SH × IND	3.13	−27.48	−26.24
	(62.15)	(64.52)	(64.97)
SH × IND × Period	0.76†	0.93*	0.69
	(0.45)	(0.47)	(1.65)
SH × IND × Period^2			0.008
			(0.05)
Economic & Sociocultural Heterogeneity [EHSH]	30.93	19.20	−8.55
	(34.45)	(33.80)	(34.04)
EHSH × Period	−0.80***	−0.80***	4.40***
	(0.25)	(0.25)	(0.87)
EHSH × Period^2			−0.17***
			(0.03)
EHSH × IND	−4.07	−2.60	−39.25
	(62.36)	(64.13)	(64.58)
EHSH × IND × Period	8.01***	7.87***	14.74***
	(0.45)	(0.47)	(1.65)
EHSH × IND × Period^2			−0.22***
			(0.05)
Mean General Trust [MGT]		35.10	35.10
		(70.40)	(70.28)
MGT × Period		3.07***	3.07***
		(0.50)	(0.42)
Period	−8.08***	−9.79***	−33.40***
	(0.18)	(0.33)	(0.67)
India [IND]	116.37*	120.50†	56.73
	(44.96)	(66.35)	(66.57)
IND × Period	−4.79***	−4.15***	7.81***
	(0.32)	(0.34)	(1.17)
IND × Period^2			−0.39***
			(0.04)
Netherlands	68.68**	87.87**	87.87**
	(26.36)	(28.41)	(28.41)
Period^2			0.762***
			(0.02)
Constant	462.88***	401.62***	527.54***
	(25.89)	(81.96)	(81.98)
Observations	14,640	14,040	14,040
Groups	122	117	117
Log Likelihood	−84,274.120	−80,854.050	−78,646.240
Akaike Inf. Crit.	168,586.200	161,758.100	157,358.500

Standard errors in parentheses.
**** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, two-sided*
Model 2 and 3 control for average age, game theory experience, number of acquaintances in experimental session and % female in each group

2.5.4 Appropriation Effort Models

Table 3 shows a three-level multilevel regression on appropriation effort, including interaction effects with India. Model 3 shows no significant differences between appropriation in EH relative to NH, and SH relative to NH for both the UKNL and the IND studies. This may seem counterintuitive as a substantive significant difference is visible between EH and NH on the macro-level for both the IND and UKNL study. However, there are two things that should be taken in consideration. Firstly, it may be possible that more statistical power is needed to detect significant differences on the micro-level. Secondly, small behavioural changes on the micro-level can result in big differences on the macro-level - even if the differences in behaviour on the micro-level are not statistically significant. For the EHSH treatment, model 3 shows that it has a significantly higher appropriation effort per period relative to NH in the UKNL treatment ($B = 0.29$, $p = 0.010$), which decreases over time as indicated by the significant interaction of EHSH and the squared term of period ($B = -0.01$, $p = 0.016$). For the IND study, the opposite is visible: appropriation per period in the EHSH treatment is significantly lower than in the NH treatment ($B = -0.63$, $p = 0.042$). Appropriation per period relative to NH does increase over time, as indicated by the positive significant interaction of EHSH for India with the squared term of period ($B = 0.02$, $p = 0.030$). To visualise the described effects, Figure 9 shows the predicted appropriation effort per treatment per period, based on the coefficients of model 3 in Table 3. It is clear from the graphs that appropriation in the SH and NH treatments are very close to each other in both the IND and UKNL study. Although the difference is not statistically significant, in both the IND and UKNL study subjects in the EH treatment appropriates less than the NH and SH treatments. But whereas in the UKNL study the EHSH treatment has the highest appropriation effort from period 10 on, this treatment has the lowest appropriation effort in the IND study for the entire duration of the game.

Figure 9: Predicted Appropriation Effort per treatment per period

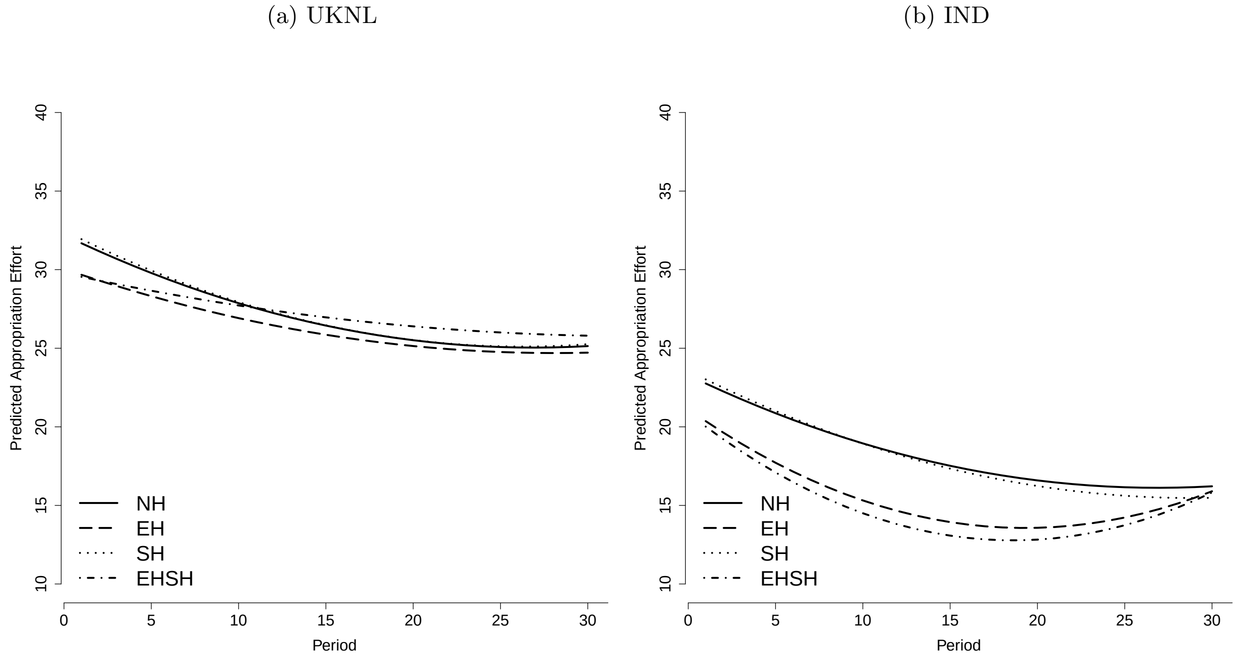


Table 3: Three-level multilevel regression on Appropriation Effort with random intercepts for groups and subjects

	(1)	(2)	(3)
Economic Heterogeneity [EH]	−0.91	−1.25	−2.16
	(1.26)	(1.38)	(1.58)
EH × Period	0.02	0.02	0.15
	(0.03)	(0.03)	(0.11)
EH × Period^2			−0.00
			(0.00)
EH × IND	−1.04	−1.92	0.85
	(2.38)	(2.80)	(3.32)
EH × IND× Period	−0.00	0.05	−0.40
	(0.06)	(0.07)	(0.32)
EH × IND × Period^2			0.01
			(0.01)
Sociocultural Heterogeneity [SH]	−0.09	0.06	0.29
	(1.28)	(1.41)	(1.60)
SH × Period	0.00	0.00	−0.03
	(0.03)	(0.03)	(0.11)
SH × Period^2			0.00
			(0.00)
SH × IND	−0.23	0.20	−0.23
	(2.39)	(2.77)	(3.27)
SH × IND × Period	−0.05	−0.04	0.00
	(0.06)	(0.07)	(0.31)
SH × IND × Period^2			−0.00
			(0.01)
Economic & Sociocultural Heterogeneity [EHSH]	−0.55	−0.56	−2.42
	(1.29)	(1.42)	(1.61)
EHSH × Period	0.02	0.03	0.29**
	(0.03)	(0.03)	(0.11)
EHSH × Period^2			−0.01*
			(0.00)
EHSH × IND	−4.74*	−4.59†	−0.23
	(2.40)	(2.75)	(3.26)
EHSH × IND × Period	0.14*	0.03	−0.63*
	(0.06)	(0.07)	(0.31)
EHSH × IND × Period^2			0.02*
			(0.01)
General Trust [GT]		−1.17	−1.23
		(1.65)	(1.62)
GT × Period		−0.11***	−0.11***
		(0.03)	(0.03)
Mean General Trust		1.15	1.49
		(3.13)	(3.07)
Period	−0.24***	−0.09***	−0.53***
	(0.02)	(0.03)	(0.09)
Period^2			0.01***
			(0.00)
India [IND]	−1.60	−2.68	−8.92**
	(1.70)	(2.72)	(2.96)
IND × Period	0.15***	0.22***	1.26***
	(0.05)	(0.05)	(0.22)
IND × Period^2			−0.03***
			(0.01)
Resourcesize (t-1)		0.02***	0.01***
		(0.00)	(0.00)
Sum appropriation others (t-1)		0.04***	0.04***
		(0.00)	(0.00)
Netherlands		−2.03†	−1.69
		(1.11)	(1.09)
Constant	36.91***	26.95***	32.20***
	(0.92)	(3.28)	(3.31)
Observations	18,080	16,895	16,895
Groups	122	117	117
Subjects	488	465	465
Log Likelihood	−71,008.380	−66,257.660	−66,248.860
Akaike Inf. Crit.	142,054.800	132,581.300	132,579.700

Standard errors in parentheses.
*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*
Model 2 and 3 control for average and individual age, game theory experience, number of acquaintances in experimental session and % female in each group and for each individual

2.5.5 Trust and Fairness

Part of the theoretical mechanism discussed in this paper is the mediating role of trust: trust is suggested to be negatively affected by heterogeneity, while having a positive influence on cooperation. The two-level multilevel regression on resource size presented in Table 2 shows that the average general trust in a group - as a mean of the individual scores from the IG - results in a significantly higher resource size per period (B = 3.07, p < 0.001). The three-level multilevel regression on appropriation effort in Table 3 shows that a higher level of individual general trust from the IG results in a significantly lower appropriation effort per period (B = −0.11, p < 0.001).[8] These results from the Fishing Game support the argument that higher trust leads to higher levels of cooperation. For the second part of the argument - trust being influenced by heterogeneity - we look at the levels of reported trust per treatment group as measured in the post-experimental survey. Ordinal logistic regression models on trust in other players and subjective trustworthiness of others show that subjects' final profit rather than treatment significantly affects how subjects answered the post-experimental survey questions on trust in the Fishing Game in the UKNL study and partially in the IND study.

Another variable that was measured in the post-experimental survey - and which may provide some additional insights on why subjects cooperated or not - is fairness. Regarding fairness of the division of endowments, significant negative effects for the EH (Odds Ratio [OR] = 0.26, p < 0.001) and the EHSH (OR = 0.18, p < 0.001) treatment compared to the NH treatment are found for the UKNL study, indicating that subjects from these treatments were significantly more likely to report lower fairness of endowment division. The IND study shows the same result: the EH (OR = 0.17, p< 0.001) and the EHSH (OR = 0.27, p = 0.005) treatment report significantly lower fairness of endowment division. But, whereas the EHSH subjects in the UKNL study report significantly lower on the feeling of being treated fairly (OR = 0.44, p = 0.003), this is not the case for the IND study, where only the EH treatment reports marginally lower on the feeling of being treated fairly (OR = 0.41, p = 0.053). The ordinal logistic regression tables can be found in Appendix E. The average score on the fair division of endowments question for EHSH subjects differs significantly between the two studies, with a mean of 1.90 for UKNL and a mean of 3.53 for IND ($t(55.74) = 4.88, p < 0.001$). The average score on the being treated fairly question for

[8] The size of these effects seems fairly small. However, considering that 1 unit increase/decrease of average trust results in 1 unit increase/decrease in profit unit per period, and 4 units increase/decrease of individual trust result in 1 unit increase/decrease in resource size per period, these effects are substantial enough to influence the individual and collective outcomes of the game.

EHSH subject also differs significantly between the two studies, with a mean of 2.50 for UKNL and a mean of 4.10 for IND ($t(59.76) = 5.13, p < 0.001$). In the UKNL study, the division of higher and lower endowments by Klee or Kandinsky preference thus significantly impacted whether subjects felt treated unfairly or not during the game for the EHSH treatment subjects, while this was not the case for the division by city origin. This can be a reason for EHSH subjects to behave more cooperatively in the IND study, which would explain the difference in EHSH outcomes between the UKNL and IND studies.

2.6 Abridgement

Formal statistical analyses are an important step to confirm and interpret behavioural differences on the micro- and macro-level, before using other tools to interpret and explain the results. The statistical analysis of the treatment effects allowed me to detect significant differences in cooperative behaviour over time and the analysis of the post-experimental survey allowed me to uncover an important motivation for cooperation. Now the differences in behaviour are detected, player type classification using LCP scores will be deployed to translate the found behaviour into free-riding, conditional cooperative and neutral cooperative categories. Whereas the regression analyses do address the micro-level to a certain extent by analysing appropriation effort, the outcomes are still an average over individuals. Player type classification will provide a different understanding of the statistical outcomes by providing insights on a more granular level; the level of the individual player. This way, the experimental outcomes can be understood in terms of player behaviour.

3 Player Type Classification

Based on research using cooperative type classification, the expectation is that most subjects will be free-riders, conditional cooperators or neutral cooperators, with conditional cooperators being the largest group (Dong et al., 2016; Fischbacher et al., 2001; Fischbacher & Gächter, 2006; Gächter, 2006; Herrmann & Thöni, 2009; Kocher et al., 2008; Kurzban & Houser, 2005; Zhang et al., 2021). Free-riders will try to make profit whilst not contributing to cooperation, neutral cooperators will always cooperate, and the level of cooperation of conditional cooperators depends on the average cooperation of the group. To explain the differences in behaviour found in the two CPR experiments, an LCP score is calculated for each subject following Kurzban & Houser (2005), to classify them as free-rider, conditional cooperator or neutral cooperator.

3.1 LCP Classification Process

The LCP score of subjects is calculated as the estimated parameters of a multilevel regression of the subject's appropriation effort on the mean appropriation effort of others in the previous period, with a random effect and random intercept on the subject level. The combined data of UKNL (for the first 30 periods) and IND data is used in this model. This approach is based on Kurzban & Houser (2005) who use a similar strategy using OLS regression. In the current strategy, however, the multilevel regression also includes individual characteristics such as level of general trust from the IG, age, sex, number of acquaintances in the experimental session and experience with game theory. Using a sum-to-zero constraint, the model also controls for the country that the experimental session took place in. The latter makes sure that the model controls for any cultural traits that may systematically influence the dependent variable. The outcome of this model provides an intercept and a slope for each subject, which indicates a subject's baseline willingness to cooperate and the subject's responsiveness to the appropriation of others respectively.

To add some uncertainty in the LCP scoring process - and thus robustness in the process - the following strategy is used. First, after calculating the slope and intercept as part of each subjects' LCP score, two simulation samples are created with the number of simulations $N_s = 100$, based on two random normal distributions: one with the individual slope as the mean and standard deviation of the slope from the regression model, and the other with the individual intercept as the mean, and the standard deviation of the intercept from the regression model. This gives us 100 simulations for the slope and 100 simulations for the intercept for each subject.

Using these simulations of LCP scores, subjects are divided into types. Firstly, the LCP scores are thought of as dots on a grid with intercept α on the y-axis and slope β on the x-axis. This grid is divided on an intercept threshold τ_s^α where α indicates the slope and s connotes the simulation aspect. The α threshold entails that if the player has an intercept of above 30, the player is considered a free-rider, as an appropriation effort of 30 or lower is the cooperative amount of appropriation in the resource. Secondly, the grid is divided on a slope threshold τ_s^β where β connotes the slope. The β threshold entails that if the player has a slope above 0, they are considered conditional cooperators.[9] These two thresholds divide the grid into four quarters, of which the top two quarters are free-riders - who almost always invest more than the cooperative

[9] A slope below 0 would also be conditional, however conditional cooperators are defined as players that cooperate when others do so too, and whenever others over-exploit the resource, they do so too. Hence, the slope sign must be positive to fit this type.

amount in appropriation - and the bottom-right quarter are conditional cooperators - who invest cooperatively when others in their group do so as well. The bottom-left quarter includes subjects of whom the basic appropriation is below the cooperative amount, and who invest more when others invest less and vice versa. As there is no player type in behavioural theory that describes this kind of behaviour - and there is thus no expectation of having many subjects in this category - we will call the subjects in this group the residual subjects. These three classifications, however, do not cover the unconditional or neutral cooperative player, who invests 30 or close to 30 in each period, regardless of what others do. As all subjects know that 30 is the cooperative amount of appropriation, we can expect a decent percentage of subjects to follow that strategy over the entire game. To classify this player type, some uncertainty is added into the thresholds. A normally distributed simulation sample is created for the intercept and the slope values, with the hard thresholds of $\tau_s^\alpha = 30$ and $\tau_s^\beta = 0$ as means, and standard deviations of respectively $sd_{\tau\alpha} = 2$ and $sd_{\tau\beta} = 0.1$.[10] The actual classification happens by comparing each of the 100 simulated intercepts and slopes for each individual with each simulated threshold for the intercept and slope. This way, subjects get a probability score to be a free-rider, conditional cooperator, or residual subject. Once a subject has a positive probability for *all three* types, the subject is classified as a neutral cooperator - the LCP of these subjects lies around the $\alpha = 30$ and $\beta = 0$ values, and is thus a neutral cooperator. To summarise, Table 4 shows the formal rules for player type classification:

Table 4: LCP type classification rules

Type	**Rule**
Free-riders [FR]	$\mathbb{1}\left(\alpha_s \geq \tau_s^\alpha\right)$
Conditional Cooperators [CC]	$\mathbb{1}\left(\beta_s \geq \tau_s^\beta \;\;\&\;\; \alpha_s < \tau_s^\alpha\right)$
Residual Subjects [RS]	$\mathbb{1}\left(\beta_s < \tau_s^\beta \;\;\&\;\; \alpha_s < \tau_s^\alpha\right)$
Neutral Cooperators [NC]	$\sum_{s=1}^{N_s} \mathbb{1}\left(\alpha_s \geq \tau_s^\alpha\right) > 0 \;\;\&$ $\sum_{s=1}^{N_s} \mathbb{1}\left(\beta_s \geq \tau_s^\beta \;\;\&\;\; \alpha_s < \tau_s^\alpha\right) > 0 \;\;\&$ $\sum_{s=1}^{N_s} \mathbb{1}\left(\beta_s < \tau_s^\beta \;\;\&\;\; \alpha_s < \tau_s^\alpha\right) > 0$

[10]The standard deviations for τ_s^α and τ_s^β were chosen to be 2 and 0.1 so that players who each period invest very close to 30 - albeit with some variation, as that is inevitable with real human players - are selected as neutral cooperators. Smaller standard deviations could result in neutral cooperators being wrongfully classified as other types, whereas larger standard deviations could lead to other type players being wrongfully classified as neutral cooperators as the margin would be too big. The setting of the standard deviations is arbitrary to some degree. However, as can be seen in the following paragraphs, the classification results - despite the added uncertainty in LCP score simulations for subjects and classification threshold simulations - do match type percentages that are often found in the literature which provides confidence in the chosen classification rules.

3.2 Player Types in the Data

The LCP classification rules are visually represented in the division of the grid in Figure 10, which shows a dot chart of LCP scores of subjects for the combined data and per country.[11] The horizontal blue line shows the average threshold for the intercept, and the vertical red line shows the average threshold for the slope. As is visible, the LCP scores are distributed similarly for the UKNL and IND studies. The plot shows that intercept and slope are negatively correlated. This makes sense, as it is not likely for subjects that already have a very uncooperative baseline appropriation (slope) to be positively affected by others in their group. Vice versa, subjects with a lower baseline appropriation are more likely to be conditionally cooperative and thus be affected by what others in their group do.

Figure 10: Plot of intercept and slope of LCP scores

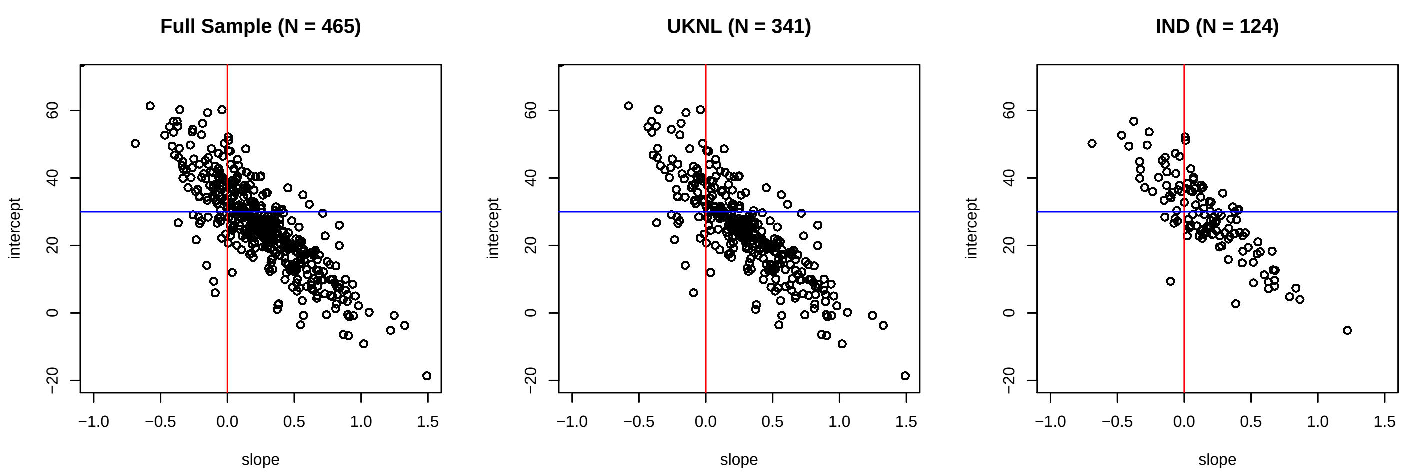
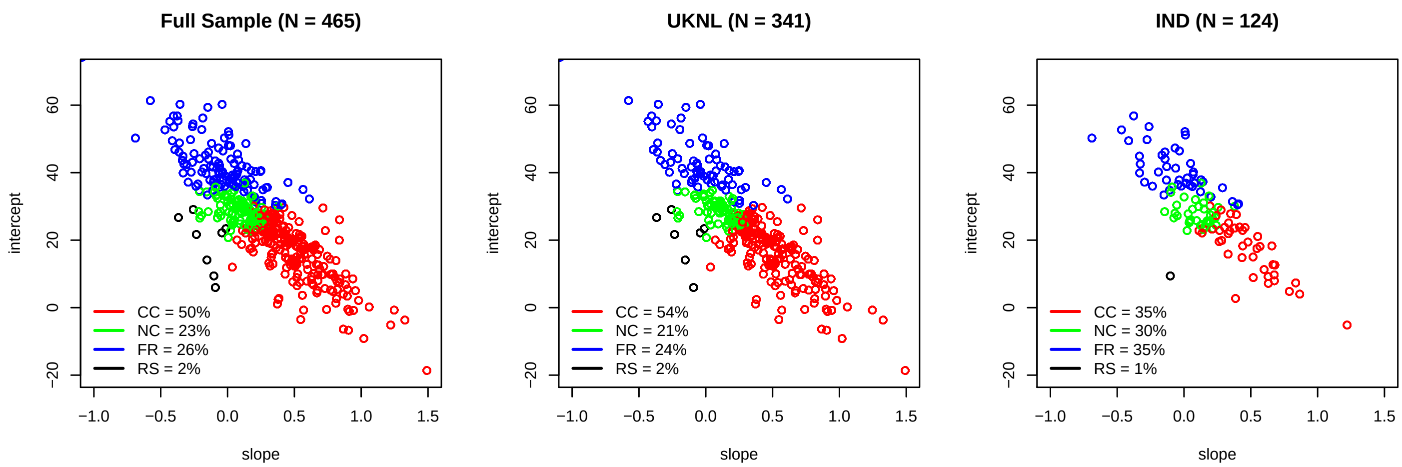


Figure 11 shows the division of subjects over the four defined player types, including the rounded up percentages of each type in the sample, with the conditional cooperators presented in red, the neutral cooperators in green, the free-riders in blue and the residual subjects in black. The percentages of types found in the experimental samples matches the percentages found in other research on cooperatives types such as Fishbacher, Gächter & Fehr (2001) who find 50% conditional cooperators and 30% free-riders, and Kurzban & Houser (2005) who find 63% conditional cooperators - or reciprocators, as they label them -, 13% cooperators and 20% free-riders. Other research also reports generally between 45% and 80% conditional cooperators (see Fischbacher & Gächter, 2006;

[11]Note that the sample size is decreased, as there are some missing observations on the post-experimental survey which includes questions on individual characteristics that were used as control variables in the LCP calculation

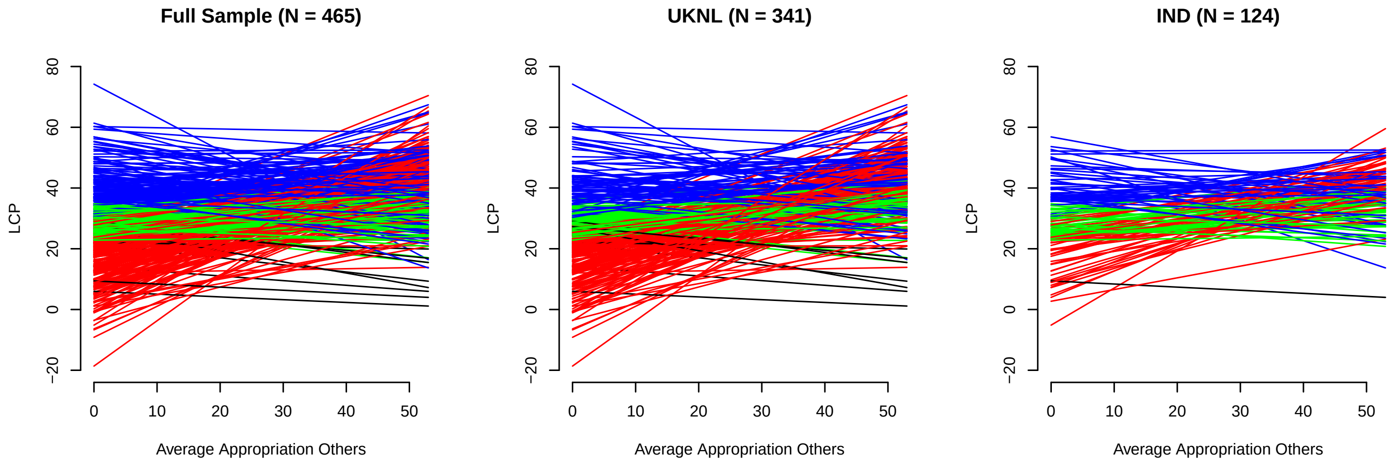
Gächter, 2006; Herrmann & Thöni, 2009; Kocher et al., 2008). The percentage of conditional cooperators in the IND sample is slightly lower than expected with only 35%, as conditional cooperators are usually the largest player-type group. However, as Kocher et al.(2008) show in a comparative study of player types in Austria, the United States and Japan, the distribution of player types and especially the extent of conditional cooperation differ per country. As expected, only very few subjects fall in the residual category.

Figure 11: Plot of intercept and slope of LCP scores - types by colour



To get a more concrete idea of what each subject would *do* given a specific amount of appropriation by the other players according to their LCP score, Figure 12 provides a line graph of subjects' LCP scores over the mean appropriation of other players in the previous period.

Figure 12: LCP (intercept & slope) by average Appropriation of others (t-1) - types by colour



One explanation for the differences in behaviour between treatments in the UKNL and IND studies could be a different division of player types over treatments. Figure 13 and 14 show the division of player types over the four treatments in the UKNL sample and the IND sample respectively.

Figure 13: LCP (intercept & slope) by average Appropriation of others (t-1) by treatment UKNL

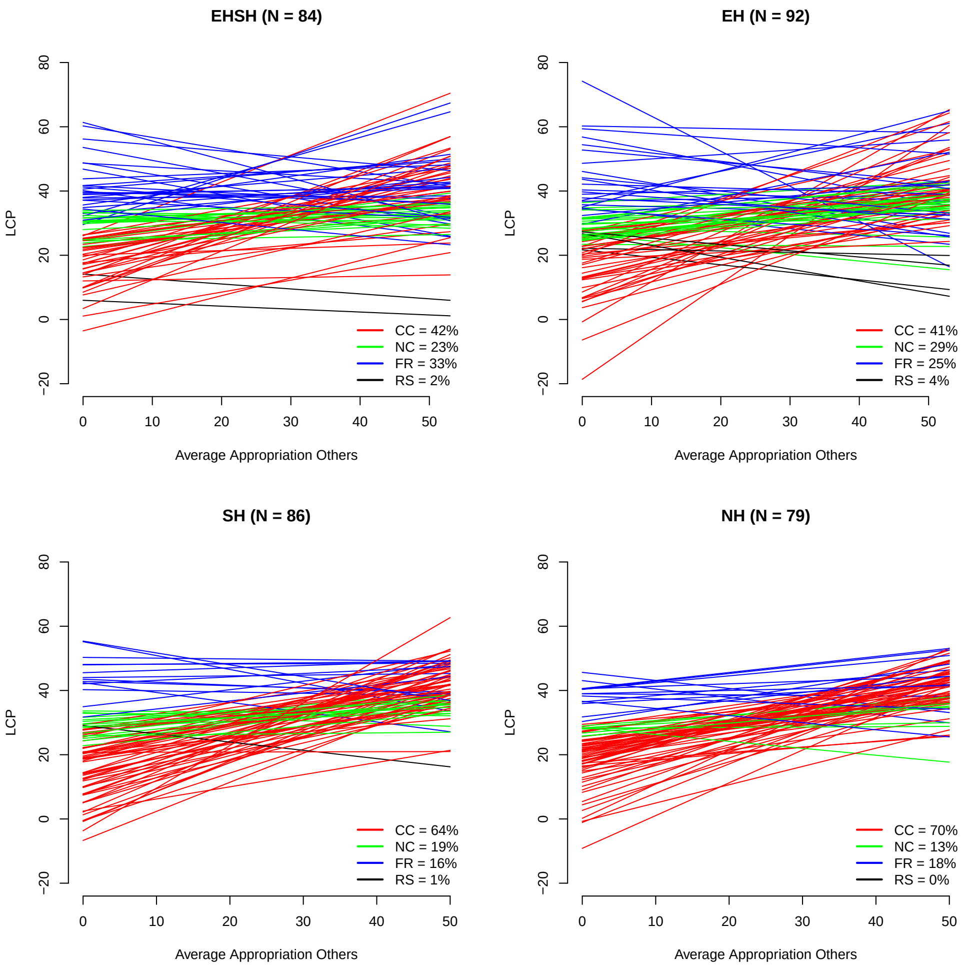


Figure 14: LCP (intercept & slope) by average Appropriation of others (t-1) by treatment IND

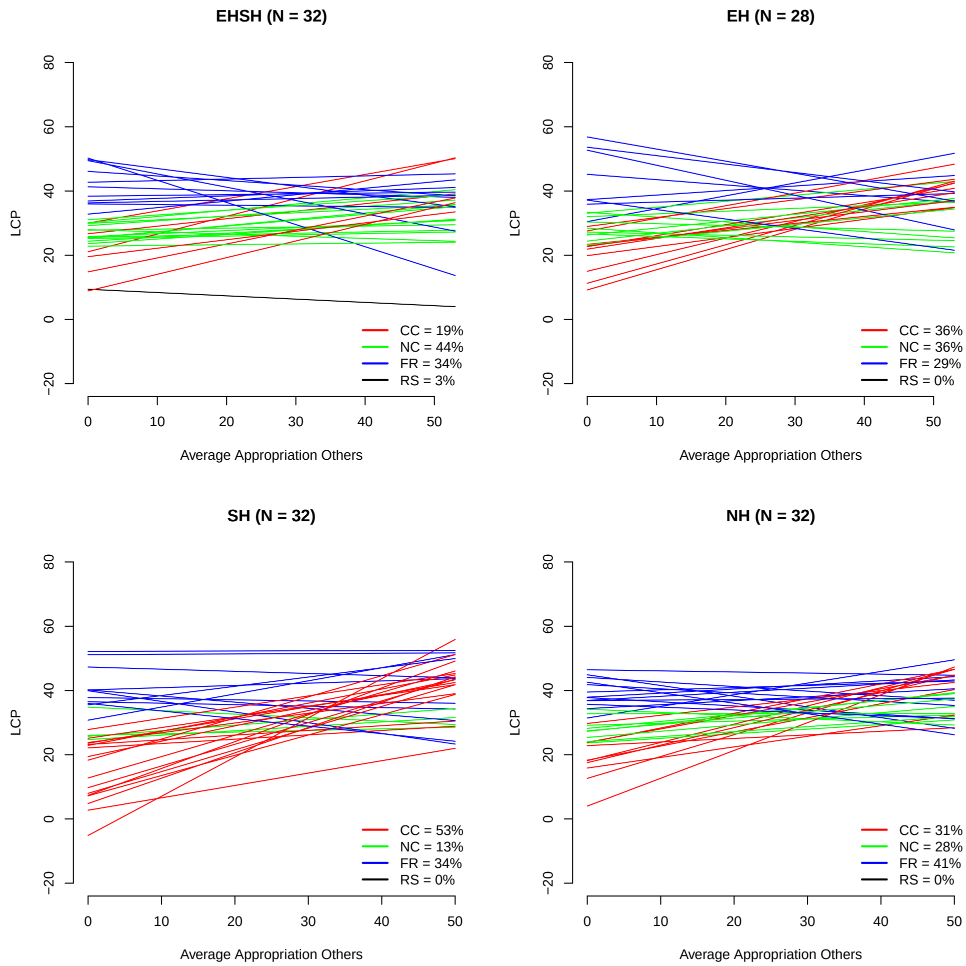


Figure 13 shows that the EHSH treatment in the UKNL study has the highest percentage of free-riders (33%), which is part of the reason that the EHSH treatment performs worst in the long run. The EH treatment has the highest percentage of neutral cooperators, which is part of the reason that the EH treatment did better than the other treatments, despite having a higher percentage of free-riders than the SH and NH treatments: whereas a conditional cooperators would increase their appropriation as a reply to the increased average appropriation of others, neutral cooperators keep investing around the cooperative amount, which keeps the resource size up. Figure 14 shows that the EHSH treatment in the IND study has the highest percentage of neutral cooperators which, as just described, can explain the success of this treatment. The EHSH treatment also has a low percentage (19%) of conditional cooperators compared to all other treatments in the IND and UKNL studies, which means that there is less of a reaction to free-rider behaviour and thus the resource size will stay relatively high.

3.3 Abridgement

Using LCP scores to classify behaviour into types allowed for the translation of complex experimental data to simple player types that are founded in experimental literature. The difference in outcome between the EHSH treatment in the UKNL study and the EHSH treatment in the IND study is representative of a discrepancy in the distribution of player types: whereas most of the EHSH subjects in the UKNL study adopt a conditional cooperation strategy, the EHSH subjects in the IND study adopt a neutral cooperation strategy, which leads to a higher resource size and thus higher levels of cooperation in the latter group. It is thus apparent that heterogeneity affects player type distribution. The next step in our quest to understand cooperative behaviour under heterogeneity is to explore whether simple free-riding, conditional cooperative or neutral cooperative agents in ABM simulation models can replicate the experimental outcomes on the macro- and micro-level. Whereas player type classification translated the average individual outcomes from the regression analyses to a more granular level, ABMs will translate information from the player type classification to a more basic understanding of cooperation by using simple theoretical agents to replicate complex behaviour. The agents are created based on theoretical rules instead of being based on real data such as LCP scores, meaning that if they succeed in replicating experimental outcomes, ABMs can be used for the creation and manipulation of dynamic hypotheses over time for CPR games. Before using the ABMs to match and replicate the experimental data, some predictions using the ABMs are made to see whether the principles regarding player type distribution and cooperative outcomes hold for the artificial version of the Fishing Game.

4 Agent-Based Models

The ABM game that the agents "play" is a direct copy of the Fishing Game as played in both experiments, with the exception that no sociocultural heterogeneity was introduced to the agents.[12] For a schematic overview of the ABM procedure see Appendix F. For the ABMs, simple agents based on the free-rider, conditional cooperator and neutral cooperator are used. In addition, a random agent is added as baseline for comparison. The free-riding agent will never cooperate. In

[12] Agents would not act differently by being placed in groups that only differ by name and do not have rules on how to behave differently from the other group. On top of that, it was not needed for agents to be grouped as the purpose of the ABMs was to fit agents' behaviour to experimental outcomes according to player type distributions found in each treatment, which in itself were already affected by the treatment effects.

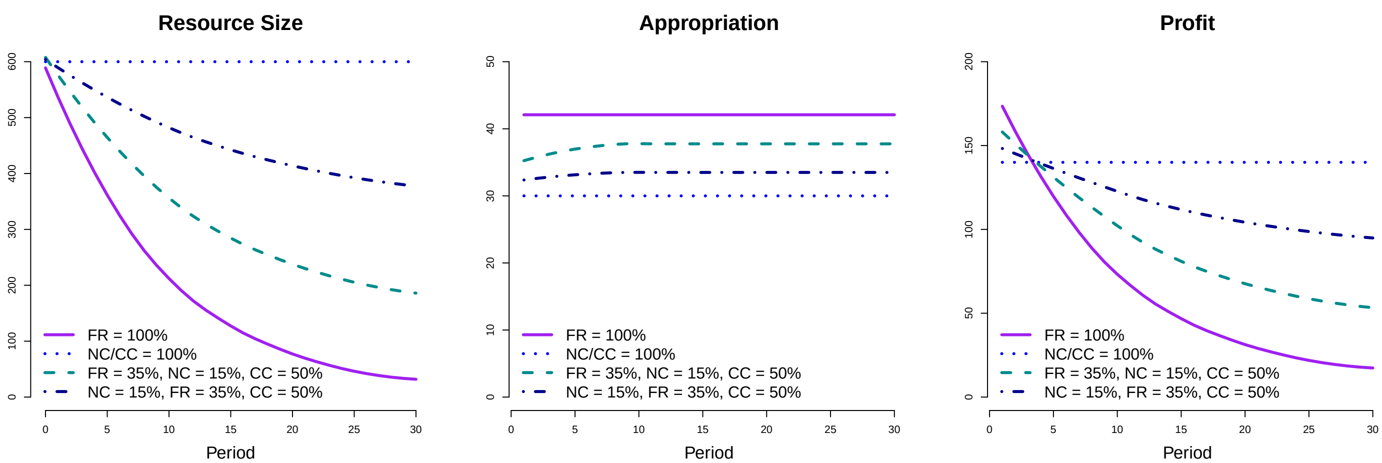
the Fishing Game, this means that the free-riding agent will never appropriate $a = 30$ or close to $a = 30$ and will always invest between $a = 35$ and $a = E$ in appropriation. The free-riding agent appropriates the same amount every period. The cooperative agent will always invest 30 in appropriation, as this is the cooperative amount to invest when the resource size is at its full size, and will never contribute to a decrease in resource size. The conditional cooperative agent will only cooperate if other players cooperate as well (see Fischbacher et al., 2001; Frey & Meier, 2004). Numerous studies, both experimental and in the field, have shown that many people are conditional cooperators: they cooperate when others cooperate as well (Fehr & Fischbacher, 2004; Herrmann & Thöni, 2009; Fischbacher et al., 2001; Chaudhuri & Paichayontvijit, 2006; Ahmed, 2011; Frey & Meier, 2004). In the Fishing Game, conditional cooperators appropriate $a = 30$ in the first period, and will then appropriate as much as the mean appropriation of others in the previous period. Lastly, the random agent is a baseline agent to compare the other agents with, that does not have a specific strategy. Each period, they will invest a random amount of a units in appropriation of the resource, in the range of $[0, E]$.

The ABMs that will be used to fit the data comprise a mixed model with free-riders, conditional cooperators and neutral cooperators - informed by player type distributions found in the experimental data - and single agent models with only one of the agents present. To fit the EH and EHSH data, two agents will be assigned $E = 40$ and two agents will be assigned $E = 60$.

4.1 ABM Player Type Predictions

When assuming the presence of the three cooperative player types as found in the experimental data, two situations can occur that will impact the level of cooperation. In the first situation, we find $FR > NC$, in which there are more free-riders than neutral cooperators. This means that the average individual appropriation will be higher and the level of collective cooperation lower, as conditional cooperators adopt the average appropriation effort from the previous period as their appropriation strategy. In the second situation we find $NC > FR$, in which there are more neutral cooperators than free-riders. The average appropriation effort will be lower and the resource size higher. Figure 15 shows what happens over time to the resource size, average individual appropriation and average individual profit under different hypothetical proportions of free-riders, neutral cooperators, and conditional cooperators. The figure is based on NetLogo (Wilensky, 1999) simulation output using 1000 simulations in the built-in *Behaviourspace* tool. As is visible from the graphs, keeping the percentage of conditional cooperators constant, more free-riders than neutral cooperators will lead to lower resource size, higher average appropriation effort and lower average profit and vice versa. This principle matches the combination of cooperative outcomes and player type percentages as found in the experimental data.

Figure 15: Predicted outcomes under various player type proportions



4.2 Calculating the Fit

How well a model matches the experimental data is measured with a fit score. The fit f of a behavioural model under a certain set of parameters is calculated by taking the difference between values of key variables in the simulated data and the data from the UKNL and IND experiments. 5000 simulation games are run using NetLogo (Wilensky, 1999), with parameters of the mixed model set to match proportions of player types as found by the LCP classifications in the experimental data. The simulated data is then compared to the experimental data to create a fit score. The four metrics that will be measured and compared are (1) resource size, (2) appropriation effort, (3) change in appropriation, and (4) individual profit. Resource size is a macro-level outcome, whereas the other variables are micro-level outcomes. The average value of these variables per period per treatment from the experimental data are compared to the value of these variables in each simulation of the Fishing Game. The fit will be calculated using the following function following Janssen & Baggio (2016):

$$f = \prod_{m=1}^{4} \left(1 - \sqrt{\frac{\sum_{t=1}^{n_{mt}} (s_{mt} - d_{mt})^2}{n_{mt}}} / \max(d_m) \right)$$

where m is the metric, t is the period, d_{mt} is the average observed data and s_{mt} is the average simulated data over the 5000 simulations for n_{mt} observations or periods. The final fit score f is the product of the fit score of the four variables. Taking the product of the fit score per metric, which will be between 0 and 1, ensures a more conservative fit score than taking for instance the sum by enlarging the difference between a good and a bad fit. The calculation of f does not control for the number of parameters. To check the robustness of f while controlling for the number of parameters in the ABM the adjusted R^2 was calculated for each metric, treatment and study and can be found in Appendix G. Regarding the relative fit between the models, the adjusted R^2 gives the same conclusion as f. Although the adjusted R^2 is not the most appropriate way of calculating the fit between so few data points and simulations (as we are only comparing the average outcomes over 30 periods) it does support the rank order of model fit amongst the ABMs.

For the EH and EHSH treatments the fit score f and the adjusted R^2 for micro-level metrics appropriation effort, change in appropriation, and profit are measured and compared separately for high and low endowed players, to make sure the simulations take into account the specific behaviours of subjects with high and low endowments. After calculating the fit score f and the adjusted R^2 for these metrics separately for high ($E = 60$) and low ($E = 40$) endowed players, the average f and adjusted R^2 of high and low endowed players is taken to represent the final score for that particular metric.

4.3 ABM Results

Table 5 shows the fit score f of the mixed and single ABMs for each of the four metrics that describe the macro- and micro-level data. The mixed models exist of free-riders, conditional cooperators and neutral cooperators according to the percentages found in the LCP classification as represented in Figure 13 and 14.[13] The fit scores of the mixed agent model, single agent models, and a model with randomly acting agents are presented. The single agents and random agent models were added to be able to compare the more complex model with simpler baseline models. For all but one treatment - EHSH in the IND study - the fit of the mixed model is higher than the simple models, indicating that the mixed model is more successful in replicating outcomes similar to the experimental data. This is different for the EHSH treatment of the IND study, of which the fit score is higher in the random and the cooperative models.[14] This is not surprising, as the shape

[13]The residual subject category is not represented in the ABMs. The type designation in the ABMs is based on the probability to be a conditional cooperator and the probability to be a free-rider - if the agent is neither they are neutral cooperators. The percentage of residual subjects is thus added to the neutral cooperation category.

[14]The fact that the random model has a relatively high fit for the EHSH treatment in the IND study does not necessarily mean that the EHSH subjects acted randomly. The random agent appropriates on average 30, which is

of the curve describing resource size and appropriation effort over time for this treatment differs from the other treatments in the IND and UKNL studies. Whereas the mixed model does well in predicting most treatments' resource size curves that follow the pattern of a quick decrease in the first 10 periods followed by a flattening of the curve - as we also see in other CPR experiments (For instance in Hey et al., 2009; Janssen et al., 2010) - it does not do well in predicting a resource size curve as visible in the EHSH treatment of the IND study.

Regarding the fit of the mixed model with the macro- and micro-level outcomes, Table 5 shows that overall the macro-level variable resource size is especially well replicated in the mixed model compared to the single agent models. The micro-level variable profit too has a consistently higher fit score in the mixed model compared to the single models. Average appropriation is replicated slightly better in the cooperative model compared to the other models. This makes some sense as the average appropriation level lies around 30 each period, which is easier to replicate with agents who invest exactly 30 - such as in the cooperative agents model - than with agents who invest according to different strategies. The last metric, change in appropriation, has a similar fit in all ABMs. Especially for the EHSH treatment in the IND study, which comprised 44% neutral cooperative players, it makes sense that the cooperative model and the random model (which also has an average appropriation of 30 each period) have a high fit score.

---

the same for the cooperative agent. Both single agent models thus have similar outcomes and a similar fit. However, when looking at the appropriation behaviour, it is visible that the cooperative model has a higher fit for general fitness for player with a low endowment and for the appropriation metric. It thus performs better than the random ABM on important aspects.

Table 5: Fit score f per ABM per treatment

		UKNL EH	SH	EHSH	NH	IND EH	SH	EHSH	NH
Mixed Model*									
	General Fit	0.726	0.707	0.722	0.736	0.699	0.657	0.552	0.675
	General Fit $E = 60$	0.813		0.766		0.769		0.580	
	General Fit $E = 40$	0.643		0.677		0.631		0.522	
	Fit Resource Size	0.949	0.865	0.929	0.905	0.919	0.847	0.746	0.884
	Fit Profit	0.893	0.915	0.945	0.939	0.895	0.901	0.850	0.928
	Fit Appropriation	0.890	0.920	0.870	0.900	0.897	0.890	0.907	0.884
	Fit Change Appropriation	0.963	0.974	0.943	0.964	0.938	0.963	0.964	0.939
Cooperative									
	General Fit	0.391	0.387	0.380	0.376	0.425	0.438	0.684	0.381
	General Fit $E = 60$	0.441		0.394		0.474		0.712	
	General Fit $E = 40$	0.337		0.364		0.373		0.656	
	Fit Resource Size	0.626	0.578	0.599	0.571	0.677	0.624	0.841	0.585
	Fit Profit	0.713	0.757	0.756	0.753	0.740	0.790	0.901	0.766
	Fit Appropriation	0.910	0.910	0.890	0.910	0.906	0.924	0.936	0.906
	Fit Change Appropriation	0.963	0.974	0.943	0.964	0.938	0.963	0.964	0.939
Free-rider									
	General Fit	0.375	0.413	0.384	0.415	0.319	0.365	0.193	0.383
	General Fit $E = 60$	0.379		0.403		0.328		0.205	
	General Fit $E = 40$	0.371		0.365		0.310		0.181	
	Fit Resource Size	0.630	0.671	0.658	0.678	0.574	0.620	0.409	0.656
	Fit Profit	0.781	0.789	0.777	0.794	0.746	0.755	0.626	0.777
	Fit Appropriation	0.790	0.800	0.800	0.800	0.794	0.810	0.780	0.801
	Fit Change Appropriation	0.963	0.974	0.943	0.964	0.938	0.963	0.964	0.939
Random									
	General Fit	0.368	0.392	0.397	0.381	0.401	0.434	0.651	0.382
	General Fit $E = 60$	0.453		0.406		0.484		0.722	
	General Fit $E = 40$	0.290		0.386		0.324		0.581	
	Fit Resource Size	0.640	0.592	0.614	0.585	0.691	0.637	0.855	0.598
	Fit Profit	0.729	0.830	0.843	0.826	0.754	0.858	0.932	0.833
	Fit Appropriation	0.820	0.820	0.810	0.820	0.822	0.826	0.848	0.819
	Fit Change Appropriation	0.964	0.975	0.943	0.964	0.937	0.963	0.964	0.938

* *This model consists of cooperative agents, conditionally cooperative agents and free-riding agents according to the player type proportions found per treatment in the LCP score calculation as apparent from Figure 13 and 14.*

To visualise how well the predictions of the ABMs fit with the actual data, Figure 16 and 17 show the mixed agent model predictions for the development of resource size and appropriation effort - being the two most important cooperation outcomes on the macro- and micro-level respectively - for the UKNL and IND study over the duration of 30 periods, compared to the actual data. The predictions are based on 1000 simulation games that were run using the *Behaviourspace* tool in NetLogo (Wilensky, 1999). Graphs visualising the single agent model predictions versus the data can be found in Appendix H. Graphs visualising the mixed agent model and single agent model predictions versus the data specifically for high and low endowed subjects in the EH and EHSH treatments in the UKNL and IND studies can be found in Appendix I.

Figure 16: UKNL mixed model predictions for Resource Size (top row) and Appropriation Effort (bottom row)

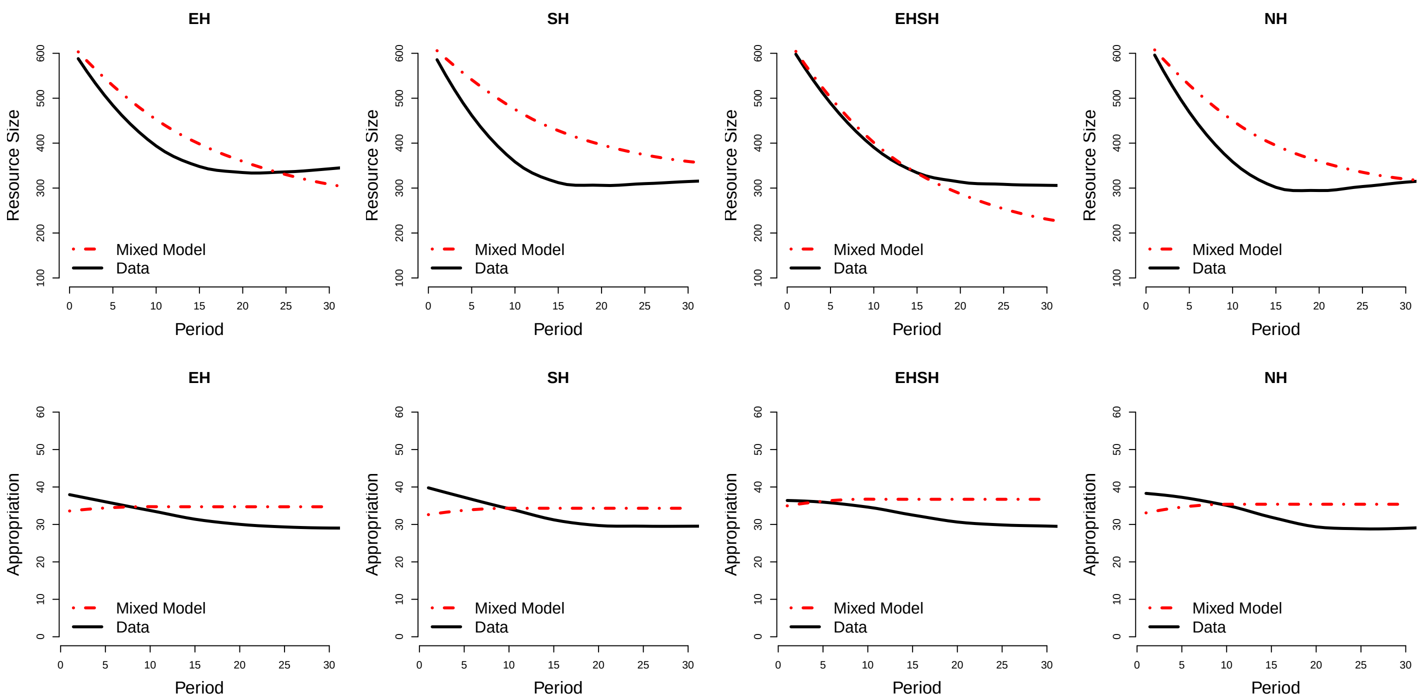
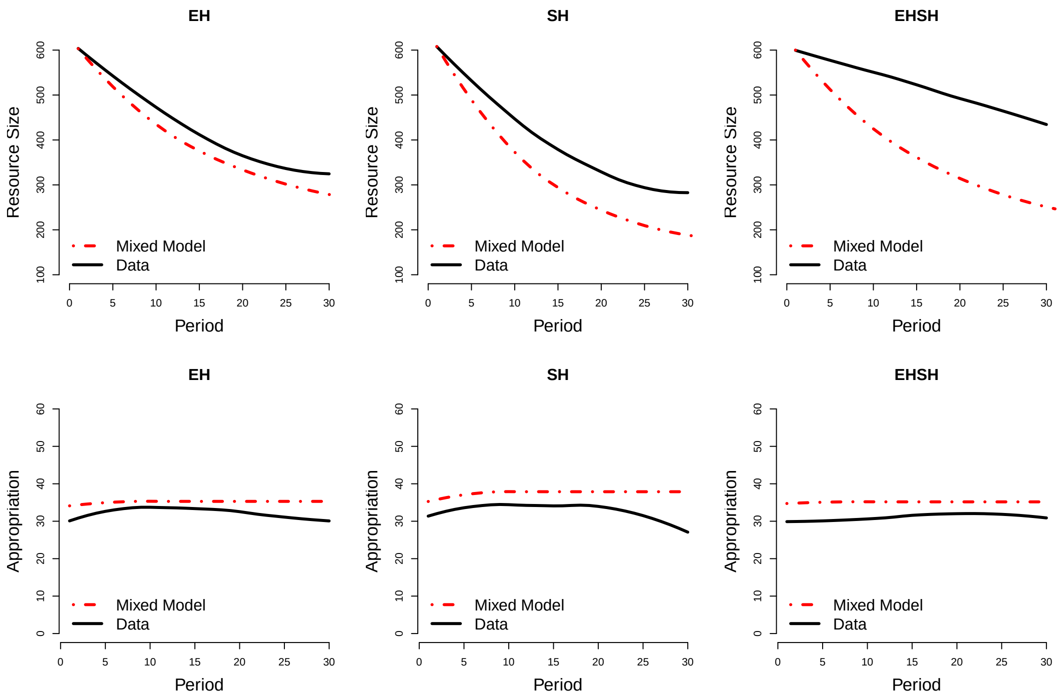


Figure 17: IND mixed model predictions for Resource Size (top row) and Appropriation Effort (bottom row)



The graphs confirm what the fit scores pointed out: the mixed ABM model comes close to replicating the experimental data in terms of resource size and appropriation effort over time in the Fishing Game, with the exception of resource size in the EHSH treatment of the IND study. However, the plots also show a discrepancy between the ABM models and the data, namely the position of the treatments relative to each other in terms of cooperation. This is better visualised in Figure 18 and 19, showing respectively the average simulated resource size and appropriation effort per treatment over time.

Figure 18: Smoothed simulated average Resource Size per treatment per period

(a) UKNL (b) IND

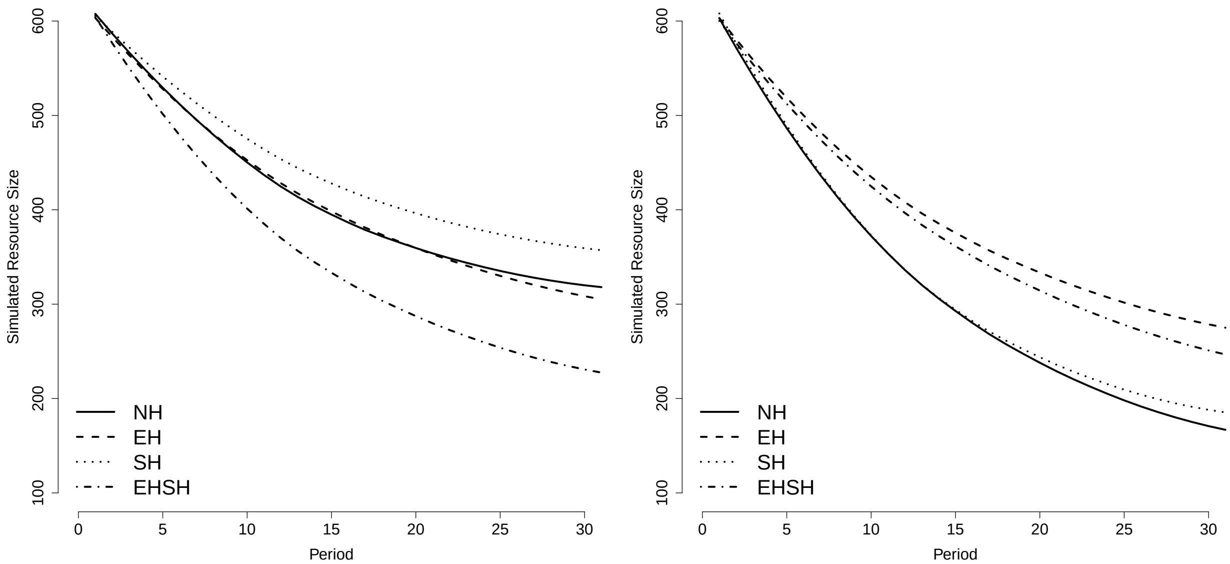
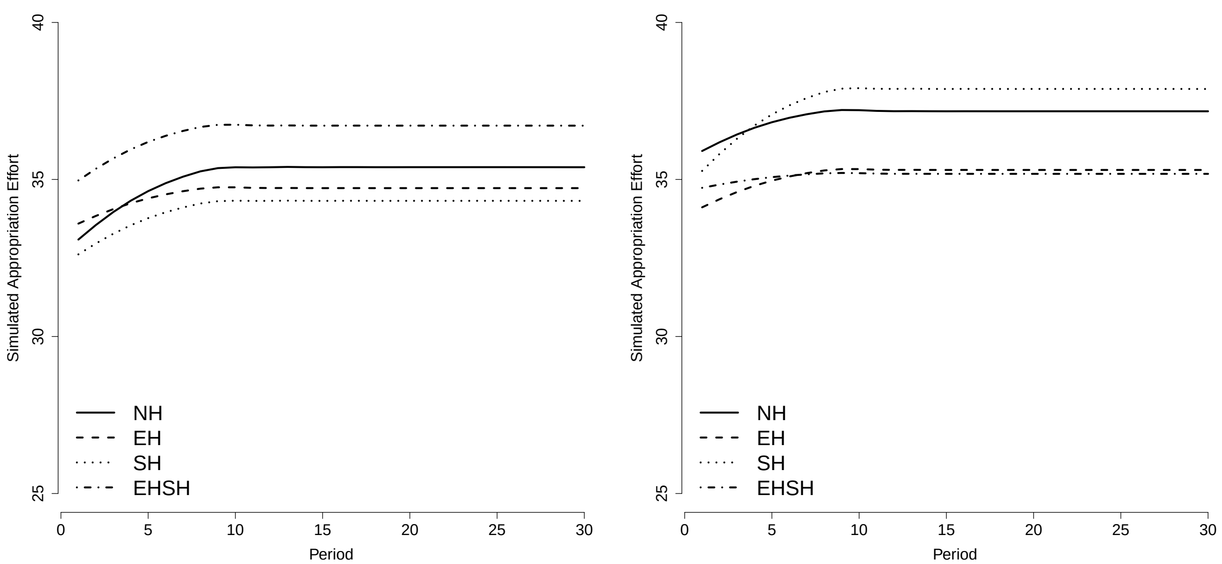


Figure 19: Smoothed simulated average Appropriation Effort per treatment per period

(a) UKNL (b) IND



In the UKNL study data, the order of treatments in terms of cooperation, taking into account resource size and appropriation effort, is roughly EH > SH ≥ NH > EHSH. The simulations, however, present SH > EH ≥ NH > EHSH for both resource size and appropriation. In the IND study, the order of treatments in terms of cooperation is roughly EHSH > EH > SH > NH, whereas the simulations show results more in line with EH ≥ EHSH > SH ≥ NH. One explanation for this discrepancy may be the operationalisation of the conditional cooperation agent. The agent is programmed to cooperate and invest 30 in the first round - hereby affecting the average cooperation of the first period and thus pushing the appropriation of conditional cooperators in the next period towards 30. In real life, conditional cooperators may not be so cooperative in the first period en perhaps react less monotonous in their response to others' appropriation effort. This affects especially treatments with a high percentage of conditional cooperators, such as SH and NH - Table 5 also shows that the fit for resource size is slightly lower for these treatments in the UKNL study and figure 16 and 17 show that the SH and NH treatments are not in the 'right' position in the UKNL graph compared to the data. This discrepancy is smaller in the IND study, where no treatment has over 53% conditional cooperators. As is to be expected after seeing the fit score of EHSH in the IND study, the simulation did not rank this treatment in the right place as it ranks slightly below EH in terms of resource size. When comparing the simulated averages over time with the averages from the data, one can see that the simulations tend to make small differences between the treatments in the data even smaller, whereas bigger differences between treatments in the data tend to be enlarged in the simulations.

Nevertheless, the simulations do capture some important findings. The ABMs correctly simulated the fact that the EHSH treatment performed worst in the UKNL study, and while the EH treatment should have been simulated as best performing, the simulations do show that the EH and SH treatments do not perform worse than the NH treatment. In the real data, the differences between EH, SH and NH in the UKNL study are very small and not necessarily significant, so it is not surprising that the simulations do not replicate these differences correctly. In addition, small differences in the data can be a result of sampling variability, which means that the order of the treatments is not 'set' per se. Thus, the slight difference between the ABMs and the data for these treatments does not mean that the ABMs did not perform well; the ABM predictions are well within a reasonable understanding of the treatment effects. In the IND study, the ABMs simulated correctly that the EHSH and EH treatments performed better than the NH treatment, and that the SH and NH treatment are very close together in terms of resource size performance.

Given that this is - to my knowledge - the first attempt to replicate experimental CPR data with ABMs based on player types, the ABMs do a decent job in replicating the data and should not be disregarded as useful tools for hypothesis building. Whereas the ABMs are not yet good enough to make precise predictions, they do reflect the larger differences between treatments in the data which is helpful in making broad predictions on cooperation in CPRs.

4.4 Abridgement

After successfully translating the average individual behavioural outcomes from the statistical analyses into granular player-level dynamics of cooperative behaviour through LCP scores, ABMs using theoretically founded free-riders, conditional cooperators and neutral cooperators were used to replicate the data using the player type distributions found in each treatment. The ABM simulated resource size and appropriation effort over time broadly resemble the experimental data, capturing significant differences between treatments. The results suggest that simple, theoretical ABMs that are informed by real player type distributions can replicate both micro- and macro-outcomes to some extent, and that ABMs can be used to create hypotheses on cooperation in CPR games under different, hypothetical player type distributions. Theoretically based agents - albeit altered to a specific CPR game - perform well in replicating outcomes of their LCP-based counterparts.

5 Discussion

The goal of this paper is to use innovative tools such as player type classification and agent-based models to understand and explain differences in cooperative behaviour between two laboratory experiments. Data from two similar CPR experiments with different subject pools were analysed and significance of the differences in cooperative outcomes were established using multilevel regression and partially explained using ordinal logistic regression of post-experimental survey data. Subsequently, the behaviours from the experiments were classified and interpreted using linear conditional-contribution profiles and replicated to some extent by agent-based models.

Results regarding heterogeneity and cooperation from the experiments show that sociocultural heterogeneity does not affect cooperation relative to homogeneity, and economic heterogeneity can affect cooperation positively relative to homogeneity. These findings reject the general hypotheses in the literature that heterogeneity affects cooperation negatively, and the latter finding adds to the evidence in favour of an Olson-effect as suggested in Van Klingeren (2020). The effect of the combination of economic and sociocultural heterogeneity is found to be positive or negative relative to homogeneity, depending on the perceived fairness of the situation by the players, which is affected by the operationalisation of sociocultural heterogeneity.

The LCP classification for the complete sample shows a similar player type distribution to other experimental research on the same three player types, validating the LCP scoring approach. The LCP classification per treatment showed that the EHSH treatment in the UKNL study has an almost equal percentage of free-riders as the EHSH treatment in the IND study. What differs is the percentage of conditional and neutral cooperators: the EHSH treatment in the IND study contains 44% neutral cooperators and the EHSH treatment in the UKNL study contains 23% neutral cooperators and 42% conditional cooperators. Due to this difference, the outcome for the EHSH treatment in the IND study in terms of cooperation levels and thus overall success is better than the outcome for the EHSH treatment in the UKNL study. Whereas one could simply assume that worse performing treatments have more free-riders due to heterogeneity, the LCP classification showed that the difference also depends on the level of conditional cooperation versus neutral cooperation. An explanation for this difference may be found in the post-experimental survey data: the survey revealed that subjects in the EHSH treatment of the UKNL study reported significantly lower levels of being treated fairly during the Fishing Game relative to subjects in the NH treatment, and this was not the case in the IND study. It can thus be argued that the combination of economic and sociocultural heterogeneity reduce the level of perceived fairness of the situation, and this perceived fairness affects the type of player someone is going to be. Important here is thus the operationalisation of sociocultural heterogeneity, which in the two experiments was deciding in the level of perceived fairness and thus levels of cooperation.

We may be able to explain the difference in sociocultural heterogeneity effect between the EHSH treatments by thinking of incompatibility between groups rather than sociocultural heterogeneity. Given the finding that perceived fairness in the EHSH treatment in the UKNL study was significantly lower than in the IND session, it is likely that the incompatibility between two groups is more important than just the degree of sociocultural heterogeneity itself: students from two rivalling cities in India may still be very compatible as they share a lot of other cultural traits - especially if they go to the same university together. The artificial nature of the identities from the MGE in the UKNL study may work more polarising, which leads to the percentage of conditional cooperators rather than neutral cooperators to be higher in the UKNL study than the IND study. By imposing and emphasising a fake incompatibility between two groups, even if it was based on a very trivial aspect, a more severe reaction to the outgroup was triggered. The competition between Mumbai and Bangalore for being the 'best city' to live or work did not induce the sense of rivalry between subjects as it was initially expected to. In their experiments on the effect of group identity on social preferences, Chen & Li (2009) show that subjects that are matched with ingroup members act more charitably when they have a higher payoff, and show less signs of envy if they have a lower payoff. Whereas this contributes to the understanding of the success of the EH treatments in both studies, this may also hold for the EHSH treatment in the IND study: a lack of incompatibility may have created a similar or higher level of goodwill amongst participants, perhaps even *because* participants were from different groups. The difference and incompatibility between two cities may be more significant when other sociocultural dimensions differ too, such as ethnic background, country of origin, or even continent of origin. When adding the results from the IND study to the UKNL study, the conclusion of Van Klingeren (2020) becomes more nuanced: not only does it matter whether economic and sociocultural heterogeneity occur at the same time, the level of polarisation and incompatibility between socioculturally heterogeneous groups also influences its impact on cooperative behaviour, by affecting people's perceived fairness of inequality and goodwill.

Results from the analytical approach show that LCP classification is a helpful tool to translate experimental data into player type behaviour and that it helps understand the level of cooperation in more detail. Player type classification is found to serve as a bridge between real behaviour in experiments and simulated behaviour from ABMs. From the ABMs it is visible that experimental outcomes can to a large extent be replicated with mixed models of simple agents. Using the player type distribution of each treatment, a mixed model including free-riders, conditional cooperators and neutral cooperators was able to replicate experimental outcomes over time relatively accurately for most treatments in both experimental studies. Agents that "played" the Fishing Game managed to capture the "signal" of the experimental outcomes, instead of noise. This suggests that ABMs using theoretically formulated agents can be used to generate dynamic hypotheses on the development of cooperation in CPRs and to validate behavioural theories before any experimental data has been gathered yet. Whereas multilevel regression models interpret data as complex behaviour, ABMs show that theoretical agents following simple rules can replicate experimental outcomes to a large extent, making ABMs a useful tool in the experimental researcher's toolbox.

This study was limited by a number of factors. Firstly, the difference in behaviour found between the two studies could be influenced by the country it was conducted in - the IND experiment took place on another continent with a different subject pool which may not have the same exposure to experimental research as the UKNL subjects. In addition, the average age of the subjects in the IND study was 7 years lower than the average age of UKNL subjects - thus in addition to having less experience with experiments, the subjects from the IND study have less experience in life, which may make it harder to directly compare results between the two studies. Moreover, there was less room in the IND study for extra games such as the other-other Dictator Game or the additional ingroup and outgroup Investment Game that were conducted in the UKNL study. Despite the expectation that these group strengthening exercises were not needed for a natural identity, this could have affected subjects' behaviour. However, when comparing each treatment between the two studies, it has become clear that for the EH, SH, and NH treatments the behavioural pattern merely "shifted" on the y-axis. The shape of the resource size curves fit that of other CPR games, and the position of the EH, SH and NH treatment outcomes relative to each other in terms of macro- and micro-level cooperation did not change between the two experiments. This provides some confidence that the change in EHSH behaviour is indeed caused by the different operationalisation of sociocultural heterogeneity, which is an interesting and important result in terms of methodology and the explanation of heterogeneity effects. Secondly, the LCP is calculated based on a linear multilevel regression, even though subjects' behaviour over time can have a quadratic, cubic or sinusoidal pattern depending on amongst others the complexity and duration of the game - as also shown by the interaction terms of treatment effects with period and the quadratic term of period. In addition, the thresholds that divide LCP scores into player types have to be created by the experimental researcher themselves and is highly dependent on the experiment type and subject to some arbitrarity. This makes the classification of LCP scores less generalisable. The same holds for the simple agent types that were used in this paper; agents have a linear rule on what to do each round, and their actions are not influenced by the duration of the game or learning effects, whilst this may be the case in real life. This may be one of the reasons that the mixed agent model did not do well in explaining the EHSH metrics from the IND study. However, working with ABMs will always bring with it the trade-off between simple models and fitting the data; adding more parameters to an ABM will likely increase the fit but the danger is that the models becomes too specific to one particular database or situation and will thus produce less generalisable results. A balance needs to be found to achieve both a good fit and general applicability of the ABM. Even though the mixed model in this paper did not result in a perfect fit with the data, it did manage to replicate experimental outcomes to a decent extent. Whereas both the results from the multilevel regression and the ABM can be used to predict outcomes, the advantage of the ABM is that only minimal information from the data was required in order to recreate a very similar situation - just by calibrating the proportions of agent types with the player types found in the data the mixed model managed to replicate big differences between resource size and appropriation effort over time between the treatments. Of course, for ABMs to be useful in building hypotheses the experimental researcher would need information on the expected player type distribution of the population of interest. By using player type classification on experimental data, this paper adds to the knowledge of player type distributions in CPR experiments. In addition, although the agents in the ABMs were based on theories on how each player type behaves, the agents' behavioural rules had to be tailored to the Fishing Game's specific rules and processes, which creates more work for the experimental researcher and makes the ABMs less versatile to be used directly for other games. Future research can develop the agent-based models to include non-linear behavioural patterns and improved versions of player types, so that ABMs can become more precise in predicting and replicating experimental outcomes.

6 Conclusion

A major hypothesis in social science is that heterogeneity decreases cooperation. The results of this paper do not support this hypothesis and provide a more nuanced understanding of the relation between heterogeneity and cooperation. In addition, this paper concludes three important findings regarding the analytical tools used. Firstly, one can express CPR experiments in terms of three simple player types: free-riders, conditional cooperators and neutral cooperators. Secondly, agent-based models comprising theoretical, simple versions of these player types can replicate experimental outcomes using the player type distribution from the data. Thirdly, in future research agent-based models can be used to generate and manipulate dynamic hypotheses about macro-outcomes of CPR games. The ability of ABMs, together with player-type classification, to 'strip down' a complex mechanism to basic behavioural rules is a valuable asset. Based on the ABM performance it is recommended that experimental researchers in the field of cooperation in CPRs test their hypotheses and theoretical mechanisms through simple but informed ABMs before conducting experiments, which can lead to an increase in quality of the design of experiments and ultimately to a better understanding of cooperative behaviour in CPRs.

References

Adams, J. S. (1965). Inequity In Social Exchange. *Advances in Experimental Social Psychology*, *2*, 267–299. doi: 10.1016/S0065-2601(08)60108-2

Adams, J. S., & Freedman, S. (1976). Equity Theory Revisited: Comments and Annotated Bibliography. *Advances in Experimental Social Psychology*, *9*, 43–90. doi: 10.1016/S0065-2601(08)60058-1

Ahmed, A. (2011). Conditional reciprocity in the investment game. *The Social Science Journal*, *48*(2), 404–408. doi: 10.1016/j.soscij.2010.11.005

Aksoy, O. (2015). Effects of Heterogeneity and Homophily on Cooperation. *Social Psychology Quarterly*, *78*(4), 324–344. doi: 10.1177/0190272515612403

Aksoy, O. (2019). Crosscutting circles in a social dilemma: Effects of social identity and inequality on cooperation. *Social Science Research*, *82*, 148–163. doi: 10.1016/j.ssresearch.2019.04.009

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904.

Alesina, A., & La Ferrara, E. (2002). Who trusts others? *Journal of Public Economics*, *85*(2), 207–234. doi: 10.1016/S0047-2727(01)00084-6

Anderson, C. J., & Paskeviciute, A. (2006). How Ethnic and Linguistic Heterogeneity Influence the Prospects for Civil Society: A Comparative Study of Citizenship Behavior. *The Journal of Politics*, *68*(4), 783–802. doi: 10.1111/j.1468-2508.2006.00470.x

Bahry, D., L., & Wilson, R., K. (2006). Confusion or fairness in the field? Rejections in the ultimatum game under the strategy method. *Journal of Economic Behavior & Organization*, *60*(1), 37–54. doi: 10.1016/j.jebo.2004.07.005

Baland, J.-M., & Platteau, J.-P. (1996). *Halting Degradation of Natural Resources: Is There a Role for Rural Communities?* Rome, Italy: Food and Agriculture Organization of the United Nations, Rome, Italy.

Bardhan, P., & Dayton-Johnson, J. (2002). Unequal irrigators: Heterogeneity and commons management in large-scale multi-variate research. In E. Ostrom, T. Dietz, N. Dolsak, P. C. Stern, S. Stonich, & E. U. Weber (Eds.), *The Drama of the Commons* (pp. 87–112). Washington, D. C.: National Academy Press, Washington, D. C.

Barr, A. (1999). *Familiarity and trust: An experimental investigation* (CSAE Working Paper Series No. 1999-23). Centre for the Study of African Economies, University of Oxford.

Becker, C. D., & Ostrom, E. (1995). Human Ecology and Resource Sustainability: The Importance of Institutional Diversity. *Annual Review of Ecology and Systematics*, *26*, 113–133.

Bellemare, C., & Kroger, S. (2003). On Representative Trust. *SSRN Electronic Journal*. doi: 10.2139/ssrn.425340

Berg, J., Dickhaut, J., & McCabe, K. (1995). Trust, Reciprocity, and Social History. *Games and Economic Behavior*, *10*(1), 122–142. doi: 10.1006/game.1995.1027

Bottom, W. P. (1998). Negotiator Risk: Sources of Uncertainty and the Impact of Reference Points on Negotiated Agreements. *Organizational Behavior and Human Decision Processes*, *76*(2), 89–112. doi: 10.1006/obhd.1998.2800

Bottom, W. P., Holloway, J., Miller, G. J., Mislin, A., & Whitford, A. (2006). Building a Pathway to Cooperation: Negotiation and Social Exchange between Principal and Agent. *Administrative Science Quarterly*, *51*(1), 29–58.

Bouckaert, J., & Dhaene, G. (2004). Inter-ethnic trust and reciprocity: Results of an experiment with small businessmen. *European Journal of Political Economy*, *20*(4), 869–886. doi: 10.1016/j.ejpoleco.2003.08.006

Bowles, S., & Gintis, H. (2002). Social Capital and Community Governance. *The Economic Journal*, *112*(483), F419-F436.

Boyd, R., & Richerson, P. J. (1985). *Culture and the evolutionary process.* Chicago: University of Chicaco Press.

Brandts, J., & Charness, G. (2000). Hot vs. cold: Sequential responses and preference stability in experimental games. *Experimental Economics*, *2*(3), 227–238. doi: 10.1007/BF01669197

Burks, S., Carpenter, J., & Goette, L. (2009). Performance pay and worker cooperation: Evidence from an artefactual field experiment. *Journal of Economic Behavior & Organization*, *70*(3), 458–469. doi: 10.1016/j.jebo.2008.02.012

Burks, S., V., Carpenter, J., P., & Verhoogen, E. (2003). Playing both roles in the trust game. *Journal of Economic Behavior & Organization*, *51*(2), 195–216. doi: 10.1016/S0167-2681(02)00093-8

Chaudhuri, A., & Paichayontvijit, T. (2006). Conditional cooperation and voluntary contributions to a public good. *Economics Bulletin*, 1–14.

Chen, Y., & Li, S. X. (2009). Group Identity and Social Preferences. *The American Economic Review*, *99*(1), 431–457.

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. doi: 10.1016/j.jebo.2003.11.010

Delhey, J., & Newton, K. (2005). Predicting Cross-National Levels of Social Trust: Global Pattern or Nordic Exceptionalism? *European Sociological Review*, *21*(4), 311–327.

Dong, Y., Zhang, B., & Tao, Y. (2016, June). The dynamics of human behavior in the public goods game with institutional incentives. *Scientific Reports*, *6*(1), 28809. doi: 10.1038/srep28809

Ellickson, R. C. (1991). *Order without Law: How Neighbors Settle Disputes.* Harvard University Press.

Evans, A. M., & Revelle, W. (2008). Survey and behavioral measurements of interpersonal trust. *Journal of Research in Personality*, *42*(6), 1585–1593. doi: 10.1016/j.jrp.2008.07.011

Fehr, E., & Fischbacher, U. (2004). Social norms and human cooperation. *Trends in Cognitive Sciences*, *8*(4), 185–190. doi: 10.1016/j.tics.2004.02.007

Fehr, E., Fischbacher, U., von Rosenbladt, B., Schupp, J., & Wagner, G. G. (2003). *A Nation-Wide Laboratory: Examining Trust and Trustworthiness by Integrating Behavioral Experiments into Representative Survey* (SSRN Scholarly Paper No. ID 385120). Rochester, NY: Social Science Research Network.

Fischbacher, U. (2007). Z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178. doi: 10.1007/s10683-006-9159-4

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

Fischbacher, U., & Gächter, S. (2006, March). *Heterogeneous Social Preferences and the Dynamics of Free Riding in Public Goods* (SSRN Scholarly Paper No. ID 874928). Rochester, NY: Social Science Research Network.

Frey, B. S., & Meier, S. (2004). Social Comparisons and Pro-social Behavior: Testing "Conditional Cooperation" in a Field Experiment. *American Economic Review*, *94*(5), 1717–1722. doi: 10.1257/0002828043052187

Gehrig, S., Schlüter, A., & Hammerstein, P. (2019). Sociocultural heterogeneity in a common pool resource dilemma. *PLOS ONE*, *14*(1), e0210561. doi: 10.1371/journal.pone.0210561

Glaeser, E. L., Laibson, D. I., Scheinkman, J. A., & Soutter, C. L. (2000). Measuring Trust. *The Quarterly Journal of Economics*, *115*(3), 811–846. doi: 10.1162/003355300554926

González, L. G., Güth, W., & Levati, M. V. (2005). When does the game end? Public goods experiments with non-definite and non-commonly known time horizons. *Economics Letters*, *88*(2), 221–226. doi: 10.1016/j.econlet.2005.02.010

Gouldner, A. W. (1960). The Norm of Reciprocity: A Preliminary Statement. *American Sociological Review*, *25*(2), 161–178. doi: 10.2307/2092623

Güth, W., Huck, S., & Müller, W. (2001). The Relevance of Equal Splits in Ultimatum Games. *Games and Economic Behavior*, *37*(1), 161–169. doi: 10.1006/game.2000.0829

Gächter, S. (2006). Conditional cooperation: Behavioral regularities from the lab and the field and their policy implications. , 33.

Hardin, G. (1968). The Tragedy of the Commons. *Science*, *162*(3859), 1243–1248.

Herrmann, B., & Thöni, C. (2009). Measuring conditional cooperation: A replication study in Russia. *Experimental Economics*, *12*(1), 87–92. doi: 10.1007/s10683-008-9197-1

Hey, J. D., Neugebauer, T., & Sadrieh, A. (2009). An Experimental Analysis of Optimal Renewable Resource Management: The Fishery. *Environmental and Resource Economics*, *44*(2), 263. doi: 10.1007/s10640-009-9285-5

Hlavac, M. (2018). *Stargazer: Well-Formatted Regression and Summary Statistics Tables. R package version 5.2.2.*

Janssen, M., & Baggio, J. A. (2016). Using agent-based models to compare behavioral theories on experimental data: Application for irrigation games. *Journal of Environmental Psychology*, *46*, 106–115. doi: 10.1016/j.jenvp.2016.04.003

Janssen, M., Holahan, R., Lee, A., & Ostrom, E. (2010). Lab Experiments for the Study of Social-Ecological Systems. *Science*, *328*(5978), 613–617. doi: 10.1126/science.1183532

Johnson, N. D., & Mislin, A. A. (2011). Trust games: A meta-analysis. *Journal of Economic Psychology*, *32*(5), 865–889. doi: 10.1016/j.joep.2011.05.007

Jones, E. C. (2004). Wealth-Based Trust and the Development of Collective Action. *World Development*, *32*(4), 691–711. doi: 10.1016/j.worlddev.2003.10.009

Kahn, K. (2019). *Crime and equality, or crime and punishment?* (Ph.D.). University of Oxford.

Knack, S., & Keefer, P. (1997). Does Social Capital Have an Economic Payoff? A Cross-Country Investigation. *The Quarterly Journal of Economics*, *112*(4), 1251–1288.

Kocher, M. G., Cherry, T., Kroll, S., Netzer, R. J., & Sutter, M. (2008, December). Conditional cooperation on three continents. *Economics Letters*, *101*(3), 175–178. doi: 10.1016/j.econlet.2008.07.015

Kurzban, R., & Houser, D. (2005). Experiments investigating cooperative types in humans: A complement to evolutionary theory and simulations. *Proceedings of the National Academy of Sciences*, *102*(5), 1803–1807. doi: 10.1073/pnas.0408759102

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1997). Trust in Large Organizations. *The American Economic Review*, *87*(2), 333–338.

Ledyard, J. O. (1993). *Public Goods: A Survey of Experimental Research.* Division of the Humanities and Social Sciences, California Institute of Technology.

Levati, M. V., Sutter, M., & van der Heijden, E. (2007). Leading by Example in a Public Goods Experiment with Heterogeneity and Incomplete Information. *Journal of Conflict Resolution*, *51*(5), 793–818. doi: 10.1177/0022002707302796

Masella, P., Meier, S., & Zahn, P. (2014). Incentives and group identity. *Games and Economic Behavior*, *86*, 12–25. doi: 10.1016/j.geb.2014.02.013

Nettle, D., & Dunbar, R. I. M. (1997). Social Markers and the Evolution of Reciprocal Exchange. *Current Anthropology*, *38*(1), 93–99.

Olson, M. (1965). *The logic of collective action: Pubic goods and the theory of groups.* Cambridge, MA: Harvard University Press, Cambridge, MA.

Ostrom, E., Walker, J., & Gardner, R. (1992). Rules, Games and Common-Pool Resources. *The American Political Science Review*, *86*(2), 404–417. doi: 10.2307/1964229

Portes, A., & Landolt, P. (2000). Social Capital: Promise and Pitfalls of its Role in Development. *Journal of Latin American Studies*, *32*(2), 529–547.

Putnam, R. D. (2000). *Bowling alone: The collapse and revival of American community.* New York: Simon & Schuster, New York.

Putnam, R. D. (2007). E Pluribus Unum: Diversity and Community in the Twenty-first Century The 2006 Johan Skytte Prize Lecture. *Scandinavian Political Studies*, *30*(2), 137–174. doi: 10.1111/j.1467-9477.2007.00176.x

Roth, A. E. (1995). Bargaining experiments. In J. H. Kagel & A. E. Roth (Eds.), *Handbook of Experimental Economics* (pp. 253–348). Princeton, NJ: Princeton University Press.

Ruttan, L. M. (2006). Sociocultural Heterogeneity and the Commons. *Current Anthropology*, *47*(5), 843–853. doi: 10.1086/507185

Sanfey, A. G., Rilling, J. K., Aronson, J. A., Nystrom, L. E., & Cohen, J. D. (2003). The Neural Basis of Economic Decision-Making in the Ultimatum Game. *Science*, *300*(5626), 1755–1758.

Seabright, P. (1993). Managing Local Commons: Theoretical Issues in Incentive Design. *Journal of Economic Perspectives*, *7*(4), 113–134. doi: 10.1257/jep.7.4.113

Shanmugaratnam, N. (1996). Nationalisation, Privatisation and the dilemmas of common property management in Western Rajasthan. *The Journal of Development Studies*, *33*(2), 163–187. doi: 10.1080/00220389608422461

Singleton, S. (2001). How distributional conflicts shape co-management institutions and collaborative environmental policy in the United States. In *"Economic Inequality, Collective Action and Environmental Sustainability" workshop.* Santa Fe Institute.

Tajfel, H. (1970). Experiments in Intergroup Discrimination. *Scientific American*, *223*(5), 96–103.

Tajfel, H., Billig, M. G., Bundy, R. P., & Flament, C. (1971). Social categorization and intergroup behaviour. *European Journal of Social Psychology*, *1*(2), 149–178. doi: 10.1002/ejsp.2420010202

Van Klingeren, F. (2020). Playing nice in the sandbox: On the role of heterogeneity, trust and cooperation in common-pool resources. *PloS One*, *15*(8), e0237870. doi: 10.1371/journal.pone.0237870

Van Klingeren, F., & De Graaf, N. D. (2020). Heterogeneity, trust and common-pool resource management. *Journal of Environmental Studies and Sciences*. Retrieved 2020-11-26, from `https://link.springer.com/epdf/10.1007/s13412-020-00640-7` doi: 10.1007/s13412-020-00640-7

Varughese, G., & Ostrom, E. (2001). The Contested Role of Heterogeneity in Collective Action: Some Evidence from Community Forestry in Nepal. *World Development*, *29*(5), 747–765.

Wilensky, U. (1999). *NetLogo.* Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wood, S. N. (2006). Low-Rank Scale-Invariant Tensor Product Smooths for Generalized Additive Mixed Models. *Biometrics*, *62*(4), 1025–1036. doi: 10.1111/j.1541-0420.2006.00574.x

Wood, S. N. (2017). *Generalized additive models: An introduction with R* (Second edition ed.). Boca Raton: CRC Press/Taylor & Francis Group.

Yamagishi, T., & Kiyonari, T. (2000). The Group as the Container of Generalized Reciprocity. *Social Psychology Quarterly*, *63*(2), 116–132. doi: 10.2307/2695887

You, J.-s. (2012). Social Trust: Fairness Matters More Than Homogeneity: Social Trust: Fairness Matters. *Political Psychology*, *33*(5), 701–721. doi: 10.1111/j.1467-9221.2012.00893.x

Zak, P. J., & Knack, S. (2001). Trust and Growth. *The Economic Journal*, *111*(470), 295–321.

Zhang, B., An, X., & Dong, Y. (2021). Conditional cooperator enhances institutional punishment in public goods game. *Applied Mathematics and Computation*, *390*, 125600. doi:

10.1016/j.amc.2020.125600

Appendix A

A description of each stage of the Fishing Game. This description is a shorter version of game description found in Van Klingeren (2020).

Appropriation of the resource

At the beginning of each period t, the appropriators all receive an endowment E of units to invest in appropriation of the resource, R. Since appropriation of the CPR is a costly activity - e.g. it takes time and requires maintenance of the boat and fishing nets - the appropriation effort $a(0 \leq a \leq E)$ represents the amount of effort an appropriator can invest in appropriation of the CPR.

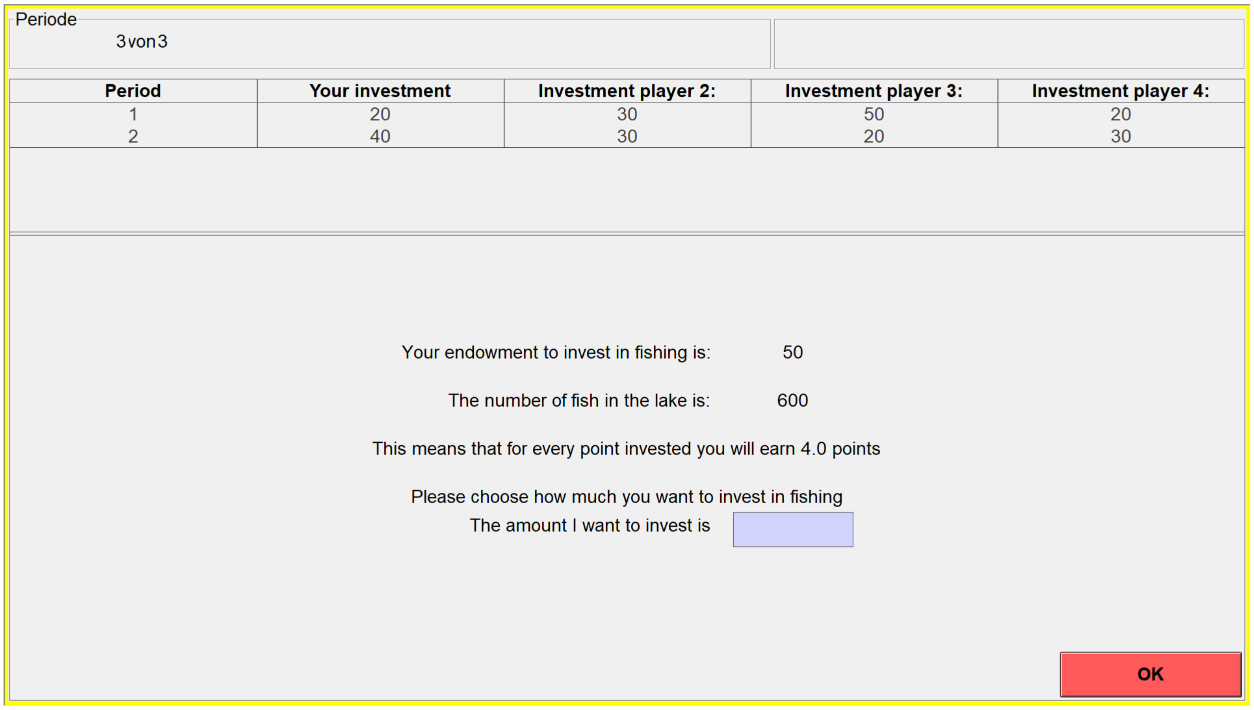
The actors can choose how much they want to invest in appropriation of the resource each period. All appropriators will make their appropriation choice at the same time, without knowing what the other appropriators will do that period. They see how many fish there are in the lake and how many fish they receive per invested unit a. The appropriators all receive the same return $(\frac{4}{R_0}R_{t-1})$ per appropriation effort unit of a. The utility function for the appropriators per period is as follows:

$$U_{it} = (\frac{4}{R_0}R_{t-1})a_{it} + (E_i - a_{it})$$

U_{it} is the total utility of an appropriator i at timepoint t. In the utility function, a_{it} is the invested appropriation effort of appropriator i at timepoint t, and E_i is the endowment of appropriator i. R_0 is the original resource size of the CPR (i.e. the maximum number of fish in the lake) for which we take $R_0 = 600$. R_{t-1} is the resource size at time $t-1$. The profit per invested appropriation effort unit of a is thus dependent on the current size of the resource, relative to its original size. If $R_{t-1} = R_0$, which is the case at the first stage of the game, the return is $4-1=3$ units per invested unit of a. When $R_{t-1} < R_0$, the return will be lower than 3 units. The amount of appropriators' endowment not used for fishing is reflected by $(E_i - a_{it})$.

At the end of the period, the players see how much they invested themselves, how much profit that yielded them, and how much was invested in appropriation of the resource in total as a group. See figure 1 for a screenshot of the appropriation stage of the experiment.

Figure 20: Appropriation stage Fishing Game



Resource renewal

Just like real natural resources, the resource in the game has a renewal rate. The renewal rate per period is modelled as follows:

$$R_t = min(600, 1.25\left(R_{t-1} - (\frac{R_{t-1}}{R_0})\sum_{i=1}^{4} a_{it}\right))$$

Here, 1.25 is the renewal rate of the resource and $R\ t$ is the resource size at timepoint t. The amount of fish in the lake is thus multiplied by 1.25 after each period. The maximum resource size is $R_t\ = 600$; the resource cannot grow beyond this size - this is the maximum amount of fish in the lake. The sum of appropriation efforts of all four appropriators is indicated by $\sum_{t=1}^{4} a_{it}$).

Overexploitation

The CPR is overexploited - that is, the pool of fish in the lake is smaller than in the previous period - when $R_t\ < R_{t-1}$, so when the resource size in timepoint t is smaller than in the previous timepoint. This happens if $\sum_{t=1}^{4} a_{it}) > 120$, because this is the limit of sustainable appropriation, based on $R_0 - \frac{R_0}{1.25}$. The CPR is thus overexploited when the four appropriators have invested on average 30 units in appropriation effort per person.[15] Investing stops being profitable if ($R_t = \frac{R_0}{4}$), so if the resource size decreased to 25 per cent of the original resource size ($R_t = 150$), because:

$$U_{it} = (\frac{4}{600}150)a_{it} + (E_i - a_{it}) = E_i$$

When this happens, any amount the appropriator invests in appropriation of the resource will result in a return of exactly that amount, and the profit consisting of the return + the leftover endowment will thus result in $U_{it} = 50$. For example, if the appropriator invests 50 the return will be $50 + 0 = 50$, if the appropriator invests 10 the return will be $10 + 40 = 50$ etc. When the resource size drops below 25 per cent of the original size, appropriators make loss by investing in appropriation. Only when the size of the resource increases again, the multiplication of the invested unit of a will increase and fishing becomes relatively more profitable.

[15] $600 - \frac{600}{1.25} = 120$

Appendix B

This appendix comprising the explanation and details of the Investment Game used in the experiments is a copy of the one found in Van Klingeren (2020, pp. 5-7) with exception of the figures showing the experimental game screens.

The Investment Game

The game that is used to measure trust before the main experiment is a variation of an investment game, as designed by Berg, Dickhaut and McCabe (1995). The Investment Game, also called the Trust Game, is the most frequently used game to study trust (Evans & Revelle, 2008). Importantly, subjects will play this game before they are asked about their background (whether they are from Mumbai or Bangalore), so their attention is not drawn yet to the group division. Subjects know, however, that only Bangaloreans and Mumbaikars are invited to the experimental sessions.

The game is played as follows. Both players are given an endowment of 10 points. Both players are given the choice of sending points to another player, ranging from 0 to 10 points, after which that amount will be tripled before it reaches the other player. Next, both players are put in the shoes of the receiving player; they are asked how many of the points received by the other player they would send back, for every possible amount of points received, ranging from 0 to 30 points.[16]This is called the strategy method, which provides the advantage of allowing me to see the percentage of points to return that is perceived as fair by subjects (Bahry & Wilson, 2006).The subjects will then randomly receive the role for which they will receive their payoff and be matched to another player with the other role for their final payoff. The utility functions for the players are as follows: For player 1, the sender/trustor, the general utility payoff function is:

$$U_i = E_i - S_{ij} + R_{ji}$$

Where E_i is the initial endowment of sender i, S_{ij} is the amount of points sent from the sender i to the receiver j, and R_{ji} is the amount of points returned from the receiver to the sender. For player 2, the receiver/trustee, the general utility function is:

$$U_j = E_j + 3 \times S_{ij} - R_{ji}$$

[16] 30 points would be the maximum amount to be received by player 2, since the maximum amount of points that player 2 can send is 10, and $3x10 = 30$.

Where again E_j is the initial endowment of received j, S_{ij} is the amount of points sent from the sender i to the receiver j but this time multiplied by 3 by the experimenter, and R_{ji} is the returned amount from the receiver to the sender. In the currect game, $E = 10$ for both players. The two variables, operationalised following Johnson and Mislin (2011) will be measured as follows:

$$Trust = \frac{number\ of\ points\ sent\ by\ i}{endowment\ of\ i} = \frac{S_{ij}}{E_i}$$

$$Trustworthiness = \frac{number\ of\ points\ returned\ to\ i\ by\ j}{number\ of\ points\ available\ to\ return\ to\ i\ by\ j} = \frac{R_{ji}}{E_j + 3 \times S_{ij}}$$

The two figures below show what the decision looks like for subjects playing the Investment Game in the experiment.

Figure 21: Decision screen IG as player 1

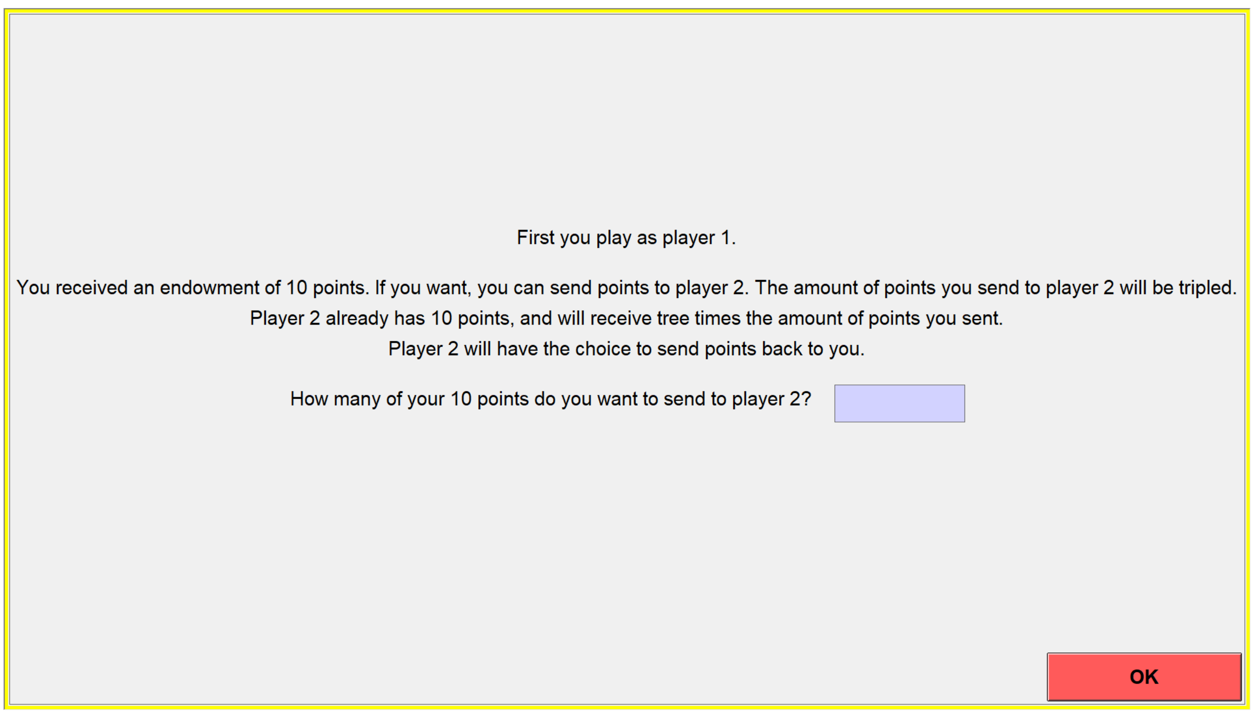
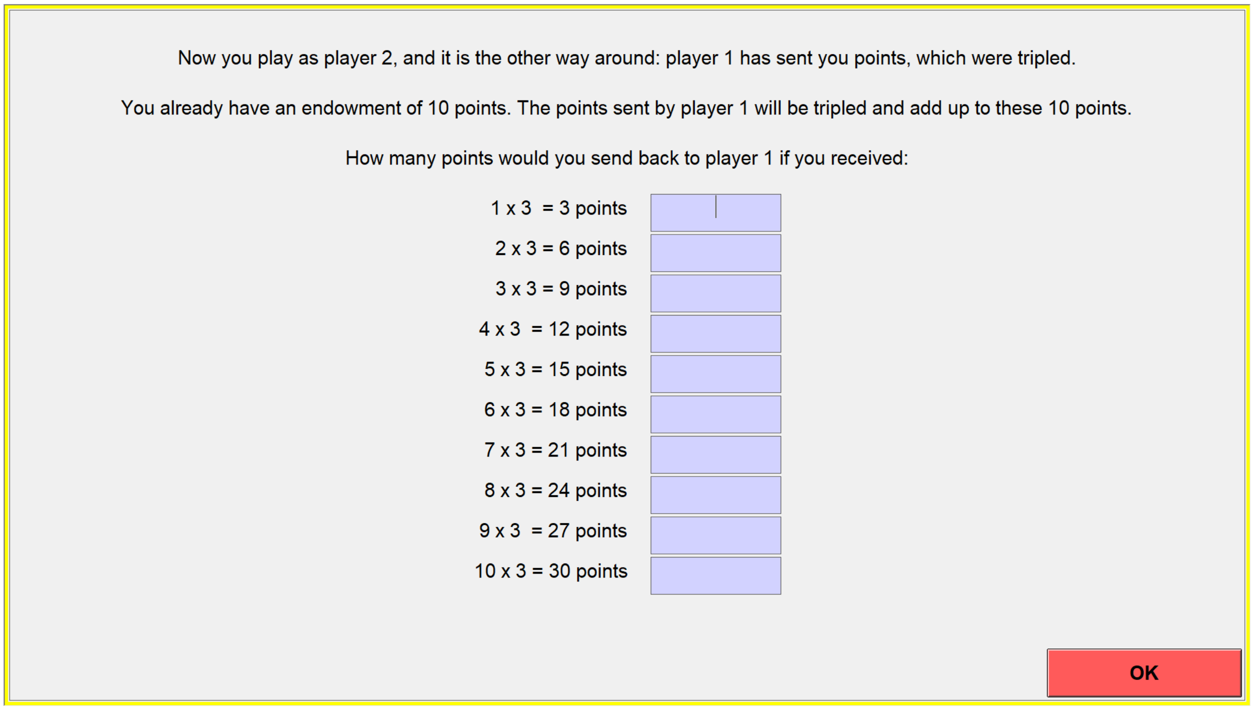


Figure 22: Decision screen IG as player 2



Characteristics of the Investment Game

There are many variations on the Investment Game. In this version of the game, choices were made with regard to the following characteristics.

(1) Players will play the role of sender as well as the role of receiver once. Burks, Carpenter and Verhoogen (2003) found that letting the players play both roles takes away a feeling of guilt that subjects in the sending role would otherwise experience towards the receivers, since the payoff would rely on only one interaction However, they also find that playing both roles reduces mutual trust and reciprocity. In this experiment, players play both roles but will be paid for only one. However, since subjects do not know for which interaction they will receive their payment, I expect the players' behaviour to be uninfluenced by feelings of guilt. An advantage of letting subjects play both roles is that more data on trusting and trustworthiness can be gathered, and different types of players - such as altruists, egoists and conditional co-operators - can be identified (see also S. Burks, Carpenter, & Goette, 2009).

(2) Real players are used instead of computerised counterparts. If subjects suspect or know that their counterpart in an interaction is computerised, they will behave differently in the sense

that they will send less money to the receiver (Bottom, Holloway, Miller, Mislin, & Whitford, 2006; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). The meta-analysis of Johnson and Mislin (2011), comprising 162 replications of the Investment Game, shows that playing against a real counterpart has a positive effect on trusting behaviour e.g. playing with a real person will yield higher amounts of points sent by the sender.

(3) A form of random payment is introduced, as stated earlier, in the sense that all subjects will be paid for one out of in total two interactions; they will be paid either for the sending or the receiving role. Random payment is in general suggested to yield more risk-averse behaviour from subjects, resulting in lower amount of points sent by the sender (Bottom, 1998). The meta-analysis of Johnson and Mislin (2011) points out that there is indeed a negative effect of random payment on trust. However, this random payment is defined as only a subset of subjects receiving payment, while in the current experiment all subjects will be paid; the randomness lies in which role interaction will be paid. Based on the latter, subjects are not expected to be influenced by random payment.

(4) The strategy method is used, meaning that all subjects in the receiving role interaction have to indicate how much they would return to the sender for every possible amount of points received (Bahry & Wilson, 2006). Some research suggests that providing this choice to subjects may alter their perception of the game (Güth, Huck, & Müller, 2001; Roth, 1995). The research, on the other hand, suggests that the strategy method has no influence of subjects' behaviour (Brandts & Charness, 2000). The meta-data analysis of Johnson and Mislin (Johnson & Mislin, 2011) found no significant effects of this method on trust or trustworthiness.

(5) Subjects in the receiving roles will receive an endowment. This will cancel out the possible effect that inequity may have on subjects. If only the sender starts with an endowment, this may cause the sender to send money to the receiver out of a feeling of injustice or guilt instead of trust (Adams, 1965; Adams & Freedman, 1976). If both players start with the same endowment, the act of sending money to the receiver can still increase the payoff for both players, and sending money while the other player has money already will be a more defined act of trust in the other player. The meta-analysis of Johnson and Mislin (2011) shows no persistent negative effect of receiver endowment (only one out of three models on trust shows a significant negative effects of receiver endowment).

(6) We will use anonymity amongst subjects. Subjects will not see each other's decisions, not do they know with whom they are matched for the payoff interaction. This will prevent reputation

(Kreps, 1990) and/or reciprocity of kind acts (Gouldner, 1960) from having an effect on trust and trustworthiness, enabling us to measure trust and trustworthiness without the shadow of the future nor from the past. The meta-analysis of Johnson and Mislin (2011) shows weak support of the suggestion that anonymity has a negative effect on trust.

Despite the game theoretic prediction that the investor will not behave trusting and will thus not send money to the trustee, empirical results show that subjects playing the Investment Game do show trusting behaviour (Berg et al., 1995). Sending money to the trustee is found to be positively correlated with amongst others a reduced social distance between trustor and trustee (Glaeser, Laibson, Scheinkman, & Soutter, 2000). It is shown that students are less trusting and less giving than adults (Johnson & Mislin, 2011) even though the general suggestion is that adults show less trusting behaviour (Bellemare & Kroger, 2003; Fehr, Fischbacher, von Rosenbladt, Schupp, & Wagner, 2003). This makes our subjects pool of only students a good one.

Appendix C

This table is a copy of the one found in the supporting information S4 of Van Klingeren (2020).

Table 6: Other-Other Dictator Game scenario 1 (A1, B1), 2 (A2, B2) and 3 (A3, B3)

	Option given for:					
	Klees & Kandinskys		Klees		Kandinskys	
	A1		B1		B1	
Scenario 1	Klee	Kandinsky	Klee	Kandinsky	Klee	Kandinsky
	330	330	345	355	355	345
	A2		B2		B2	
Scenario 2	Klee	Kandinsky	Klee	Kandinsky	Klee	Kandinsky
	420	420	440	445	445	440
	A3		B3		B3	
Scenario 3	Klee	Kandinsky	Klee	Kandinsky	Klee	Kandinsky
	320	320	300	280	280	300

Appendix D

Predictions of multilevel regression models [ML] including up to a second order polynomial of 'period' versus predictions from a Generalised Additive Models [GAM] with splines.

Figure 23: ML vs GAM with splines for Resource Size UKNL (Van Klingeren, 2020, S4)

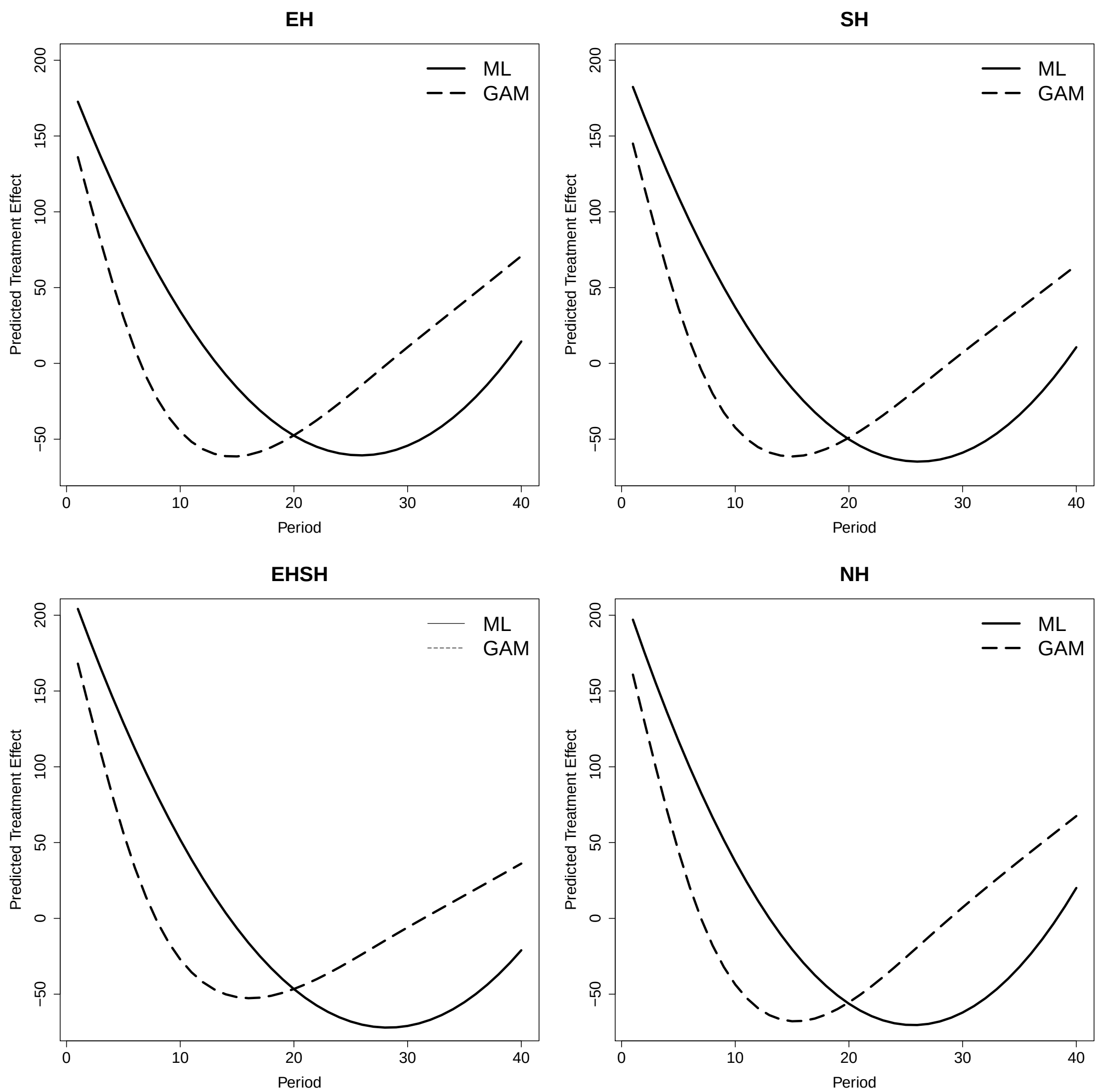


Figure 24: ML vs GAM with splines for Appropriation Effort UKNL (Van Klingeren, 2020, S5)

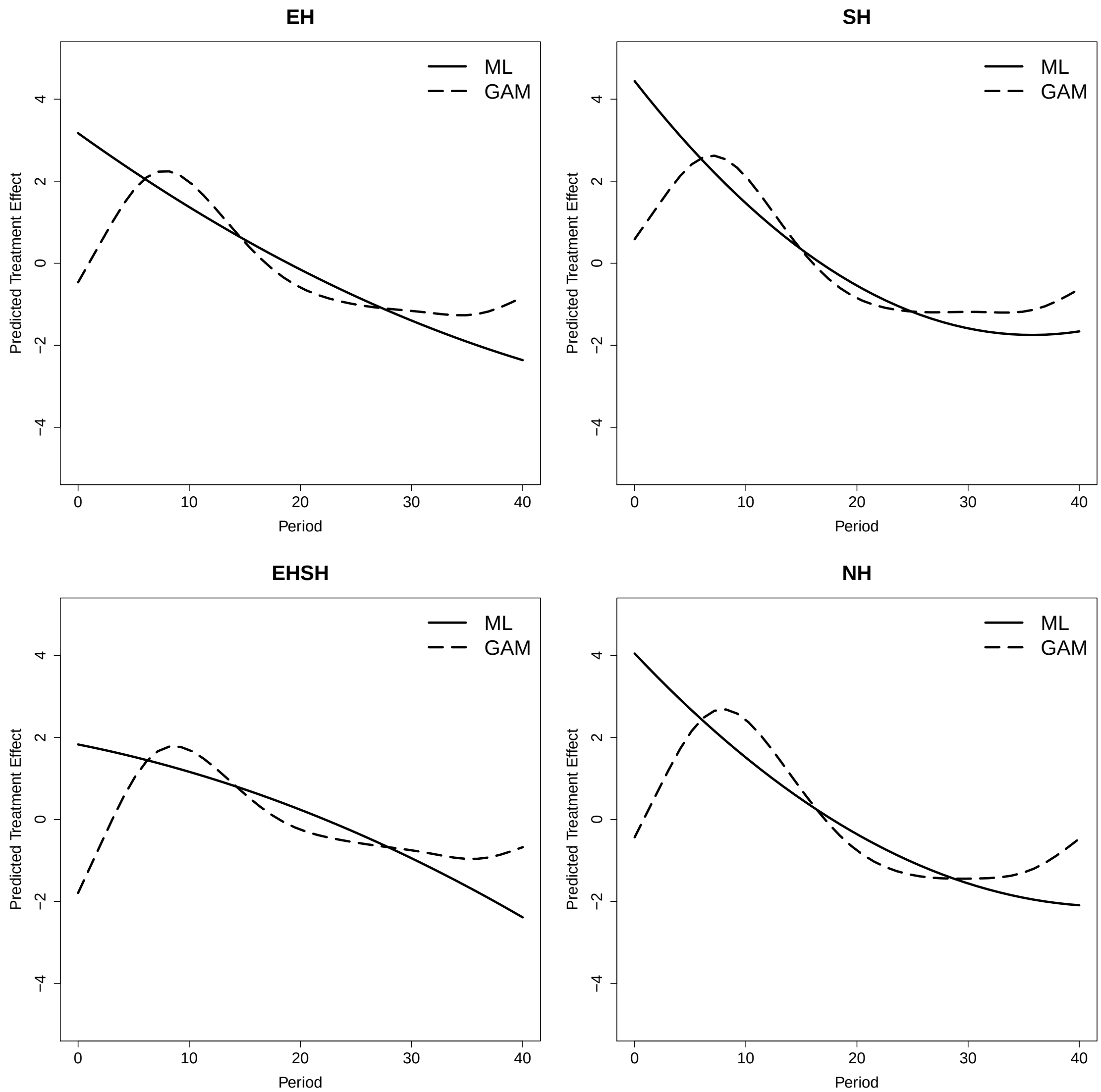


Figure 25: ML vs GAM with splines for Resource Size IND

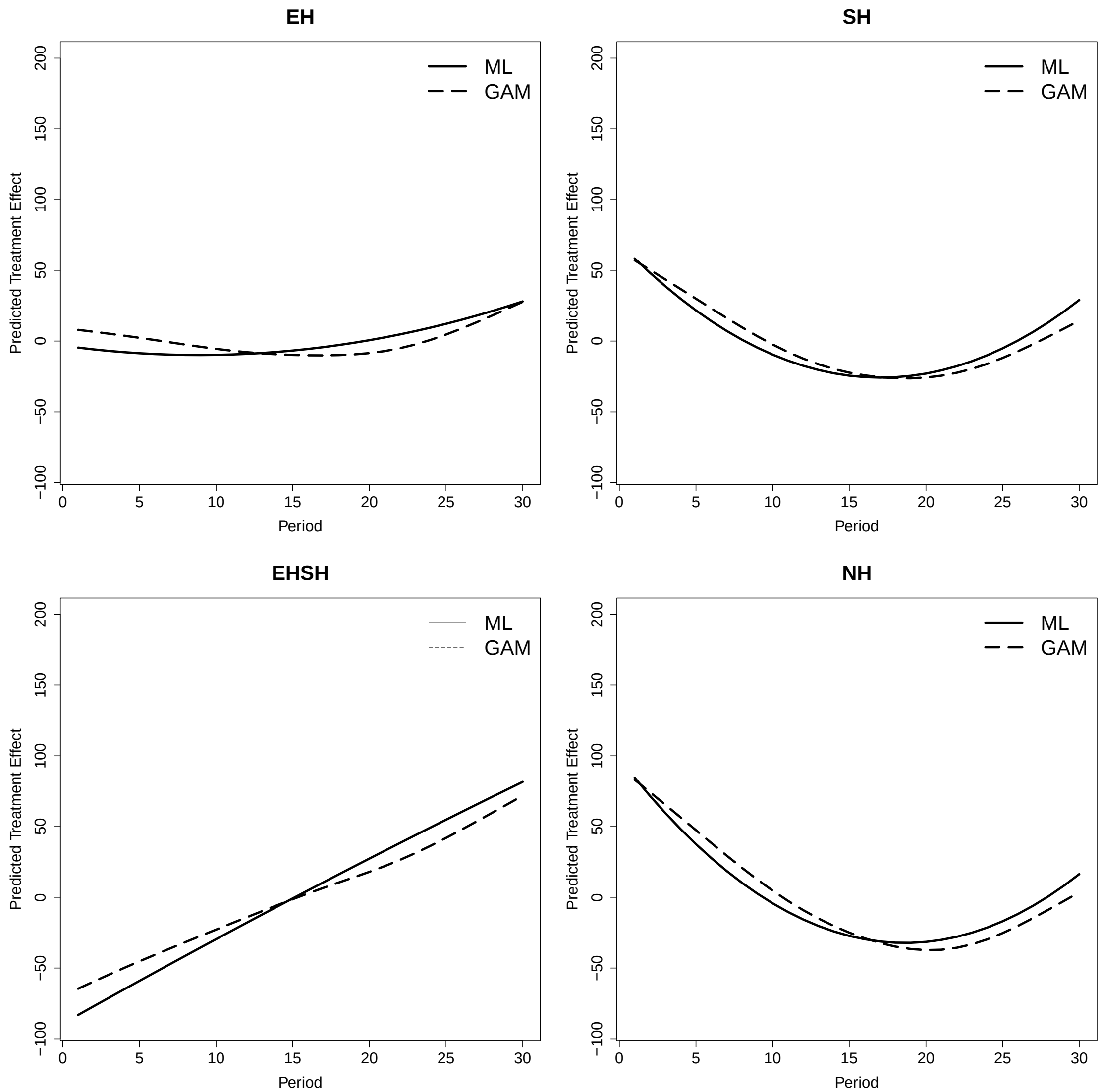
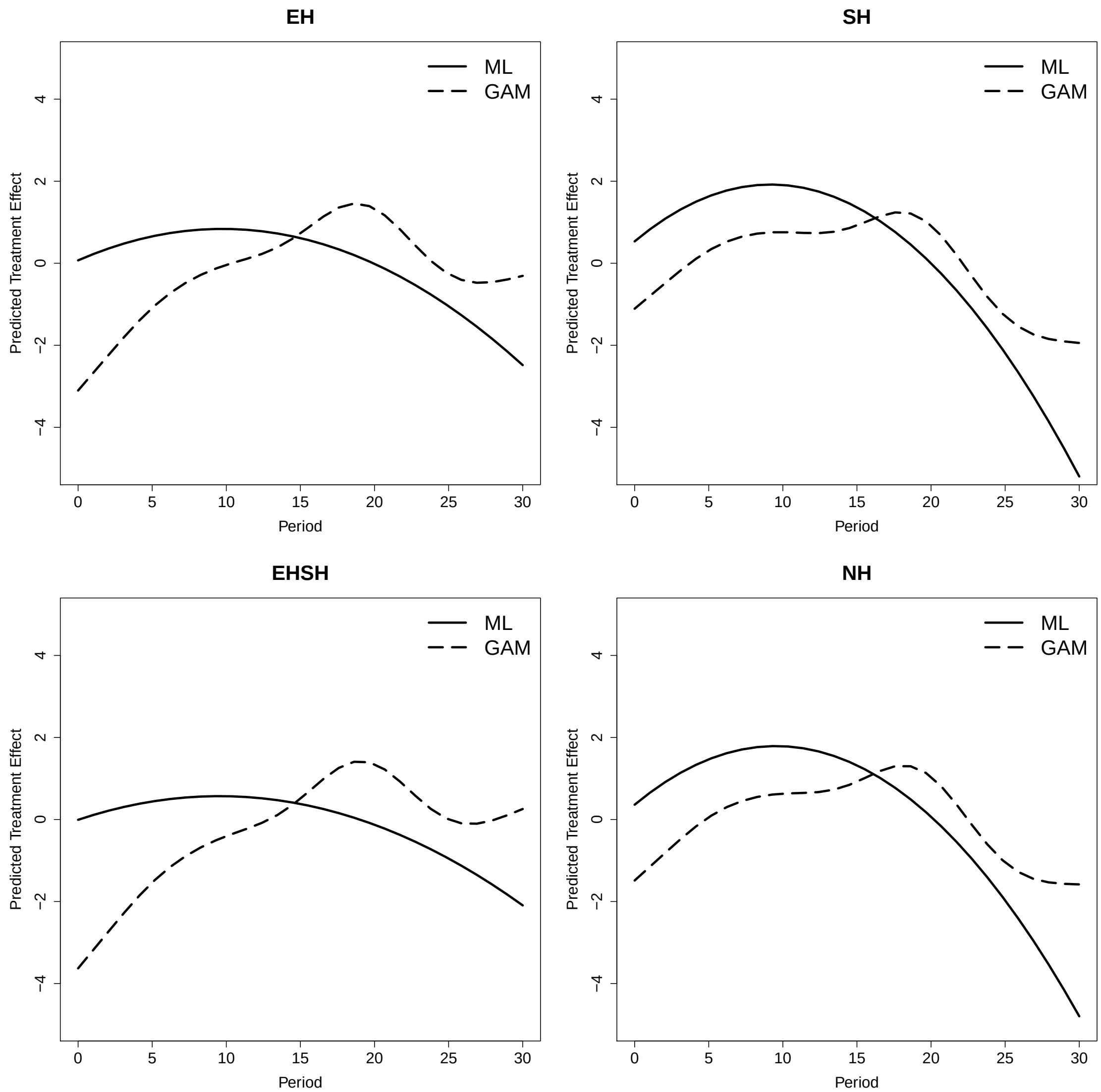


Figure 26: ML vs GAM with splines for Appropriation Effort IND



Appendix E

Regression models on Trust and Fairness variables from the post-experimental survey.

Table 7: UKNL study: Ordinal Logistic Regression on post-experimental measures of trust (Odds Ratios) (model 1 and 2 from Van Klingeren, 2020)

	(1) Trust in other players	(2) Subjective trustworthiness of others	(3) Subjective fairness of endowment division	(4) Subjective feeling of being treated fairly
EH	1.67†	1.21	0.26***	0.63
	(0.46)	(0.33)	(0.07)	(0.18)
SH	1.60†	1.13	1.67†	0.91
	(0.45)	(0.32)	(0.47)	(0.26)
EHSH	1.67†	1.06	0.18***	0.434**
	(0.47)	(0.30)	(0.05)	(0.12)
Controls				
Final Profit	1.19***	1.39***	1.16***	1.31**
	(0.06)	(0.07)	(0.05)	(0.06)
Age	1.04**	1.02	1.03***	1.03***
	(0.01)	(0.01)	(0.01)	(0.01)
Friends	0.97	0.82†	1.02	0.97
	(0.01)	(0.08)	(0.07)	(0.07)
Game Theory Experience	1.10	0.88	1.16	0.89
	(0.23)	(0.19)	(0.24)	(0.18)
Female	1.63*	1.11	0.91	1.04
	(0.33)	(0.23)	(0.18)	(0.21)
Netherlands	1.12	1.26	0.92	0.76
	(0.25)	(0.29)	(0.21)	(0.18)
Observations	341	341	341	341

Standard errors in parentheses.
*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*
N = 341 due to 20 missing responses on the survey. Tables produced with Stargazer(Hlavac, 2018)

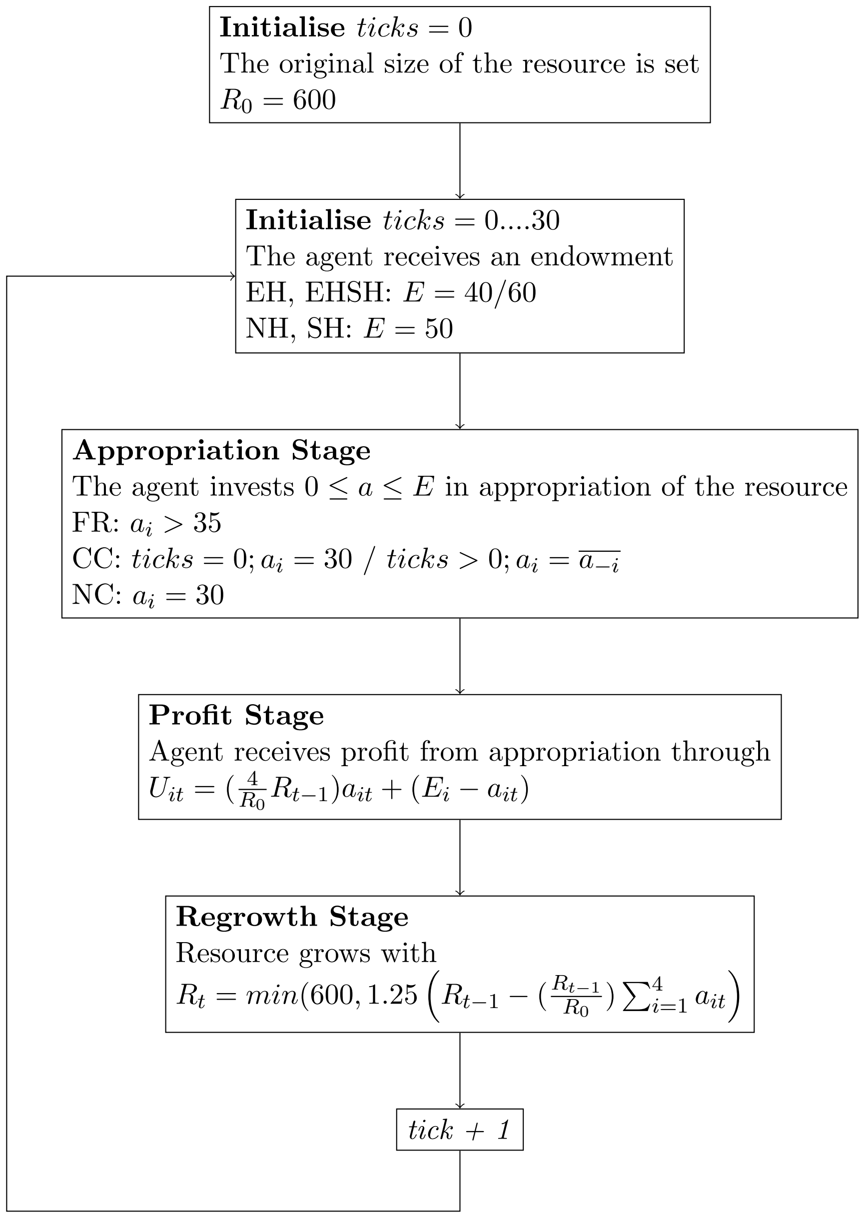
Table 8: IND study: Ordinal Logistic Regression on post-experimental measures of Trust and Fairness (Odds Ratios)

	(1) Trust in other players	(2) Subjective trustworthiness of others	(3) Subjective fairness of endowment division	(4) Subjective feeling of being treated fairly
EH	0.95	0.94	0.17***	0.41†
	(0.44)	(0.43)	(0.09)	(0.19)
SH	0.64	0.49	1.16	0.89
	(0.30)	(0.23)	(0.53)	0.42
EHSH	1.00	0.70	0.27**	0.63
	(0.46)	(0.32)	(0.13)	(0.28)
Controls				
Final Profit	1.00	1.01*	1.02***	1.01**
	(0.00)	(0.00)	(0.00)	(0.00)
Age	1.02	1.15†	1.01	1.11
	(0.09)	(0.10)	(0.09)	(0.09)
Friends	1.00	1.07†	1.08*	1.08*
	(0.04)	(0.04)	(0.04)	(0.04)
Game Theory Experience	0.92	1.02	1.29	1.48
	(0.31)	(0.35)	(0.45)	(0.51)
Female	1.09	1.09	0.47*	0.77
	(0.39)	(0.40)	(0.18)	(0.28)
Observations	124	124	124	124

Standard errors in parentheses.
*** $p< 0.001$, ** $p < 0.01$, * $p < 0.05$, † $p < 0.1$, *two-sided*
N = 124 due to 20 missing responses on the survey. Tables produced with *Stargazer*(Hlavac, 2018)

Appendix F

A flow chart overview of the ABM model as coded in NetLogo(Wilensky, 1999).



Appendix G

The adjusted R^2 is calculated using

$$AdjR^2 = 1 - \left(\frac{\sum_{t=1}^{n_{mt}} (d_{mt} - s_{mt})^2)/(n_{mt} - k)}{\sum_{t=1}^{n_{mt}} (d_{mt} - \overline{d_{mt}})^2/(n_{mt} - 1)} \right)$$

where k is the number of parameters available in each ABM.

Table 9: Adjusted R^2 per ABM per treatment

	UKNL EH	SH	EHSH	NH	IND EH	SH	EHSH	NH
Mixed Model*								
Adj. R^2 Resource Size	0.840	-0.032	0.743	0.509	0.742	0.161	-9.501	0.188
Adj. R^2 Profit	0.600	0.455	0.758	0.714	0.602	0.205	-10.137	0.318
Adj. R^2 Appropriation	-3.620	-0.450	-3.289	-0.717	-2.684	-4.162	-6.023	-2.932
Adj. R^2 Change Appropriation	-0.091	-0.107	-0.086	-0.088	-0.081	-0.077	-0.075	-0.077
Cooperative								
Adj. R^2 Resource Size	-7.652	-8.231	-6.361	-7.310	-3.669	-3.723	-2.636	-3.493
Adj. R^2 Profit	-0.965	-3.120	-3.371	-3.006	-1.293	-2.302	-4.108	-2.002
Adj. R^2 Appropriation	0.018	-0.513	-1.956	-0.0475	-1.616	-1.237	-3.246	-0.412
Adj. R^2 Change Appropriation	-2.046	0.004	0.023	0.021	0.027	0.031	0.033	0.033
Free-rider								
Adj. R^2 Resource Size	-7.652	-8.231	-6.361	-7.310	-3.667	-3.723	-2.636	-3.493
Adj. R^2 Profit	-1.637	-2.094	-2.594	-1.785	-2.185	-3.475	-61.281	-1.742
Adj. R^2 Appropriation	-9.384	-6.330	-7.636	-5.705	-10.581	-13.002	-46.220	-5.403
Adj. R^2 Change Appropriation	0.018	0.004	0.023	0.021	0.027	0.031	0.033	0.033
Random								
Adj. R^2 Resource Size	-7.003	-7.643	-5.836	-6.790	-3.280	-3.400	-2.062	-3.219
Adj. R^2 Profit	-1.701	-1.008	-0.840	-0.997	-1.044	-0.529	-1.179	-0.542
Adj. R^2 Appropriation	-8.568	-4.983	-6.409	-4.518	-8.277	-10.777	-15.544	-4.323
Adj. R^2 Change Appropriation	-0.052	-0.068	-0.047	-0.049	-0.042	-0.038	-0.036	-0.036

∗ *This model consists of cooperative agents, conditionally cooperative agents and free-riding agents according to the percentages found per treatment in the LCP score calculation as apparent from figure 19 and 20.*

Appendix H

Additional graphs showing ABM predictions from the single agent ABMs compared to the data from the UKNL and IND studies.

Figure 27: UKNL Basic Models predictions for Resource Size (top row) and Appropriation (bottom row)

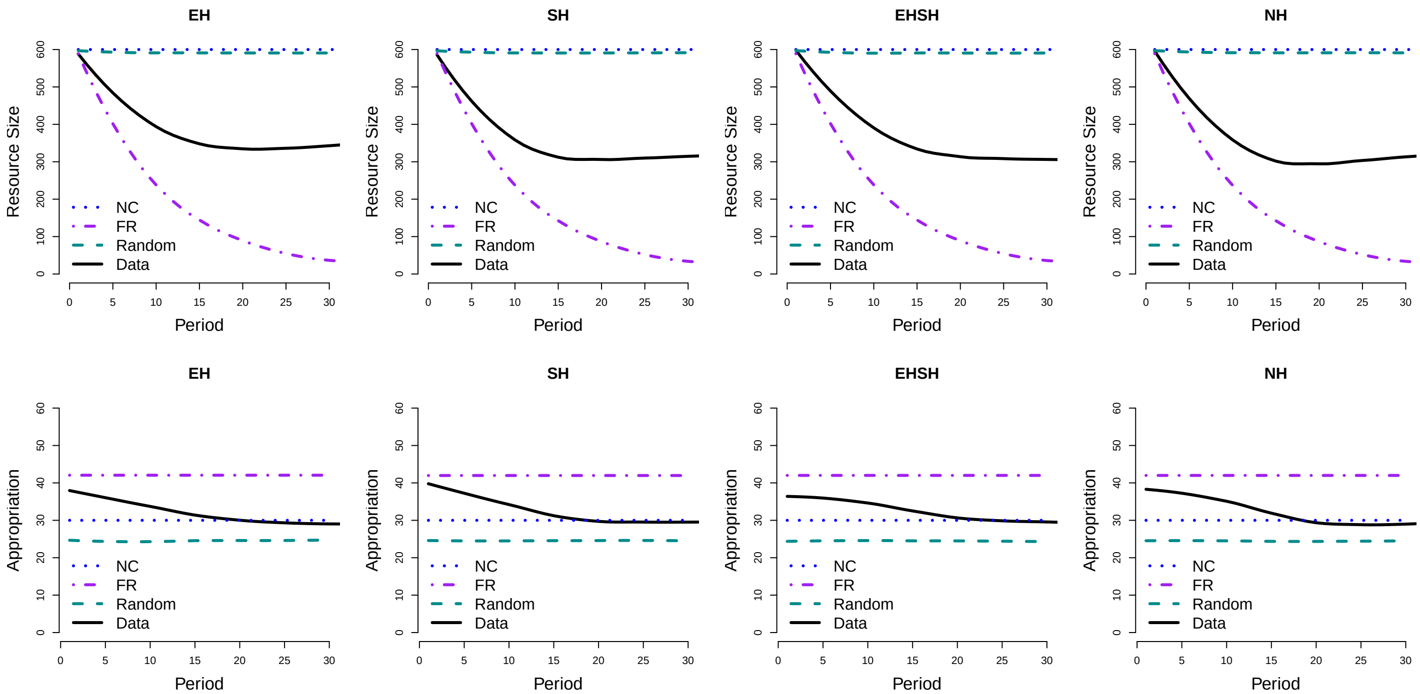
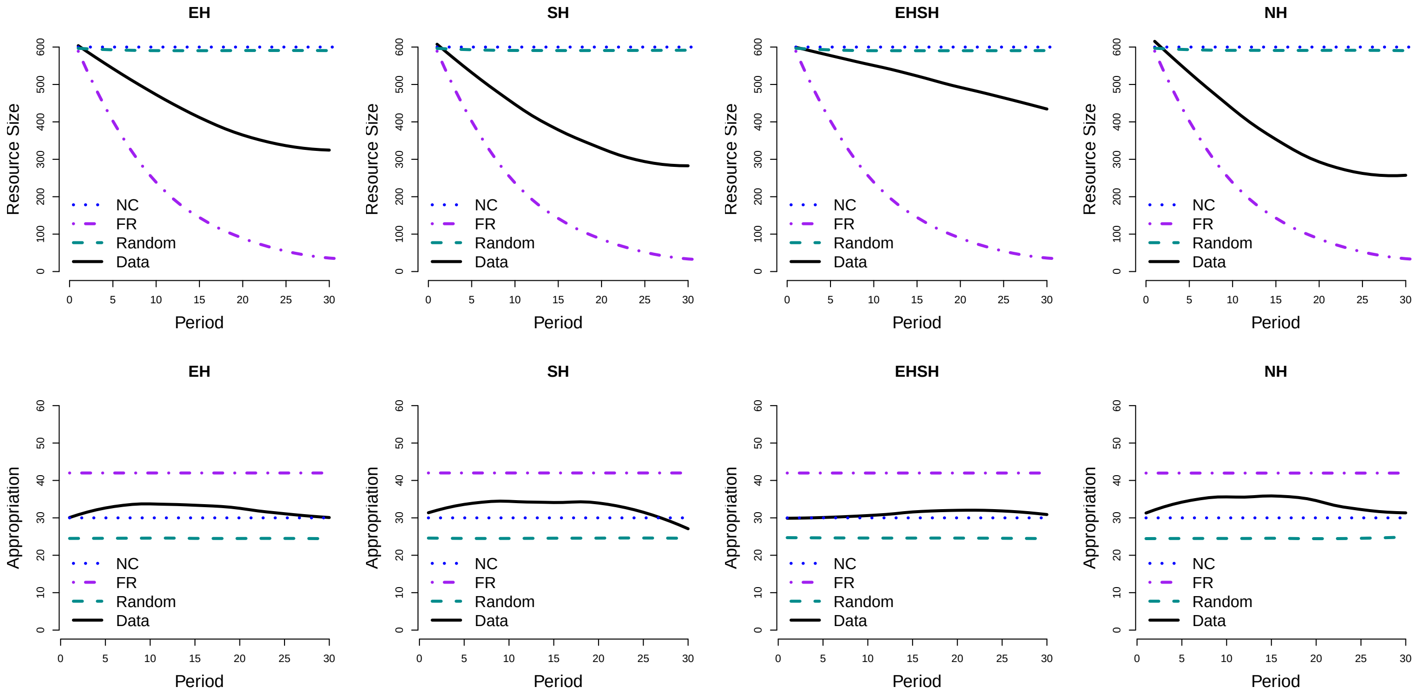


Figure 28: IND Basic Models predictions for Resource Size (top row) and Appropriation (bottom row)



Appendix I

Additional graphs showing mixed agent and single agent ABM predictions for high and low endowed subjects from the EH and EHSH treatments compared to the data from the UKNL and IND studies.

Figure 29: UKNL Mixed (top) and Basic Model (bottom) predictions for Appropriation for high and low endowments in EH and EHSH

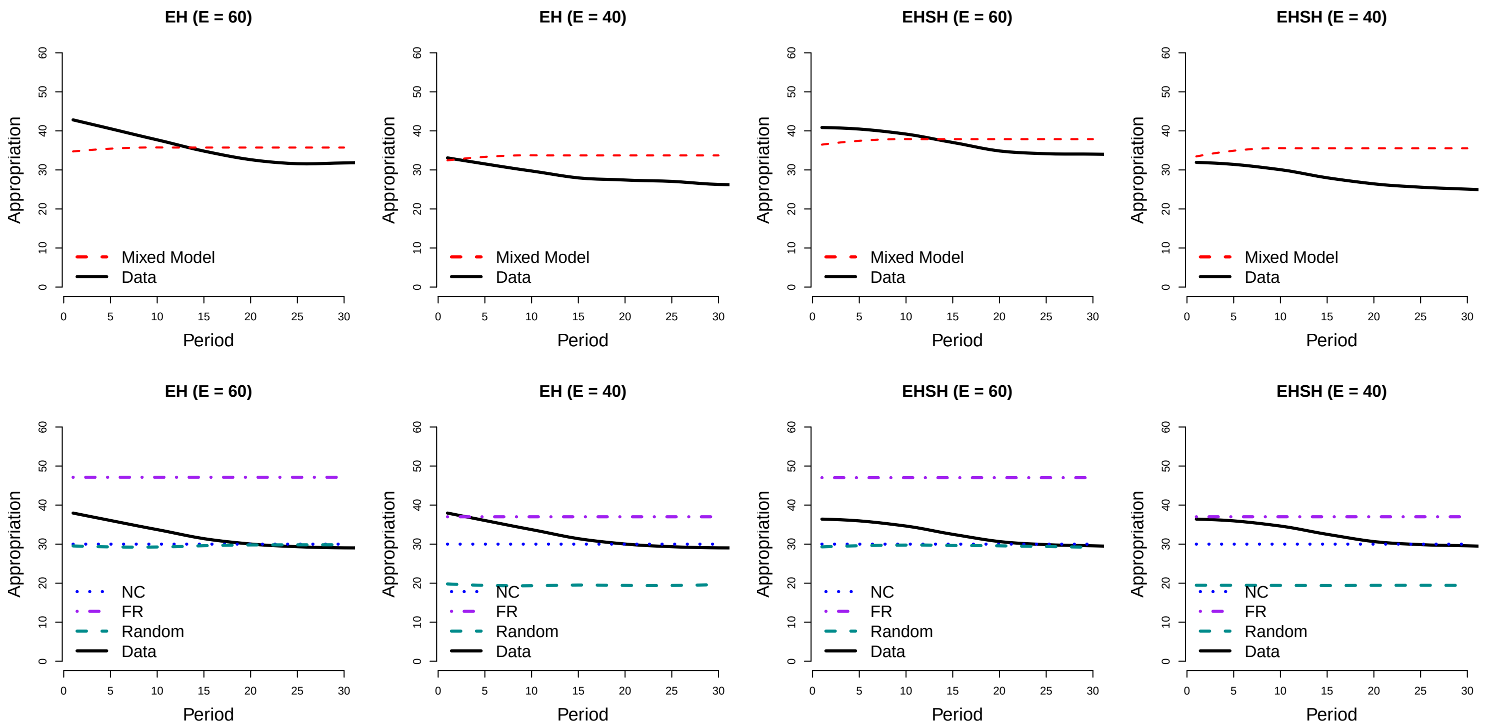
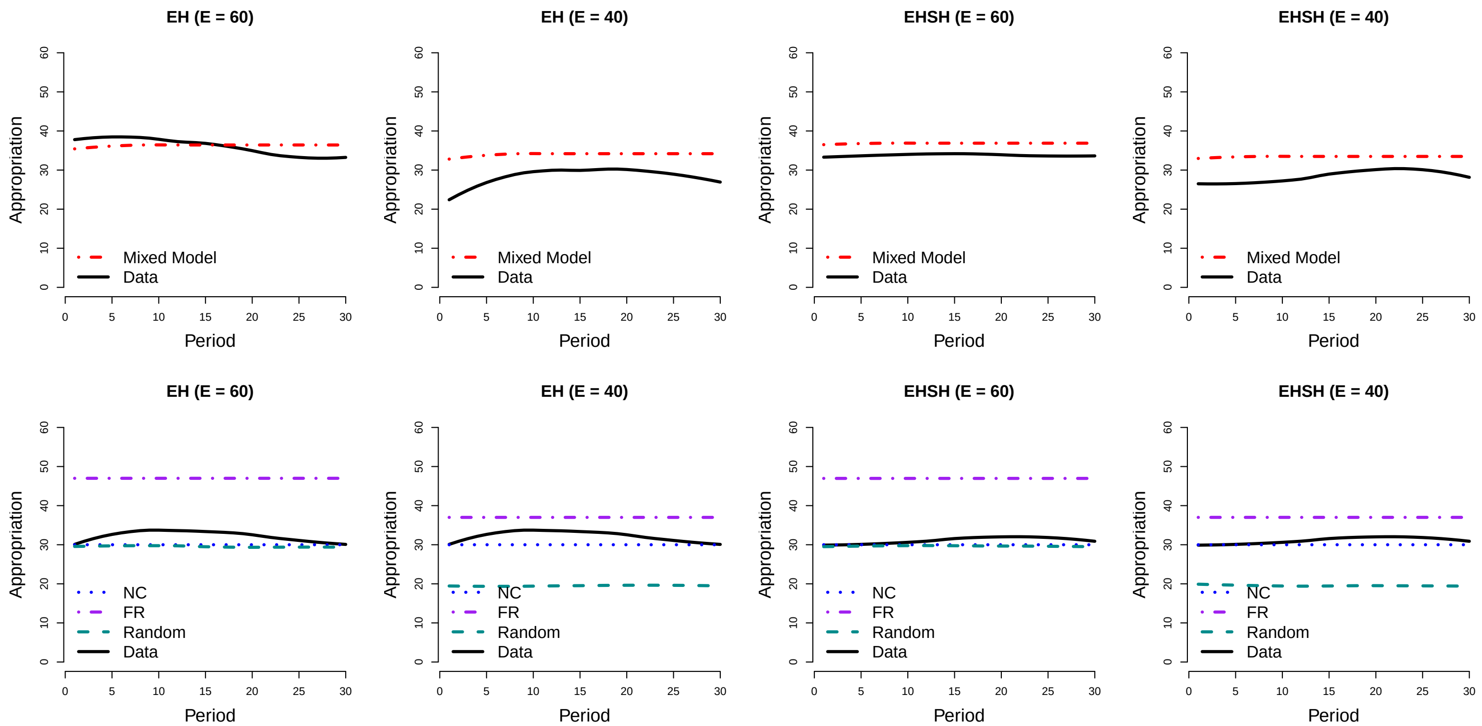


Figure 30: IND Mixed (top) and Basic Model (bottom) predictions for Appropriation for high and low endowments in EH and EHSH



Chapter V:
Conclusion

In this thesis I have investigated the relation between heterogeneity, trust and cooperation in common-pool resources. All three papers contribute in their own way to this investigation. In the first paper the relation between economic and sociocultural heterogeneity, trust and successful commons management for fisheries and irrigation systems is analysed. Using multiple imputation with chained equations, random forests, and predictive mean matching, Elinor Ostrom's CPR Database was used in its full potential. The second paper investigates the effects of economic and sociocultural heterogeneity - and the combination of the two - on trust and cooperation in common-pool resources using a CPR game in a laboratory experiment comprising 344 subjects from the United Kingdom and the Netherlands. The third paper uses regression analysis, player-type classification with linear conditional-contribution profiles and agent-based models to compare, understand and replicate the experimental results of the CPR experiment from the second paper and a CPR experiment conducted in India comprising 144 subjects from Mumbai and Bangalore. In this final chapter, findings from all three papers regarding economic heterogeneity, sociocultural heterogeneity and trust and their relation to each other and to cooperation and CPR success will be discussed. At the end of this chapter I will summarise the main findings of this thesis, discuss suggestions for future research and present some final thoughts.

Economic Heterogeneity

In the first paper, economic heterogeneity is found to be negatively related to trust and trust is found to have a positive relation with CPR success. Partial support is found for a negative indirect relation of economic heterogeneity with CPR success through trust. These findings partially support the hypothesis that economic heterogeneity has an indirect negative effect on CPR success mediated by trust. However, no robust direct relation is found between economic heterogeneity and CPR success.

The experimental results of the second paper show that economic heterogeneity results in higher levels of individual and collective cooperation relative to homogeneity. The explanation for this counterintuitive finding is suggested to lie in the Olson-effect: a phenomenon describing a situation under economic inequality in which the richer actors bear the cost of cooperation for the poorer (Olson, 1965). The results show that the rich subjects in the economic heterogeneity treatment invested less in appropriation than the rich subjects in the combination treatment, which resulted in more space for the poor players in the economic heterogeneity treatment to appropriate more whilst keeping overexploitation of the resource to a minimum. Although this behaviour does not exactly fit the description of the Olson-effect, it does show an extra effort from the rich players to cooperate and to keep the average appropriation sustainable. This resulted in the economic heterogeneity treatment having the highest resource size on average over time compared to all other treatments. The combination treatment did not showcase this behaviour from the rich players, leading to overexploitation and the lowest resource size over time of all treatments. The second paper concludes that whether economic heterogeneity has a positive or negative effect on cooperation in the CPR game depends on the presence of sociocultural heterogeneity. The first paper did not show a positive effect of economic heterogeneity and thus shows no support for a type of Olson-effect - something I will comment on later.

The findings of the third paper show that economic heterogeneity results in higher levels of cooperation than homogeneity in the IND study, just as it did in the UKNL study. This adds to the robustness of the findings from the second paper and the conclusion that economic heterogeneity on itself can result in high levels of cooperation under certain conditions. Regarding the combination of economic and sociocultural heterogeneity, the results of the third paper show that subjects in the in the IND study behaved very differently from the combination treatment subjects in the UKNL study, and have in fact the *highest* level of cooperation in this experiment. Results from the multi-method analysis suggests that the operationalisation of sociocultural heterogeneity in the UKNL experiment induced feelings of being treated unfairly amongst subjects in the combination treatment whereas this is not the case in the IND experiment. For the UKNL combination treatment this subjective feeling of being treated unfairly may have resulted in subjects adopting the conditional cooperative player type, whereas the subjects in the IND combination treatment mostly adopted an unconditional, neutral cooperative player type. As more neutral cooperators means a higher level of cooperation in the group, it makes sense that the combination treatment group performed so much better in the IND experiment relative to the UKNL experiment. It is argued that economic heterogeneity can have a positive effect when combined with sociocultural homogeneity, or with a type of sociocultural heterogeneity that does not foster feelings of unfairness when groups are treated unequally in terms of endowments.

There are several takeaways from these results. Firstly, as the second and third paper show, as long as there is no sociocultural dimension on which actors vary or are incompatible on, economic heterogeneity can have a positive effect on cooperation through a type of Olson-effect. The rich help out the poor by bearing the burden of cooperation - in our case, by appropriating less from the resource than they could in order for the lower endowed players to appropriate a little more. However, the first paper did not find a positive effect of economic heterogeneity on CPR success. Olson states certain conditions need to be met for the Olson-effect to happen. He mentions that it pertains to “smaller groups, marked by considerable degrees of inequality” (Olson, 1965, p. 34). Whereas the experiments in the second and third paper meet these requirements, this may not be the case for the CPRs featured in the CPR Database (Ostrom, Agrawal, Blomquist, Schlager, & Tang, 1989) used in the first paper. The cases featured in the database are of varying sizes, with different amounts of subgroups and different levels of economic inequality. It is less likely for there to be many cases featured in the data that fit Olson’s description, thus it is less likely that the Olson-effect is found in this data.

The second takeaway from the results regarding economic heterogeneity is that it is important to look at the difference in operationalisation of economic heterogeneity between the experiments and the data obtained from case-study research, as it may yield different results. In the CPR Database, economic heterogeneity represents the difference in income between real resource appropriators, who undoubtedly worked hard to get where they are. In the economic heterogeneity treatments in the experiments, however, getting more money than others is like a lottery: randomly selected subjects receive a higher endowment than others, without working for it or earning it in any way. Even in the combination treatment there is no apparent reason for members of either the Klee, Kandinsky, Mumbai or Bangalore group to get the higher endowment. Allocating higher and lower endowments randomly - instead of using another game in which participants earn money - was done to avoid another stage in an already complicated and long experiment. The lottery or windfall type of being rich from the experiments is less likely to affect trust amongst actors, and rich actors may be more inclined to share their wealth or to pay more for cooperation as they did not earn their higher endowment through effort. On the other hand, the 'hard earned' type of being rich, which is likely more representative of wealth in the CPR Database in the first paper, may cause actors to be less keen on sharing or to give up part of their wealth to help others. Hence, economic heterogeneity as presented in the data of the first paper can be expected to reduce trust as it is more likely to create a rift and real differences between actors, reducing trust as a consequence. Although it is more common for people to work for their money rather than receive it through a lottery, the type of economic heterogeneity used in the experiments does still resemble real-life situations in which people were born into a wealthy environment, perhaps due to the economic success of forebears. Another situation could be where a specific type of appropriator is subsidised by the government whereas others are not. The notion that the origin of wealth influences the way people share their wealth is well-researched. For instance, the often-found result in Ultimatum Games is that subjects split the money 50/50 (Henrich et al., 2001; Rotemberg, 2008). However, in most of these games subjects receive their endowment as a lottery rather than earning their initial endowment. A growing body of research finds that subjects who earn endowments share less of their wealth than subjects who received endowments as a lottery (Barber IV & English, 2019; Cappelen, Hole, Sørensen, & Tungodden, 2007; Carlsson, He, & Martinsson, 2010; Cherry & Shogren, 2008). This explains the difference in the results of the CPR Database and the experimental data. As both types of economic heterogeneity may occur in real-life societies, both the CPR Database and the experimental data offer valuable insights into the effect of economic heterogeneity on cooperation in CPRs.

Sociocultural Heterogeneity

In the first paper, no robust effects are found regarding the relation between sociocultural heterogeneity, trust and CPR success. In addition, the experimental data from the second and third paper show no significant effect of sociocultural heterogeneity on cooperation relative to homogeneity. Although a significant difference was visible in trust towards ingroup and outgroup members in the second IGs in the second paper, did this not translate to less cooperation in the CPR game. This is an interesting finding, as there is a large body of literature suggesting the opposite. However, as mentioned in the previous paragraph, various effects of sociocultural heterogeneity on cooperation were found when combined with economic heterogeneity: a negative effect of the combination of economic heterogeneity and sociocultural heterogeneity in the second paper, and a positive effect in the third. The player type classification in the third paper shows that depending on the operationalisation of sociocultural heterogeneity, players in the combination treatment show more conditional or unconditional cooperative behaviour, acting as conditional cooperators if sociocultural heterogeneity induces feelings of unfair treatment and as neutral cooperators if this is not the case.

Overall the results show that the effect of sociocultural heterogeneity depends on its operationalisation and the level of economic heterogeneity present. No effect of sociocultural heterogeneity is found under economic homogeneity, and the effect under economic heterogeneity depends on which characteristics or dimensions the sociocultural heterogeneity measure is based. In the second paper, the groups were based on an artificial criterion: their preference for paintings from painters with very similar painting styles. This in itself does not necessarily sound like a reason for the two groups to treat ingroup and outgroup members differently, yet research points out that even artificial identities can result in ingroup favouritism and outgroup 'disfavouritism' (Aksoy, 2015; Billig & Tajfel, 1973; Chen & Li, 2009; Singleton, 2001; Tajfel, Billig, Bundy, & Flament, 1971; Yamagishi & Kiyonari, 2000). This was also visible in the second round of IG games in the second paper, where the ingroup was trusted significantly more than the outgroup. Even though one would argue that real identities would create an even bigger ingroup and outgroup feeling, the real identities used in the IND study did not cause the same effect as the artificial identities from the UKNL study, despite subjects' own indication of their affinity and identification with the city of origin. There are several possible reasons for this. Firstly, although subjects identify with their city, the rivalry between the cities may not have been strong enough to create rivalry in the experiment. The rivalry between the Klees and Kandinsky groups in the second paper may have resulted from the fact that subjects' choices lead to them being member of either group, the extra bond strengthening binary other-other DG game and the emphasis on the group splitting process. Secondly, whereas Klee or Kandinsky group membership is very unlikely to correlate with any real characteristics of the subjects, the city of origin may correlate with for instance subjects' socioeconomic status and their choice of university. This may cause subjects to feel related to other subjects in their surroundings - in this case the university campus - that have those same characteristics, despite originating from different cities. The student community at FLAME University campus is fairly close-knit, and many of the subjects knew each other, which may have resulted in the city of origin not playing a big role in the experiment. It may not so much be a matter of cultural characteristics, but rather a matter of incompatibility or rivalry between groups that reduces cooperation under economic inequality. An example is the rivalry between Japanese and Chinese fishermen between 1920 and

1930 and after World War II; two groups who differed greatly not only in economic assets but also in culture, making them incompatible as users of the same resource (Keyuan, 2003; Muscolino, 2008).

An interesting conclusion regarding sociocultural heterogeneity is that induced sociocultural heterogeneity is as strong or, as apparent from this thesis, sometimes stronger than real forms of identity when combined with economic heterogeneity. This has multiple implications. Firstly, it may be the case that induced identities may be more useful to investigate the effect of sociocultural heterogeneity on certain behaviours in laboratory experiments than real identities. Induced identities are controllable and do not correlate with other individual characteristics that may correlate with in-game behaviour (Aksoy, 2015; Kahn, 2019). The second implication is that an insignificant label such as Klee and Kandinsky can influence group behaviour and cause subjects to behave less cooperatively with outgroup members under some circumstances. A group name and some group strengthening exercises are all that is needed to invoke caution and conditional instead of unconditional cooperation between two groups, even if these groups are in fact not incompatible when looking at sociocultural characteristics. In line with this result it is worth remembering one of the first agent-based models on heterogeneity, namely Schelling's model on segregation (Schelling, 1971). This model showed that a small preference on the micro-level can lead to big changes on the macro-level. Even though the MGE only caused subjects in the combined heterogeneity treatment to appropriate a few units more than in the other treatments, the difference in the resource size compared to other treatments is considerable.

The takeaway from this thesis regarding measuring the effect of sociocultural heterogeneity is that the effects of sociocultural heterogeneity on human behaviour may vary greatly depending on the exact operationalisation of sociocultural differences and depending on the level of economic heterogeneity. Sociocultural heterogeneity may be seen as a multidimensional scale rather than a binary or ordinal variable, which ranges from insignificant to significant differences and depends on the combination of heterogeneous characteristics of the groups. In addition, it may be important to look at incompatibility rather than just sociocultural differences; demographic faultlines may be of help here. Demographic faultlines are present when, in a group of people, there is a clear divide based on a salient demographic attribute (Flache & Mäs, 2008; Lau & Murnighan, 1998, 2005). A demographic faultline can be weak or strong, depending on how many attributes coincide within the same faultline:

> "To give an example, a faultline is strong in a team consisting of two Caucasian, highly

educated women and two African–American men with low level of education. In this case, all three demographic dimensions along which team members differ (race, sex, educational level) split the team along the same line." (Flache & Mäs, 2008, p. 176)

For future research on the effects of sociocultural heterogeneity on cooperation or other behaviour it is important to identify the type of sociocultural heterogeneity one wants to investigate, to know where it falls on the 'scale' of sociocultural heterogeneity - or perhaps sociocultural incompatibility -, how to operationalise it and to understand whether this concerns a strong demographic faultline or not.

Trust

All three papers find a positive relation between trust and cooperation. The first paper shows a positive relation between trust amongst appropriators of a resource and the balance of withdrawal and availability of the CPR, despite the fairly weak operationalisation of trust with only three categories. This adds to many findings in the literature on the positive association between trust and cooperation and other positive societal outcomes (Acedo & Gomila, 2013; Alesina & La Ferrara, 2000; Gächter, Herrmann, & Thöni, 2004; Gehrig, Schlüter, & Hammerstein, 2019; Knack & Keefer, 1997; La Porta, Lopez-de-Silanes, Shleifer, & Vishny, 1997; Romano, Balliet, Yamagishi, & Liu, 2017; Zak & Knack, 2001). It can therefore be regarded as an empirical regularity. It is shown in the paper that trust especially matters for CPRs where mutual monitoring is not self-evident, such as fishing grounds. Despite not being able to prove the causal direction of this effect in the first paper, the significance and causal direction of this result are backed up by experimental findings in the literature (Acedo & Gomila, 2013; Gächter et al., 2004) and from the second and third paper of this thesis. The experiments show how a higher level of individual trustfulness displayed in the Investment Game leads to more cooperative behaviour on the individual level in terms of appropriation effort, and that a higher average of trustfulness on the group level leads to more cooperative behaviour on the collective level in terms of resource size.

The results of the three papers do not provide a convincing conclusion on whether or not trust is affected by heterogeneity. The first paper shows a negative effect of economic heterogeneity on trust and partial support for an indirect effect of economic heterogeneity through trust on CPR success. The second and third paper do not show more than marginally significant relations between heterogeneity and trust during the main game; rather, it was found that the profit of each subject was the main influence on how they reported trust in their co-players in the post-experimental survey. This is a downside of only being able to measure trust after the experiment and not during. However, the second paper does show that in the second iteration of the Investment Game, outgroup trust is significantly lower than ingroup trust and lower than general trust from the first iteration. The Investment Game was specifically designed to measure trust, whereas the Fishing Game was not. Future research should incorporate trust measures within CPR games, so trust can be measured in the game instead of only before and after it. This way, the mediating effect of trust can be tested using real life data, with the additional assurance of the causal direction of the effect through laboratory experiments.

Summary

To summarise the discussed results regarding the relation between economic heterogeneity, sociocultural heterogeneity, trust and cooperation or CPR success, Table 1 provides a per chapter overview of the findings in this thesis.

Table 1: Relation between heterogeneity, CPR cooperation/success (left), and trust (right) per chapter of this thesis

	Dependent variable:					
	Cooperation / Success			Trust		
	Chapter II	Chapter III UKNL	Chapter IV IND	Chapter II	Chapter III UKNL	Chapter IV IND
EH	×	+	+	−	×	×
SH	×	×	×	×	×	×
EHSH		−	+		×	×
Trust	+	+	+			
	Cooperation / Success through Trust					
EH	−					
SH	×					

× = no significant relation, + = sig. positive relation, − = sig. negative relation

Contrary to suggestions in the literature, the results of this thesis do not fully support the hypothesis on the negative effect of heterogeneity on cooperation in CPRs. Instead, this thesis suggests no negative relation between sociocultural heterogeneity and cooperation and that the relation between economic heterogeneity and cooperation in CPRs depends on (1) whether wealth is earned or not, (2) whether the conditions for an Olson-effect are met, (3) the presence of sociocultural heterogeneity and (3) the level of unfairness that actors in a situation with sociocultural and economic heterogeneity perceive. In accordance with the literature, this thesis supports the hypothesis that trust increases cooperation and CPR success.

Future Research

There are some relevant suggestions for future research. Firstly, it would be interesting to research whether the results for economic heterogeneity and the combination treatment in the experiments hold if subjects have to work for their money, and the endowment is thus earned rather than based on a lottery. For instance, subjects could be made to do a calculating task before the main experiment (see for instance Kahn, 2019), and the best performing 50% of subjects could be rewarded a higher endowment.

Secondly, as mentioned before, it is important to investigate what type of sociocultural heterogeneity leads to incompatibility or rivalry between groups. More research on demographic faultlines can help guide this investigation. The experiment could be repeated using characteristics as gender, ethnicity, religion or political ideology - either separately or in combination with each other - to single out exactly which combination of characteristics will lead to incompatibility and potentially reduced cooperation between groups. An interesting variation on this could be to reveal the identities only halfway through the experiment, to see whether the dynamic between group members changes when they know they are playing the game with outgroup members, or whether they will keep behaving as they did in the first half of the experiment. In addition, it is important to investigate whether the effects of sociocultural heterogeneity also differ between different types of games and decision situations. Yamagishi & Kiyonari (2000) show with a series of sequential and simultaneous one-shot Prisoner's Dilemmas that increased ingroup cooperation - with groups based on the minimal group paradigm - only shows up in the simultaneous games and not in the sequential games. Whereas the CPR game played in the experiments in this thesis had simultaneous decision stages, the game was played over many periods and there was thus an opportunity for players to base their behaviour on other players' actions from the previous period rather than on expectations of ingroup reciprocity alone. More insight into how sociocultural heterogeneity affects cooperation in various decision contexts is needed to understand the effects fully.

Thirdly, an important addition to the experimental design would be to crosscut the heterogeneity treatment so that the sociocultural identities are not lined up with the economic inequality (see for example Aksoy, 2019). Although in real life it is likely that sociocultural identities are related to economic wealth, it is important to measure whether it is indeed the fact that the identities are lined up with endowments that make the combination of both types of heterogeneity perform better or worse than homogeneity in CPRs.

Lastly, future research should further develop agent-based models to be used as a tool to replicate not only experimental data as was done in this thesis, but also case-study based contemporary or historical data on the development of CPRs over time. The results of the third paper of this thesis showed that mixed models of simple agents can explain and replicate complex experimental data to a large extent, hereby proving the additional worth of simple ABMs in stripping down complex mechanisms to basic behaviour. However, simple agents are only one application possibility of ABMs - creating more realistic, complex agents with non-linear behavioural rules may prove useful too. By training the agents to behave like the existing data, simulations over more periods can be run to generate dynamic hypotheses on human behaviour over longer periods of time than is available in case-study data or possible with experimental sessions. In general, experimental researchers should be looking to expand their ways of analysing, interpreting and explaining their findings using innovative tools outside of regular statistical methods, to enhance the quality of hypotheses, experimental designs and ultimately experimental research as a whole.

Final Thoughts

This thesis contributes not only to the theoretical understanding of the relation between heterogeneity, trust and cooperation in CPRs, but also presents a methodologically innovative approach to answering research questions. Investigating the same research question in three different ways, using three different data sources and multiple analytical methods provides a more comprehensive and unbiased answer than single-method studies. In addition, my approach enabled me to check for robustness of effects within and across different methods. The answer to the research question is nuanced and multifaceted, but research rarely finds an unambiguous 'one size fits all' solution, or a true or false answer. Instead, a nuanced understanding of the relation between heterogeneity, trust and cooperation in CPRs was established using a combination of multiple methods. Depletion of natural and man-made resources is the order of the day, and we overexploit the earth's resources earlier and earlier every year. In addition, the number of modern commons such as citizen initiatives for green energy, infrastructure, social security and food is growing. It is important to understand why humans behave as they do in CPR cooperation dilemmas in times of increasing migration and heterogeneity, for the sake of both traditional and new institutions for collective action. The findings from this thesis contribute to that understanding.

References

Acedo, C., & Gomila, A. (2013). Trust and cooperation: A new experimental approach: Trust and cooperation. *Annals of the New York Academy of Sciences*, *1299*(1), 77–83. doi: 10.1111/nyas.12142

Aksoy, O. (2015). Effects of Heterogeneity and Homophily on Cooperation. *Social Psychology Quarterly*, *78*(4), 324–344. doi: 10.1177/0190272515612403

Aksoy, O. (2019). Crosscutting circles in a social dilemma: Effects of social identity and inequality on cooperation. *Social Science Research*, *82*, 148–163. doi: 10.1016/j.ssresearch.2019.04.009

Alesina, A., & La Ferrara, E. (2000). Participation in Heterogeneous Communities. *The Quarterly Journal of Economics*, *115*(3), 847–904.

Barber IV, B. S., & English, W. (2019). The origin of wealth matters: Equity norms trump equality norms in the ultimatum game with earned endowments. *Journal of Economic Behavior & Organization*, *158*, 33–43. doi: 10.1016/j.jebo.2018.11.008

Billig, M. G., & Tajfel, H. (1973). Social categorization and similarity in intergroup behaviour. *European Journal of Social Psychology*, *3*(1), 27–52. doi: 10.1002/ejsp.2420030103

Cappelen, A. W., Hole, A. D., Sørensen, E. Ø., & Tungodden, B. (2007). The Pluralism of Fairness Ideals: An Experimental Approach. *American Economic Review*, *97*(3), 818–827. doi: 10.1257/aer.97.3.818

Carlsson, F., He, H., & Martinsson, P. (2010). Windfall vs. Earned Money in the Laboratory: Do They Affect the Behavior of Men and Women Differently?

Chen, Y., & Li, S. X. (2009). Group Identity and Social Preferences. *The American Economic Review*, *99*(1), 431–457.

Cherry, T. L., & Shogren, J. F. (2008). Self-interest, sympathy and the origin of endowments. *Economics Letters*, *101*(1), 69–72. doi: 10.1016/j.econlet.2008.04.007

Flache, A., & Mäs, M. (2008). Why do faultlines matter? A computational model of how strong demographic faultlines undermine team cohesion. *Simulation Modelling Practice and Theory*, *16*(2), 175–191. doi: 10.1016/j.simpat.2007.11.020

Gächter, S., Herrmann, B., & Thöni, C. (2004). Trust, voluntary cooperation, and socio-economic background: Survey and experimental evidence. *Journal of Economic Behavior & Organization*, *55*(4), 505–531. doi: 10.1016/j.jebo.2003.11.006

Gehrig, S., Schlüter, A., & Hammerstein, P. (2019). Sociocultural heterogeneity in a common pool resource dilemma. *PLoS ONE*, *14*(1). doi: 10.1371/journal.pone.0210561

Henrich, J., Boyd, R., Bowles, S., Camerer, C., Fehr, E., Gintis, H., & McElreath, R. (2001). In Search of Homo Economicus: Behavioral Experiments in 15 Small-Scale Societies. *American Economic Review*, *91*(2), 73–78. doi: 10.1257/aer.91.2.73

Kahn, K. (2019). *Crime and equality, or crime and punishment?* (Ph.D.). University of Oxford.

Keyuan, Z. (2003). Sino-Japanese joint fishery management in the East China Sea. *Marine Policy*, *27*(2), 125–142. doi: 10.1016/S0308-597X(02)00086-6

Knack, S., & Keefer, P. (1997). Does Social Capital Have an Economic Payoff? A Cross-Country Investigation. *The Quarterly Journal of Economics*, *112*(4), 1251–1288.

La Porta, R., Lopez-de-Silanes, F., Shleifer, A., & Vishny, R. W. (1997). Trust in Large Organizations. *The American Economic Review*, *87*(2), 333–338.

Lau, D. C., & Murnighan, J. K. (1998). Demographic Diversity and Faultlines: The Compositional Dynamics of Organizational Groups. *The Academy of Management Review*, *23*(2), 325–340. doi: 10.2307/259377

Lau, D. C., & Murnighan, J. K. (2005). Interactions Within Groups and Subgroups: The Effects of Demographic Faultlines. *Academy of Management Journal*, *48*(4), 645–659. doi: 10.5465/amj.2005.17843943

Muscolino, M. (2008). The Yellow Croaker War: Fishery Disputes between China and Japan, 1925–1935. *Environmental History*, *13*(2), 306–324. doi: 10.1093/envhis/13.2.306

Olson, M. (1965). *The logic of collective action: Pubic goods and the theory of groups.* Cambridge, MA: Harvard University Press, Cambridge, MA.

Ostrom, E., Agrawal, A., Blomquist, W., Schlager, E., & Tang, S. Y. (1989). *CPR Coding Manual.* Indiana University, Bloomington, Indiana.

Romano, A., Balliet, D., Yamagishi, T., & Liu, J., H. (2017). Parochial trust and cooperation across 17 societies. *Proceedings of the National Academy of Sciences of the United States of America*.

Rotemberg, J. J. (2008). Minimally acceptable altruism and the ultimatum game. *Journal of Economic Behavior & Organization*, *66*(3), 457–476. doi: 10.1016/j.jebo.2006.06.008

Schelling, T. C. (1971). Dynamic models of segregation. *The Journal of Mathematical Sociology*, *1*(2), 143–186. doi: 10.1080/0022250X.1971.9989794

Singleton, S. (2001). How distributional conflicts shape co-management institutions and collaborative environmental policy in the United States. In *"Economic Inequality, Collective Action* *and Environmental Sustainability" workshop.* Santa Fe Institute.

Tajfel, H., Billig, M. G., Bundy, R. P., & Flament, C. (1971). Social categorization and intergroup behaviour. *European Journal of Social Psychology*, *1*(2), 149–178. doi: 10.1002/ejsp.2420010202

Yamagishi, T., & Kiyonari, T. (2000). The Group as the Container of Generalized Reciprocity. *Social Psychology Quarterly*, *63*(2), 116–132. doi: 10.2307/2695887

Zak, P. J., & Knack, S. (2001). Trust and Growth. *The Economic Journal*, *111*(470), 295–321.