COLLECTIVE ACTION, INSTITUTIONS AND THE EVOLUTION OF CENTRAL ASIAN IRRIGATION WATER GOVERNANCE

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SUMMARY

This Ph.D. research project focuses on the institutional analysis of irrigation water governance in Central Asia. The overall objective of the research work is to investigate how institutions influence the cooperative behavior of water users.

The thesis contains five chapters. The first chapter introduces the dissertation's general background and main research questions of the study. Empirical findings of chapters two and three are related to socio-experimental observations obtained from farmers of Turkistan's (Southern Kazakhstan's) Maktaaral and Uzbekistan's Samarkand regions. Chapter 4 employs a theoretical argumentation line based on evolutionary game theory. Chapter 5 concludes.

The second chapter answers the question of why cooperation happens among water users in Maktaaral and Samarkand subject to layers of information, cultural and exogenous institutional determinants. The chapter finds that farmers' cooperation is viable in an autonomous decision-making setting and that the top-down regulation crowds out the intrinsic motivation to work together. Furthermore, the chapter reveals that historical practices do not determine individuals' decision today and that panacea approaches to local water users' cooperation are unlikely to succeed. The third chapter answers the question of how cooperation or non-cooperation occurs and can be locked in at one or another convention. It traces the inherent dynamics of reaching different cooperative equilibria. The chapter confirms that the rural Central Asian water users' decisions in experiments are subject to multiple absorbing states with both inferior and superior efficiency. This chapter also unveils that, although the communication treatment (emulating self-governance arrangement) resulted in higher collective investment levels, such an opportunity did not guarantee the complete elimination of inferior conventions (equilibria) from best response play. The fourth chapter investigates the question of how and why the institutions of water governance in Central Asia changed. It finds that the pre-Tsarist Central Asian water governance setting, due to its synergetic and pluralistic aspects, was associated with higher efficiency than both Tsarist and Soviet periods. Civic-mindedness was found to be the behavioral preference and the fundamental trait granting the continuous accountable

traditional water self-governance. A small administrative intervention by the Tsarist regime shifted the equilibrium towards a regressive one due to endogenous dynamics, reflected in the corruption of the traditionally decentralized water governance in the region. Although there was an option of irrigation water privatization among the mitigation instruments, the ruling regimes in Central Asia ultimately shifted the governance towards full bureaucracy. The chapter suggests that eventually, although unintentionally, central water governance destroyed the water users' civic-mindedness. Finally, the fifth chapter synthesizes the research findings, indicates the contribution of the study to the international academic literature pool, summarizes the policy implications along with research limitations and identifies research questions as a promising starting point for future research.

Keywords: Water-management, self-governance, field experiment, cultural determinants, multiple dynamic equilibria, evolutionary game theory, investment traps, history, Central Asia

ZUSAMMENFASSUNG

Diese Arbeit konzentriert sich auf die institutionelle Analyse der Bewässerungswasser-Steuerung und das Wassermanagement in Zentralasien. Das übergeordnete Ziel der Forschungsarbeit besteht darin, zu untersuchen, wie Institutionen das kooperative Verhalten von Wassernutzern beeinflussen.

Die Dissertation setzt sich aus fünf Kapitel zusammen. Das erste Kapitel stellt den allgemeinen Hintergrund der Dissertation und die Hauptforschungsfragen der Studie vor. Die empirischen Ergebnisse der Kapitel zwei und drei beziehen sich auf sozio-experimentelle Daten, die von Landwirten (Wassernutzern) in Maktaaral (Turkistan, Südkazachstan) und in Samarkand (Usbekistan) erhoben wurden. Kapitel 4 verwendet eine theoretische Argumentationslinie, die auf evolutionärer Spieltheorie basiert. Kapitel 5 schließt ab.

Das zweite Kapitel beantwortet die Frage, warum die Zusammenarbeit zwischen Wassernutzern in Maktaaral und Samarkand stattfindet, abhängig von Informationsschichten, kulturellen und exogenen institutionellen Determinanten. Dieses Kapitel stellt fest, dass die Zusammenarbeit der Landwirte in einer autonomen (unabhängigen) Entscheidungsfindung möglich ist und dass die „top-down" Regulierung nach unten die intrinsische Motivation zur Zusammenarbeit verdrängt. Darüber hinaus zeigt es, dass historische Praktiken nicht die heutige Entscheidung des Einzelnen bestimmen und dass Panacea-Ansätze für die Zusammenarbeit der lokalen Wassernutzer wahrscheinlich nicht erfolgreich sind. Das dritte Kapitel beantwortet die Frage, wie Kooperation oder Nicht-Kooperation auftreten und in bestimmten Konventionen eingeschlossen werden können (lock-in). Es zeichnet die innere Dynamik des Erreichens verschiedener kooperativer Gleichgewichte nach. In diesem Kapitel wird bestätigt, dass die Entscheidungen der ländlichen Wassernutzer in den zentralasiatischen Ländern bei Experimenten von vielen Informationsquellen abhängen, wobei die Effizienz mal hoch, mal niedrig sein kann. Im dritten Kapitel wird zudem gezeigt, dass Kommunikation (die eine Selbstregulierungsvereinbarung nachahmt) ein höheres Niveau der kollektiven Investitionen zur Folge hat, dass eine solche Gelegenheit jedoch nicht die vollständige Beseitigung minderwertiger Abkommen (Gleichgewichte) gegenüber der besten Reaktion garantiert. Das vierte Kapitel untersucht die Frage, wie und warum sich die Institutionen des Wassermanagements in Zentralasien verändert haben. Das Kapitel stellt fest, dass die vor-zaristische Wasserpolitik in Zentralasien aufgrund ihrer synergetischen und pluralistischen Aspekte mit einer höheren Effizienz verbunden war als die zaristische und die sowjetische. Wie sich zeigt, ist ein Bürgersinn diejenige Verhaltenspräferenz, die maßgeblich die fortwährend verantwortungsbewusste Selbstverwaltung von Wasser gewährleistete. Kleine administrative Eingriffe des zaristischen Regimes führten aufgrund innerer Dynamiken zu einem regressiven Gleichgewicht, das zur Korruption der etablierten traditionellen dezentralen Wasserregierung in der Region führte. Obwohl es eine Möglichkeit für die Privatisierung von Bewässerungswasser gab, verlagerten die herrschenden Regime in Zentralasien letztendlich die Steuerung in Richtung einer vollständig bürokratischen Ordnung. In diesem Kapitel wird darauf hingedeutet, dass die zentrale Wassergovernance den Bürgersinn der Wassernutzer dadurch schließlich unbeabsichtigt abschaffte. Im fünften Kapitel werden die Forschungsergebnisse abschließend zusammengefasst, auf den Beitrag der Studie zur internationalen akademischen Literatur hingewiesen, die politischen Implikationen zusammen mit den Einschränkungen der Forschung zusammengefasst und Forschungsfragen als aussichtsreicher Ausgangspunkt für zukünftige Forschung identifiziert.

Schlagwörter: Wassermanagement, Selbstverwaltung, soziales Feldexperiment, kulturelle Determinanten, multiple dynamische Gleichgewichte, evolutionäre Spieltheorie, Investitionsfallen, Geschichte, Zentralasien.

TABLE OF CONTENTS

EXTENDED TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

AGRICHANGE	Institutional change in land and labor relations of Central Asia's irrigated agriculture (project)
CPR	Common Pool Resources
ESS	Evolutionarily Stable Strategy
IWRM	Integrated Water Resource Management
OLS	Ordinary Least Squares
RCT	Randomized Control Trial
SES	Social-Ecological-System
SSR	Soviet Socialist Republic
USSR	Union of Soviet Socialist Republics
WUA	Water User Association

1 GENERAL INTRODUCTION

1.1 Collective action problem

The *collective action problem* is one of the principal notions in the socio-environmental studies. The typical scenario of such a problem is as follows. There is a common and rival resource such as surface irrigation water, and there is an irrigation infrastructure (system) to maintain while there are several users. The irrigation water faces an overuse problem. In case of the irrigation system, users choose actions such as whether to build (or maintain) the infrastructure or not in an interdependent situation. To avoid the resource's unsustainable exploitation and abandonment of the irrigation system, all users should withhold (refrain) from short-term profit-maximizing use of the common pool resource (CPR) and overcome their own *free riding* temptation in collective investment decision making. Here is the point where the dilemma stems from. If user 'X' refrains from resource consumption, and or invests in infrastructure, but the rest of the users do not, then the CPR collapses and / or the irrigation infrastructure is not created anyway. That is, the suboptimal joint outcome is an equilibrium. What is more is that the user 'X' has given up the opportunity of the short-term benefit as well. This is the very reason that the commons are canonically postulated to end tragically and that the socially desirable outcome is predicted not to occur (Hardin, 1968; Ostrom, 2010).

The collective action problem symbolizes the *social dilemma* (or *coordination problem*) where human subjects face a situation where individual interests conflict with the group interests. Founders of European political philosophy including Thomas Hobbes along with classical economists like Adam Smith or John Stuart Mill all aspired to look for institutions that would address this very social dilemma. Because they believed that such an institutional solution for the dilemma would be pivotal in human wellbeing, for these philosophers and economists, the central question was: "how can social interaction be structured so that people are free to choose their actions while avoiding outcomes that none would have chosen?" Bowles (2004: 24) calls this the "*classical constitutional conundrum*".

Irrigation is a social-ecological system (SES). It is the complex adaptive classification where biophysical and social agents interact at multiple temporal and spatial dimensions (Janssen & Ostrom, 2006). Any irrigation water system faces two central challenges: the shared use of the CPR (water) and the collective generation of the public good (infrastructure). Coordination problems associated with the CPR use and the public good creation differ in one aspect: the sign of the direct effect of the other users' actions on one's utility are opposite. That is, CPRs are associated with negative externalities, and public goods are associated with positive externalities (Ostrom, 2010). In other words, the classical constitutional conundrum of fundamental economists and political philosophers is perfectly portrayed in challenges of the irrigation water systems.

Hardin’s tragedy of the commons highly influenced the so-called canonical expectations (analytical views). However, Hardin’s thesis has long been criticized as an oversimplification (Dietz et al., 2003). These oversimplifications are twofold: first is that Hardin claimed that there are only two institutional arrangments, namely, state (centralized government) and market (private property) which can sustain the commons over the long run. He presumed that resource users are trapped in such a dilemma and are unable to design their own solutions (Hardin, 1968; Platt, 1973). There are some theoretical confusions associated with the collective action problem (Ostrom, 2010). Hardin overlooked the point that in reality, many social groups including herders or water users have struggled successfully against threats of CPR degradation through establishing and maintaining self-governing (community) institutions (Dietz et al., 2003). That is, despite the expectedly dominant free riding outcome in such a social dilemma, there is empirical evidence revealing both cooperation and defection patterns among resource users (Uphoff, 1990; Lam, 1999; Sneath, 1999; Ostrom et al., 1999; Bardhan, 2000; Agrawal & Ostrom, 2001; Fujiie et al., 2005). It is also true that self-governance institutions did not ubiquitously become a success story, the same, however, is true for the other two alternative institutions (state and market), which were the preferred solutions of Garrett Hardin (Dietz et al., 2003).

1.2 *Coordination of cooperation*

So, market, state, and community are the major institutions mediating the continuous cooperation of individuals within different circumstances. These institutions carry different allocative consequences where conflicts of interests exist among actors whose interdependence is not governable with full contracts hence are prone to coordination failures. While every institution is efficient under particular circumstances, similarly each of them can fail if employed under inappropriate settings (Ouchi, 1980). We empirically discovered that there is no single-universal coordination mechanism solving all possible failures. Institutional *complementarity*: the synergy of the market, state, and community mechanisms instead seems to be a promising configuration in achieving truly good governance and foster sustainable cooperation (Bowles, 2004:494). However, the institutional complementarity is not always obtainable just through the combination of several governance mechanisms. So-called institutional *crowding out* is a possible ill-favored consequence of an inappropriate combination or effectuation (Bowles, 2004:495). State intervention with the aim of fostering cooperation but, in fact, destroying the community's capacity of self-governance is one such example (Bowles, 2008). The Central Asian water governance history offers some examples for the synergies with various consequences. Table 1-1 provides a brief overview of Central Asian irrigation water governance path, by focusing on three historical epochs of the region: pre-Tsarist, Tsarist and Soviet. This overview classifies each epoch's own water governance into practices leading to either institutional complementarity or crowding out consequences. We sort the traditional (Pre-Tsarist) water governance into the practice with the highest relative efficiency measure (symbolically denoted with ρ) due to prevailed institutional complementarity among all three epoch considered.

The rational choice model with its exclusively self-regarding preferences dominates economic theory and serves as an underpinning assumption in Hardin's thesis as well. Moreover, the explanations usually ignore the possibility of the existence of the social mechanisms to control self-interest, such as communication, trust, and the ability to make binding agreements (Dietz et al., 2001). However, there are alternative views regarding human preferences as people sometimes move beyond their self-interests and opt for cooperation instead of competition. Reciprocity, altruism, fairness, and trustworthiness are possible unconventional norms of behavior which coexist with self-regarding ones. (Ostrom, 2005; Fehr & Fischbacher, 2005).

Table 1-1: Brief overview of Central Asian irrigation water governance path

Central Asian irrigation water governance across selected epochs	**Governance structure**	**How did it function?**	**Characteristic of the way how coordination was approached**	**Outcome * [ρ: efficiency, social surplus]**
Pre-Tsarist Central Asia (Traditional)	Community-state-synergy	-Use of election-sanctioning mechanism; -Reliance on water users' free labor (annual khashar) -Federation of water management with attribute of pluralism -Second-order punishment enabling institutions as mahalla and waqf, which triggered continuous civic engagement of water users in self-governance interactions	Institutional **complementarity**-successfully and continuously handled the coordination	ρ_0 status quo
Tsarist Central Asia	State community-synergy	-Irrigation staff – civil servant -Reliance on water users' khashar	Institutional **crowding out** which led to weak community; coordination failure.	ρ_1
Soviet Central Asia	State	-Irrigation staff- civil servant (fixed wage) -Water user – worker with a fixed wage	**Coercive coordination** of cooperation with imperfect monitoring and enforcing instruments.	ρ_2

*Note: here the efficiency and respective distribution (absolute values) which increased due to technological shifts across the epochs are ignored, but instead the focus is given to the social surplus sourced from institutional settings. Consequently, the conditional values are: $\rho_0 > \rho_1$; $\rho_0 > \rho_2$;

Source: Author based on O'Hara (2000); Bowles (2004); Morrison (2008) and Obertreis (2017)

Whether the true behavior of real-life resource users inclines towards benevolence, public morality, or reciprocity and retaliation or else towards self-interest, free ride, rational egoism, what we know for sure is: when the resource is scarce and rival there is a need for coordination of interaction of those users, possibly endowed with meta-preferences. To avoid conflicts, to enhance the social surplus and, or to attain equity in such situations there is a need for institutions to govern the resource designed either by the group of users themselves based on common agreement, or else by some third party imposed rules (Wade, 1988). In either case, a principal purpose of any coordination institution is similar to what Hirschman (1985) mentioned, that is, to stigmatize self-regarding behavior and thereby to influence users' values and behaviour codes.

1.3. Central Asia

Historically the irrigated Central Asian territory is bounded on the north by the Syr Darya River Basin, on the south by the Kopet Dag Mountains and the Iranian Plateau, on the west by the Caspian Sea, and on the east by the Pamir and Tien Shan mountains. This region possesses a long history of irrigated agriculture, with salient water management systems and governance practices (Lewis, 1966; O'Hara, 2000). Irrigation systems diverged regionally, locally, over time and were interwoven with the social and political organization of the societies in Central Asia across different epochs (Obertreis, 2017).

The subsequent investigation here is restricted to irrigation water management in arid and semi-arid Central Asia. Water is very crucial for arid and semi-arid zones as a means of improving the total volume and reliability of agricultural production (Worthington, 2013) Therefore, the water issues are important for Central Asia, a region where the irrigated agriculture makes considerable economic significance, especially since these countries' national independence (Lerman, 2009). The countries of the region are facing complex and compelling water problems. Territorial expansion of irrigated agriculture during Tsarist and Soviet rule was not so immense, however the impact of continuous and unsustainable water withdrawal from the Syr Darya and the Amu Darya, to irrigate mostly cotton, have depleted and polluted the water and land endowments of the Aral Sea Basin (Glantz, 2005; Micklin, 2007; Saiko & Zonn, 2000).

Pervasive land degradation, ever increasing demand for irrigation, deteriorating water quality and droughts are among the major water-related troubles of Central Asia, which are in turn threatening human development and security. The fundamental water problem of Central Asia, however, is not the lack of water but rather its *mismanagement and bad-governance* (Lioubimtseva & Henebry, 2009).

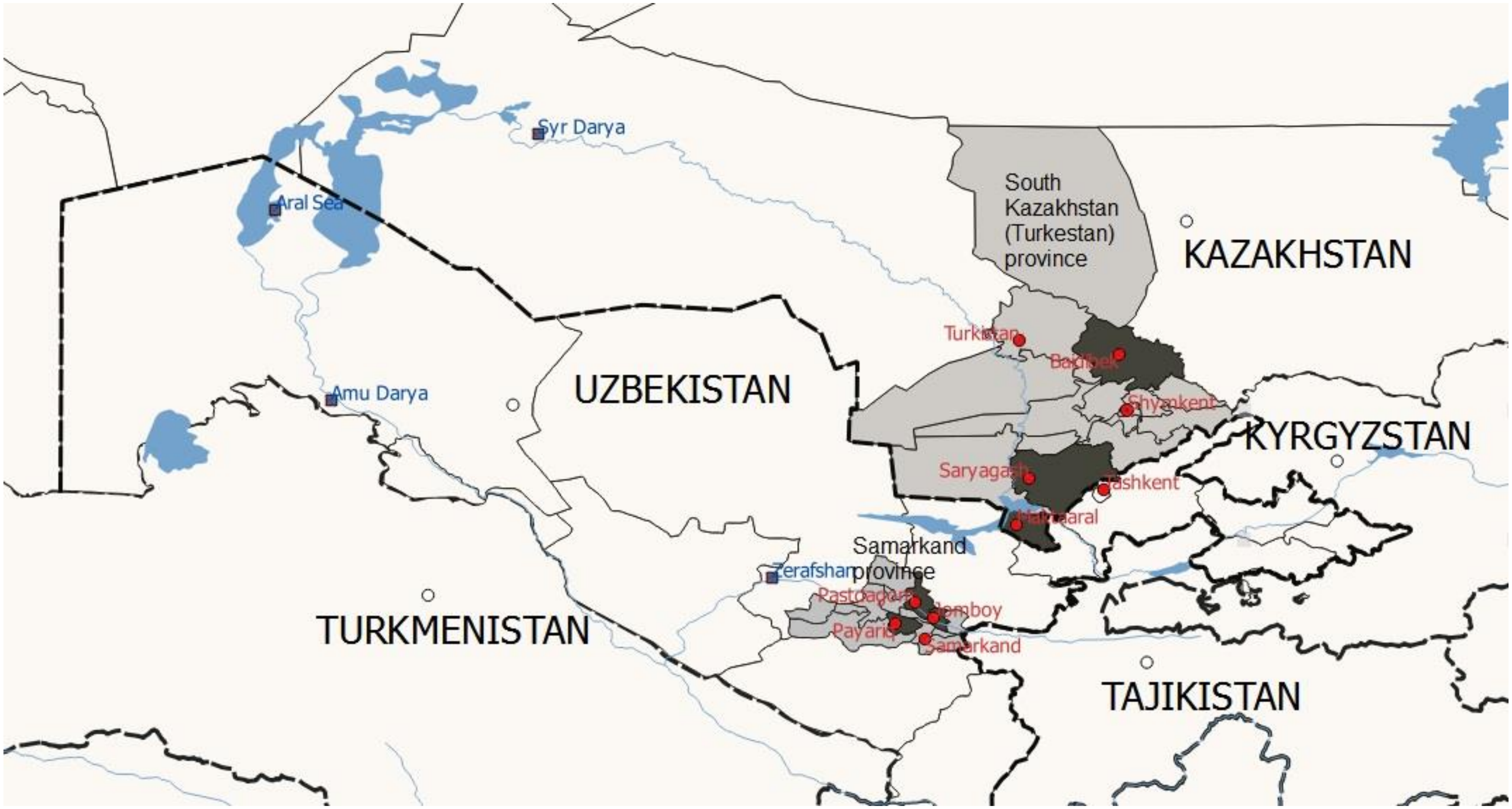
Irrigation water is the sector where the challenges and repercussions of coordination institutions and their transition (change) in Central Asia are showcased. Investigating the region in its aggregate form (i.e., generalizing them) probably does not produce much insight about its true contrasting picture. Thus, the current study conducts an (empirical) comparative analysis focusing on Kazakhstan and Uzbekistan.

Both for Kazakhstan and Uzbekistan irrigated agriculture has been of considerable significance before and after the collapse of the Soviet Union. Selection of these two countries for the comparative analyses is not a mere coincidence but instead due to a historical reason. Massive imperialistic cotton production ambition took its first start in the areas of current Kazakhstan and Uzbekistan. Correspondingly Russian gigantic irrigation projects such as the systems in Hungry Steppe were implemented in these two, now, politically independent countries (Obertreis, 2017; Morrison, 2008). After more than 25 years of national independence, we witness that most shares of irrigated land are still allocated for cotton production in both of the countries. Due to sunk cost rationale or due to path dependency South Kazakhstan (now named as Turkistan) and nearby located Samarkand are the major cotton producers of Kazakhstan and Uzbekistan respectively. Therefore, our empirical analysis focuses on Turkistan of Kazakhstan and Samarkand of Uzbekistan (Map 1-1). Furthermore Table 2-1 presents more detailed contrasting attributes of these two study sites with respect to their historical water management, post-independence role of agriculture, land tenure system, farm structuring, and their current water governance.

Due to agriculture's significance in their economies, all post-Soviet Central Asian Republics paid special attention to land reforms as part of their transition programs. Although every country's land reform varied from each other, in terms of degrees of state monopoly over agricultural land and central control over production decisions (Spoor, 1995), they all faced the common problem over water use and its management, which resulted from the individualization of agriculture (Abdullaev et al., 2009). The introduction of Integrated Water Resource Management (IWRM) principles was supposed to cure the emerging failure of water coordination. The implementation tool of the IWRM principles were Water Users Associations (WUAs). WUAs, as a re-invented self-governance organizational innovation, should have promoted a water governance system built on democratic principles (Zinzani, 2015). By doing so, they should have increased the water use efficiency, and they should have served as a conflict mitigating body (Veldwisch & Mollinga, 2013). But the implementation of this version of water decentralization has not yet achieved success in neither of the Central Asian countries (Wegerich, 2008; Yakubov, 2012; Abdullaev & Rakhmatullaev, 2013; Zinzani, 2015; Hamidov et al., 2015). Instead, there is empirical evidence revealing that since the start of the decentralization process, the irrigation infrastructure has eroded (Djanibekov et al., 2012).

Given the decentralization favoring political will of the post-Soviet Central Asian Republics, the social dilemma attributable to the irrigation system suggests that the ability of Central Asian water users to self-organize is a decisive factor of current water institutional change process in the region.

Map 1-1: AGRICHANGE project's study sites in Central Asia



Source: Miloserdova, Khabieva, & Djanibekov (2019)

1.4. Problem Statement

This dissertation was carried out in the framework of a research project ‘‘Institutional change in land and labor relations of Central Asia’s irrigated agriculture” (AGRICHANGE). Like the project does, this thesis focuses on irrigated Central Asia. Consequently, studying collective action in irrigation water governance of this region is the overarching objective of the research work. Its decomposed research objectives are introduced in Section 1.6. below.

- ***Determinants of water cooperation in Central Asia***

Many scholars recommend that local users should govern their CPRs including irrigation water themselves (Dietz et al., 2003; Ostrom, 2005). At the same time, these scholars recognize that one size fits all approaches should not be the solution in all social dilemmas associated with CPRs. Trust is among the crucial factors playing a central role in influencing the prospects of self-governance (Poteete et al., 2010: 223). Today’s post-Soviet Central Asia is a world region with a reputation of low levels of trust among individuals (Rose-Ackerman, 2001). With such characteristic, the region’s struggle to establish real civil society and functional grassroots organizations (Omelicheva, 2015) indeed does not seem just a coincidence. Consequently, attempts to create self-governance principle in the form of WUAs with mostly unsatisfactory results are as if revealing the self-governance potential of Central Asian water users. But the top-down nature, which is a widely acknowledged way of WUAs’ establishment in the region (Abdullaev et al., 2009) lets us to say little about the self-organizing ability of the Central Asian water users, but rather it implicitly evidences about external rule’s crowding out effect.

So, why water users do or do not cooperate in water self-governance in the region remains an unaddressed question until now. This dissertation aims to close this gap.

- ***Twofold observations in water self-governance***

The Prisoner’s Dilemma game, with the free-riding option being the only dominant solution, is a default setting to model water users’ interaction. Hardin’s tragedy stands on the logic of the Prisoner’s Dilemma, where players are assumed to interact only once, symmetrically possess full knowledge and are endowed with only self-regarding preference. Many experimental studies found that, indeed, more than half of the experimented human subjects exhibit reciprocal preference rather than purely self-regarding one (Fehr & Fischbacher, 2005). It makes sense to include this kind of observations (deviations to canonical expectations) into the modelling exercise. Moreover, albeit the dominant free riding outcome in a social dilemma such as water self-governance, there is accumulated empirical evidence, from different cultural and economic settings, that reveals both cooperation and defection patterns among water users (Bardhan, 2000). In game theoretic modelling language, such twofold empirical observations are interpreted as the interactions having multiple equilibria. The theoretical explanations for multiple equilibria either through an Assurance game (with a payoff structure alternative to the Prisoner's Dilemma) or through the iteration of a Prisoner's Dilemma are well established in the literature (Friedman, 1971; Trivers 1971; Axelrod & Hamilton 1981; Taylor, 1987, Cosmides & Tooby 1989). However, the question if rural Central Asian water users are subject to such multiple equilibria where the interactions can be trapped in good (cooperative) or bad (defective) outcomes remained open till now.

- ***Modelling the evolution of water governance arrangements***

Institutional success is a crucial element of overall economic development. The structure of institutions constitutes the framework of social life. Hence it dramatically influences the success or failure of cooperation and thus the prosperity in a community and eventually in the society (Knight, 1992). The Central Asian past reveals supportive evidence for the importance of cooperation-inducing arrangements in the society's prosperity (O'Hara, 2000). The history of the region indicates that it had prosperous stages of existence during exactly those times when the society of the region could establish a traditional system of sustainable cooperative behavior, which integrated several institutions in itself and achieved institutional complementarity effects. Table 1-1 provides the respective supportive arguments from the irrigation management path of Central Asia. There is an international literature quite thoroughly describing the evolution of water governance arrangements in Central Asia (e.g., O'Hara, 2000; Morrison, 2008;

Abdullaev & Rakhmatullaev, 2013; Obertreis, 2017). However, there is a lack of analytical literature studying the water governance history of Central Asia. This dissertation attempts to address this scarcity as well.

The importance and the value addition of the dissertation stand on its answers to the three main research inquiries. Firstly, the thesis digs into the exogenous factors of cooperation in water management in two countries of Central Asia with common but also different history, along with diverse post-independence trajectories of governmentality and economic development paths. Secondly, the research work sheds some light on why and how the continuous underinvestment in irrigation infrastructure in the region is taking place and how that vicious circle can be demolished with the acknowledgment of endogenous dynamics. Thirdly, the thesis systematically explains why the particular path of evolution of water governance institutions took place in Central Asia by endogenizing institutions and preferences into the analytical model.

To summarize, the *collective action concept* is the theoretical focus of the study. The study takes a long-run, evolutionary perspective. *Evolutionary game theory* is the modelling tool. *The irrigation water system* is the common good (with public good nature as well) I picked to focus on throughout the dissertation. *Central Asia* is the study region the whole research refers to. Maktaaral of Turkistan (Kazakhstan) and Samarkand of Uzbekistan are the study sites of the empirical part of the research work.

1.5. Evolutionary game theory

Evolutionary game theory relaxes the common knowledge and common rationality assumptions and rather relies on empirically (experimentally) grounded assumptions about how real life people interact. Usually, evolutionary game theory assumes that decision makers possess limited information about the consequences of their own decisions. Furthermore, these individuals are assumed to update their preferences (beliefs) based on a trial and error approach through the use of local knowledge, mainly sourced from their own experience. In other words, in contrast to classical game theory's highly cognitive and forward-looking players, the evolutionary game theory's players are backward looking and only boundedly rational (Bowles, 2004: 53).

The evolutionary-analytical character of this dissertation is explicitly reflected in the way individual behaviour is modelled (in Chapters 3 and 4), in the population or N-person level dynamics (in Chapters 3 and 4), and in the analysis through which the water users' behaviours (preferences) and water governance institutions (conventions) coevolve (in Chapter 4). Findings of Chapter 2 provide supportive evidence for the prevalence of alternative preferences (one could also name them as social preferences) to self-regarding ones. The prevalence of social preferences, being part of evolutionary game theory, potentially explains why individuals more often cooperate toward the common good, and why short-term incentive schemes (such as penalizing defectors) sometimes fail to boost cooperation and crowd-out intrinsic motivation to work together instead. Moreover, the evolutionary analytical perspective is evident in the absence of diagnostic blueprints that is, the scrutiny in Chapter 2 captures the idiosyncrasies at community (village) levels. This finding, then, is used to warn policymakers against one-size-fits-all like approaches in the process of water decentralization.

1.6. Research questions and contributions

The advancement in the understanding of the collective action problem including its reasons, and the variety of (dys) functional cooperation coordination mechanisms attributable to the Central Asian water governance are the overarching objective of the dissertation.

The three main (guiding) research questions of the thesis are as follows:

1. Why does cooperation (non-cooperation) happen among Kazakhstani and Uzbekistani water users?
2. How does water cooperation (non-cooperation) occur and how is it locked in one or another equilibrium?
3. How and why did the institutions of water governance in Central Asia change?

To answer the first and second research questions, the thesis uses artefactual (social-science) field experiments; to address the third question the research work employs a theoretical argumentation line based on evolutionary game theory. Chapter two, three and four respectively answer the major research questions of this dissertation.

Chapter 2 contributes to the understanding of long- and short-term determinants of cooperation among water users. The results of the analysis in this chapter suggest that sustainable self-governance of water resources is viable in Central Asia, the world region that has a reputation for low levels of generalized trust among individuals. The analysis also warns about heterogonous coordinative capacity across villages depending on the skills of community members to bargain and to carry out the deliberation, which closely resembles the policy criticism regarding one-formula-fits-all approach.

By using the experimental field data described in chapter 2, chapter 3 integrates evolutionary game theory into an empirical analysis such that the corollaries of the theoretical model are directly tested with the experimental database. Therefore, chapter 3 provides new insight into the processes of cooperation or non-cooperation in irrigation water management. Findings demonstrate the presence of autoregressive lock-ins in collective investment decisions. Chapter 3 concludes that institutional arrangements which allow user participation, give users the power to bargain and provide opportunities to devise endogenous rules are promising candidates for breaking the vicious circle of underinvestment in irrigation infrastructure in a region as Central Asia.

By analyzing three epochs (pre-Tsarist, Tsarist and Soviet) of Central Asia, Chapter 4 compares a range of coordination mechanisms (institutions) of water governance in the efficiency spectrum. This chapter, by using extensions of the evolutionary Hawk-Dove game, finds that the traditional water governance setting, due to its synergetic and pluralistic aspects rewarding civic engagement of water users, was more efficient than both Tsarist and Soviet periods. Although modelling history with such games might not fully capture the real, complex nature of water governance evolution, such an analytical approach and its respective results can guide contemporary Central Asia which direction to look both in the diagnosis of the problem and in its solution.

1.7. Research Outline

This dissertation is organized as follows. There are three main, separate, and non-consecutive chapters: two, three, and four. Chapter 2 and Chapter 3 employ the experimental method and accordingly include analyses of experimental data generated from sessions with 235 rural Central Asian farmers from the irrigated zones. Chapter 4 uses a theoretical argumentation line and enriches it with historical observations.

Chapter 2 investigates determinants of water users' cooperation subject to short- and long-term factors. The subsequent Chapter 3 presents investment traps in collective water governance and traces the inherent dynamics of reaching different cooperative equilibria. Chapter 4 models the evolution of water governance in Central Asia by fixating focus on three historical epochs. Chapter 5 summarizes the dissertation's research questions, respective findings and policy implications. Moreover, this chapter discusses some limitations along with a list of potential research questions to stimulate further research.

2 LONG- AND SHORT-TERM DETERMINANTS OF WATER USER COOPERATION: EXPERIMENTAL EVIDENCE FROM CENTRAL ASIA[1]

2.1 Introduction

At least since Hardin's (1968) publication of the "tragedy of the commons", how to prevent natural resources from over-exploitation has been a long-standing matter of academic and practical debate. Today many scholars argue that resources such as water, pastures or forests should be managed by local communities based on self-management principles rather than subjected to command and control regulation by a central government authority (Dietz et al., 2003; Pretty, 2003; Ostrom, 2005).

Yet the literature also increasingly acknowledges that arrangements for natural resource management which work in some places cannot be easily transplanted to others and that some countries or cultures may even be less suitable for local resource management models than others. For example, experimental work in fifteen indigenous societies found enormous variation in the levels of individual selfishness or in willingness to contribute to the public good (Henrich et al., 2004). The prolific literature on social capital recognizes that mutual trust among individuals and the inclination to cooperate vary a lot across localities and may obstruct their long-term prosperity (e.g. Putnam et al., 1993; Knack & Keefer 1997; Guiso et al., 2004). Views widely differ, however, to what extent such social capital is pre-determined by cultural endowments and historical antecedents that resist any short-run modification. If this was the case, policymakers can hardly hope to promote local cooperation by institutional reforms or other interventions, a view that runs counter to the very idea of development policy.

In this chapter, we focus on Central Asia, a world region that has a reputation for low levels of generalized trust among individuals (Rose-Ackermann, 2001) and that struggles to establish a vibrant civil society and effective grassroots organizations (Omelicheva, 2015). Attempts by international donors to promote

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principles of Integrated Water Resources Management (IWRM) in the region have been decisively mixed (Yakubov, 2012; Zinzani, 2015). By modifying a field experimental setting due to Cárdenas et al. (2011), we investigate the contributions of individual farmers to a public irrigation infrastructure in two agricultural regions of Kazakhstan and Uzbekistan. Our interest focuses on the following questions: How does the self-governance of farmers affect their contributions to the public infrastructure compared to exogenous regulation based on penalizing defectors? How effective are such short-term alterations of incentives in relation to long-term cultural factors? What can thus be learned for the prospects of self-governed water management in these regions?

Our experiments were conducted in twelve villages in South Kazakhstan (Maktaaral district) and Samarkand provinces in 2016, involving 235 farmers in a total of 47 sessions. We chose the villages according to their up-, mid-, and downstream location along major irrigation canals. During the experiments, farmers obtained an endowment to be allocated either for private consumption or to a public irrigation fund. Depending on the size of the irrigation fund, water availability and thus returns from farming for individual farmers increased. Based on experimental protocols developed by Cárdenas et al. (2011) and a regression analysis of the data, we test the effect of two treatments on the share of farmers' budget dedicated to the irrigation fund: group-internal communication during the experiments as a facilitator of self-governance and penalties for defectors as a form of external regulation.

In addition, we selected the experimental locations in a way that allows comparison of country and possibly cultural influences. Our two study sites have a very different history of irrigation development and, since the collapse of the Soviet Union, belong to two independent states with specific policy contexts. Irrigation in Samarkand had been managed at the community level since ancient times. Local water consumers used to elect and sanction water masters (mirabs) for centuries (O'Hara, 2000). To the contrary, large-scale irrigation infrastructure and bureaucracy were brought to South Kazakhstan only by the Soviets in the early 20th century (Obertreis, 2017). Since independence, however, Kazakhstan has moved further towards a decentralized system of water management than Uzbekistan, and agricultural water policy has been more liberal (Zinzani, 2015). At the same time, the majority populations in the two study sites share a Turkic ethnicity and Muslim religion as well as a history of first Russian and then Soviet political control.

Against the stereotype that trust and the self-organizing power of citizens in the post-Soviet societies are underdeveloped, we find that the option to communicate within the group of users increased individuals' commitments to the common pool in a statistically significant way. While this is now a standard result in the literature (Cárdenas & Ostrom 2004; Cárdenas et al., 2011), our study is among the first to confirm it for water cooperation in Central Asia and the post-Soviet realm in general. Consistent with research on the crowding out of publicly spirited behaviour by government regulation (Bowles, 2008), we also find that strong penalties reduce individual contributions. However, this effect was statistically significant only in our Kazakhstani site. Across our core econometric specifications, water users in Kazakhstan contributed significantly more to the irrigation infrastructure than those in Uzbekistan. Even so, differences between villages irrespective of their location in either one of the countries were even more pronounced than between countries per se.

These results allow us to speculate about the long- and short-term drivers of water cooperation in Central Asia. We don't find evidence that cooperation is more prevalent in societies that have a long-standing tradition of labour- and coordination-intensive agriculture (such as in the irrigated areas of Uzbekistan). This result disagrees with studies such as by Talhelm et al. (2014) trying to establish a "rice theory of culture" but supports Carnap (2017) arguing that there were no clear-cut connections between historical agricultural practices and current levels of social capital in India. Our findings suggest that in comparison with paternalistic Uzbekistan, the more liberal style of local governance in post-independence Kazakhstan encouraged individual cooperation.

Our results thus call into question the long-term cultural determination of local cooperation. They rather suggest that short-term policy modifications of water users' interaction may well have relevant effects on cooperation outcomes. In our study sites, other than top-down regulation, autonomous interaction by group members can improve their willingness to contribute to the common good. At the same time, the general inclination to work together was highly location specific. Taken together, these experimental results should encourage policymakers in Central Asia to pursue an agenda of decentralization and local self-governance for water management.

The next section briefly reviews the literature describing both short-and long-term determinants of cooperation in the commons in an experimental and cultural context. Section 2.3 explores the historical and current patterns of irrigation management in Central Asia. Section 2.4 elaborates on how field experiments capture context and inform policy. Section 2.5, then, gives the core hypotheses of the study and provides insights into our experimental design and methodology. Section 2.6 presents the results to be discussed in the context of the literature, and section 2.7 concludes.

2.2 Determinants of cooperation in the commons

2.2.1 Information layers

The management of common pool resources (CPRs) represents a social dilemma, where human subjects face a situation in which individual interest conflicts with group interests. Consequently, organizing users' groups to achieve a collective solution is prone to free riding (Hardin, 1968). To understand how it could be overcome, Cárdenas and Ostrom (2004) ask how individuals make decisions concerning the use of natural resources within a group context and how those individuals come up with self-governed solutions mitigating the unsustainable exploitation of CPRs. They suggest that the participants of the experiment transform the material payoffs into a subjective-internal game in the field, driven by three categories of variables: (i) the material payoff of the game, (ii) the group-context and (iii) identity layer variables.

The information belonging to the *material-payoff* layer is the common knowledge of formally introduced rules of the game. Furthermore, the decisions of the individual might depend on how much that person knows about other participants of the game. The *group* composition knowledge thus refers to processes of reciprocity and retaliation, which might affect the level of trust and, thus, the cooperation decisions. Additionally, there are some types of information which are possessed or stored by the individuals themselves. This type of information about their *identity* is not conditional on others' behaviour in the game, but rather reflects the players' own characteristics, cultural and moral values, perceptions and experiences (Cárdenas & Ostrom, 2004).

This multi-layer framework helps to explain how other factors than short-run material payoffs will affect the cooperation decision of actors. In fact, the layers may make cooperation the best response in the internally re-constructed game. But they also illustrate how some of these factors may be influenced by on-the-spot alterations of material payoffs, whereas others are predetermined by long-term processes of socialization and cultural identity formation. This distinction has important implications for the extent to which cooperation can be influenced by policy measures, as they typically affect material payoffs only. If in a given empirical setting, cooperation outcomes are largely driven by material payoffs rather than culture, institutional and policy reforms will have much bigger leverage to affect these outcomes.

2.2.2 Treatments as stylized interventions

In experimental research, two widely studied options for influencing cooperative outcomes include endogenous cooperation via communication and external regulation via penalties. Laboratory experiments extensively proved the positive effect of *communication* on individuals' decision to cooperate in a repeated common pool resource environment. Ostrom & Walker (1991) found that when the communication was costless, players were able to successfully use this opportunity to efficiently improve their own understanding of the game settings, devise verbal agreements over the implementation of strategies and deal with non-conforming players. Furthermore, sanctioning opportunities, on a volunteer and majority-rule base, enabled the groups to achieve the highest average net yield (Ostrom et al., 1994). Furthermore, Cárdenas et al. (2011) detected similar positive effects of communication on cooperation decisions in a field experimental study with Colombian and Kenyan CPR users under anonymous individual decision making.

On the other hand, when faced with a credible *threat of punishment*, free riders will be induced to cooperate as well (Falk et al., 2002). Tenbrusel & Messick (1999) found that in dilemma situations, cheating was more likely to occur when sanctioning was weak. They also found evidence that sanctions made more people think of the decision as a business decision rather than an ethical one. When sanctions were high, cooperation could only be induced for the individuals who considered the decisions to be a business problem. However, Andreoni & Varian (1999) argue that the implementation of explicit incentive devices in the form of sanctions may also be damaging as they might crowd-out voluntary cooperation. If sanctions signal that selfishness is an appropriate response, if they compromise individuals' sense of self-determination, or if they convey an atmosphere of distrust or unfair treatment, they are likely to undermine the inclination to contribute to the common good (Bowles, 2008). Cárdenas et al. (2011) found a positive high-penalty effect as opposed to a negative effect of low-penalty treatment, thus supporting Tenbrusel & Messick's findings.

2.2.3 Long-term determinants

The long-term determinants of cooperation have recently become the focus of empirical work using the concept of social capital, such as norms of reciprocity and networks of civic engagement (Putnam et al., 1993: 167). Carnap (2017) reviews the literature showing how agricultural practices and agro-ecological conditions of the past continue to exert an influence on the current-day organization of cooperation. This work has become more fine-grained and focusing on specific subgroups of populations or societies. For example, Cohen et al. (1996) analyzed behavioural differences between US males grown up in Northern or Southern states of the US to argue that descendants of pastoralists (the Southerners) display more aggressive behaviour than those of crop farmers (the Northerners), as they were used to defend their territory. Northerners, on the other hand, were more inclined to cooperate and coordinate. In their "rice theory of culture", Talhelm et al. (2014) show that Chinese students originating from rice-growing regions displayed more interdependent and collectivist behaviour than students from wheat growing regions. They argue that rice growing needs much more coordination and interpersonal exchange in irrigation and labour management.

Cultural predispositions may make short-run policies more or less effective. For example, Cárdenas & Ostrom (2004) provide evidence of stronger externally introduced rule compliance among participants who self-classified as "state-believers", i.e. players who indicated that the state organization should take care of local CPR management. According to Wittfogel's (1957) classic theory of "hydraulic societies", the need to coordinate water management fostered the emergence of strong and hierarchically structured states based on rule compliance. On the other hand, more "individualistic" societies may be more inclined to rely on grassroots organization and self-governance. In particular, the degree of autonomy that local communities enjoy vis-à-vis a central government has been shown to be a decisive factor in improving local self-management of the commons (Wade 1989; Ostrom, 2005: 219-254).

2.3 The context of irrigation management in post-Soviet Central Asia

2.3.1 From ancient to Soviet water management practices

Dominated by low-lying deserts and flanked by extensive mountain ranges, the Central Asia region has been dependent on irrigation water conveyed by river streams since the beginning of civilization (O'Hara 2000). Water availability determined the location of early settlements, but ancient agricultural producers learned how to use this scarce resource as effectively as possible by establishing widely branched irrigation networks, water lifts, and accompanying management systems (Abdullaev & Rakhmatullaev 2013; Dukhovny & Schutter 2011). Ancient cities like Bukhara, Samarkand or Merv thrived on their ability to economize on the precious resource. Archaeologists and historical geographers documented how traditional water management relied on a highly hierarchical system of water masters (mirabs) who nevertheless were accountable to the water user communities. Specifically, the water masters were elected by water users and were paid a portion of the grain harvest, thus providing incentives for productive water management (O'Hara, 2000: 373). Historic water user associations (ketmans) encompassing several villages were responsible for the local maintenance of the irrigation system and entrusted elders (aksakals) to decide about water distribution. Accountable to their local neighbourhood community (mahalla), elders would conscript the water users for regular construction and maintenance work (Dadabaev, 2017a). Villagers who refused to take part in labour mobilization campaigns (hashar) would be fined or denied access to land and water.

The advent of first Russian Tsarist and later Soviet control of Central Asia in the early twentieth century undermined the traditional systems of water management. It replaced them with a state-run water bureaucracy detached from the finely calibrated incentive systems that had ensured productive water use for centuries (O'Hara, 2000). Central Asia became a major cotton exporter to the rest of the Soviet Union, as vast areas of former desert and steppe land was turned into irrigated cotton plantations (Dukhovny & Schutter, 2011; Obertreis, 2017). For example, major land development took place in the Hunger Steppe, including the Maktaaral district of the then Kazakh Soviet Socialist Republic (SSR), and in the Vaksh river valley in the Tajik SSR. Under the order of Moscow, massive canal structures were constructed and local decision making was replaced by scientifically determined irrigation norms administered by agricultural and water ministries and their local agencies. Workers from other parts of the Soviet Union or formerly nomadic Kazakhs were settled in the newly developed territories (Obertreis, 2017). In the existing settlements, social institutions such as the neighbourhood community were absorbed by the collective and state farms established by the Soviets (kolkhozes and sovkhozes; Sievers, 2002). As in other parts of the Soviet economy, coordination failures, inefficiencies and the squandering of resources loomed largely. However, access to water was no longer regarded as a problem: "Diversion schemes brought what seemed to many an infinite supply of free water; the population, who had long viewed water as a scarce commodity, forgot its worth" (O'Hara, 2000: 376). Considered nowadays one of the biggest environmental disasters of humankind, extensive irrigation led to the almost complete desiccation of the Aral Sea (Micklin et al., 2014).

The disintegration of the Soviet Union in 1991 left the independent republics of Central Asia with a legacy of dilapidated irrigation networks, an inefficient and underfunded water administration, a cotton monoculture planted on increasingly salinized soils and the challenge to develop a strategy for their agricultural sectors (Saiko & Zonn, 2000; Lioubimtseva & Henerby, 2009). Administrative borders between the former Soviet republics that were almost invisible before suddenly raised the question of who would be entitled to use the water resources of the major transboundary rivers. Each independent republic embarked on a process of national identity formation that also led to different styles of governmentality and economic development strategies. Despite the common Soviet history, notable differences emerged between the two most populated countries of the region, Kazakhstan and Uzbekistan.

2.3.2 Governance approaches in independent Kazakhstan and Uzbekistan

Since independence, both Kazakhstan and Uzbekistan have been ruled by long-standing presidents who had been appointed as party leaders already during the late Soviet Union. However, referring to popular perceptions, Adams & Rustemova (2009, 1272) described state leadership in Kazakhstan as “managerial, flexible and pragmatic”, whereas Uzbekistan’s government was seen as “paternalistic and dogmatic”. The authors’ review of the recent academic literature suggests that these attributes of governmentality in both countries may reflect historic agro-ecological characteristics of the two nations:

“The nomadic Kazakhs had loose governmental structures that required consensus among various leaders, thus permitting them considerable autonomy, whereas sedentary societies such as that of the Tajiks and Uzbeks … required strong central control, rewarding submission to the needs of the group, which leads to monitoring and control over individual behaviour. … State centralization in Kazakhstan may also be hampered by the vastness of the territory and low density of Kazakhstan’s population, … [which] led to an elite at the time of independence that was divided ethnically and regionally fragmented, pulling the state in various directions and resulting in a greater diversity of policy and greater pragmatism”. On the other hand, “Uzbekistan’s dense rural population and the distribution of water for the irrigation-dependent agriculture that makes up a large part of Uzbekistan’s economy make it a ‘hydraulic economy’” (p. 1274).

We concur with Adams & Rustemova that such historical determinism should be critically scrutinized, yet the agricultural reform paths chosen in both countries after independence and subsequent scholarly analysis lend some support to the general tendency (Table 2-1). Kazakhstan followed a course of gradual liberalisation of agriculture, dismantled the former collective farms and introduced private land ownership in 2003 (Petrick & Pomfret, 2018). In South Kazakhstan province, currently, about half of the land is used by individual farms. The remaining land remains in state farms or private agricultural enterprises. On average, individual farms in South Kazakhstan cultivate much less land than similarly organized farms in the rest of the country, about 6 hectares of arable land per farm. A private cotton export sector had emerged in the 1990s that re-attracted government attention only recently (Petrick et al., 2017).

Table 2-1: The two study sites in comparison

	Maktaaral (Kazakhstan)	**Samarkand (Uzbekistan)**
Historical water management practices	Soviet land & irrigation development, water bureaucracy	Ancient irrigation systems based on communally accountable water masters, widely deformed during Soviet rule
Post-independence strategic role of agriculture	Production widely liberalized, the emergence of a private cotton chain, recent subsidy increases	Cotton & wheat considered strategic crops, state-mandated delivery quotas, price controls
Land tenure	Private land ownership possible, long-term leases of state land	Long-term leases, state-mandated land allocations to strategic crops
Farm restructuring	Dissolution of state farms in the early 1990s, av. the cotton farm has 6 ha of land	Land distribution after 1998, reconsolidation after 2008, av. the cotton farm has about 60 ha of land
Water governance	Formation of water user associations in the 1990s, state water agency	Partly dysfunctional water user associations est. after 2003, central planning of water allocation prioritizing irrigation of strategic crops

Source: authors.

To the contrary, Uzbekistan left the existing state administration of cotton production widely intact and sweepingly introduced private farms only in the 2000s (Pomfret, 2008). This combination created a very particular Uzbekistani individual farmer who “has to bear the contradictions of being a state-steered, but privately owned, family managed enterprise” and who faces indirect taxation for production of state order crops such as wheat and cotton (Trevisani, 2007: 150). On a more general level, in Uzbekistan, “the state is still perceived by the people as the most legitimate organization for meeting their needs. The fundamental respect for the state as a legitimate representative institution is maintained in the minds of the people and is rooted in the Soviet-era political traditions and mindset in which the government was expected to provide an adequate living standard while the people did not challenge its authority” (Dadabaev et al., 2017: 17). The traditional institution of the Uzbekistani neighbourhood community (mahalla) underwent a gradual transformation that turned it into a hybrid organization increasingly integrated into official legislation and co-opted by the government to exercise control over its citizens. This process started under Soviet rule and was further promoted after political independence (Sievers, 2002; Dadabaev, 2017a).

2.3.3 The advent of Integrated Water Resource Management

Under the influence of international donors, both Kazakhstan and Uzbekistan considered the introduction of IWRM principles to tackle the long-standing challenges in irrigation management (Dukhovny & Schutter, 2011; Zinzani, 2015). IWRM as a policy framework emerged from the principles endorsed by the International Conference on Water and the Environment held in Dublin in 1991 ("Dublin principles"). Found in several variations in the literature, the main prescriptions of IWRM include that (a) as a finite resource, water should be managed within natural hydrologic boundaries of rivers or catchment areas, (b) decisions about water management should involve the participation of all users at the lowest appropriate level, and (c) water should be treated as an economic good (Woodhouse & Muller, 2016; Zinzani, 2015). In Central Asia, donors but also governments supported the establishment of Water Users Associations (WUAs) as a key strategy of IWRM (Abdullaev & Rakhmatullaev, 2013; Barrett et al., 2017). Implemented at different scales, often within the boundaries of former collective farms, donors envisioned WUAs as self-governing bodies of water users promoting the democratization of water management, improving water use efficiency and lowering costs and defusing conflicts (Veldwisch & Mollinga 2013).

Again, Kazakhstan introduced WUAs earlier than Uzbekistan and went further in granting them autonomy from state administration. However, local implementation proved difficult in either of the countries, as top-down government initiatives often conflicted with donor interests favoring bottom-up mobilization of water users, and because of the rapid increase in the number of individual farms, changes in cropping patterns, generally poor financial and technical capacity of the new organisations, lacking leadership skills, and the persistence of mandatory state deliveries in Uzbekistan (Abdullaev & Rakhmatullaev 2013; Barrett et al., 2017; Hamidov et al., 2015; Veldwisch & Mollinga 2013).

2.4 How field experiments capture context and inform policy

2.4.1 The role of cultural context

Because they allow the isolation of individual factors influencing cooperative outcomes while still providing a contextual frame to real-world decision makers familiar with that context, field experiments have become increasingly popular among social scientists (Baldassarri & Abascal, 2017). Within a spectrum ranging from laboratory experiments to observational studies, researchers conducting field experiments thus steer a middle ground between internal validity (does the study provide an unbiased estimate of a causal effect?) and external validity (does the effect prevail in other contexts too?). In contrast to laboratory experiments, field experiments are conducted with subjects belonging to a target population of interest to the study question, often in or near their place of residence. Experiments are framed by making explicit how the task and information set offered to participants relates to their everyday practice. In this way, contextual triggers and heuristics attached to the field setting are captured that may substantially influence behaviour in the experiment (Harrison & List, 2004).

Of course, even a field experimental setting abstracts from the real life of participants. Combining experimental results with other methods and complementary data may ease this constraint. By including data from post-experimental surveys into a regression analysis of experimental cooperation outcomes, Cárdenas & Ostrom (2004) show that contextual variables indeed do influence how people decide in field experiments – such as demographic or group characteristics. Our results below support this finding.

Field experiments are also used to study the effect of varying cultural context explicitly. A fixed experimental design allows controlling some of the incentives to which subjects are exposed, while the choice of the field setting serves to capture the cultural context prevailing in that particular setting and thus introduces cultural variation into the experiment. In this way, Henrich et al. (2004) studied the effect of culture on pro-social behaviour among humans in fifteen indigenous societies. Talhelm et al. (2014) compared the behaviour of students originating from two culturally different parts of China. Again, while culture is an amorphous concept, controlling for observable individual or group characteristics helps to pinpoint what aspect of culture is actually studied and how its influence could be separated from other confounders.

2.4.2 Field experiments and policy evaluation

Roth (1995) distinguishes three uses of experimentation: (a) "speaking to theorists", (b) "searching for facts" and (c) "whispering in the ears of princes". The latter, informing policymakers, has been a recurrent aim of experimental work, although at different levels of abstraction. Recent literature drawing on randomized control trials (RCTs) to test specific policy packages in developing countries declares upscaling as a major goal (Banerjee et al., 2016). Many other studies engage in a dialogue between theory, empirics, and policy-making at a more abstract level. Challenging theoretical propositions may call into question the very foundations of certain policy approaches. For example, evidence of pro-social behaviour in field experiments suggests that command and control may not be the only or even best policy option to avert the "tragedy of the commons". At the same time, to what extent members of a certain community in fact voluntarily engage in the provision of public goods is a largely empirical question to which standardized experiments can give a meaningful answer (Cárdenas et al., 2011). Knowing which sort of stylised intervention promotes pro-sociality in a given context may give important hints for specific policy instruments to be developed in a later step. Moreover, experimental evidence suggests that some interventions may even have counterproductive effects and that small differences in institutional design may result in very different aggregate outcomes (Bowles, 2008).

2.4.3 Field experiments and IWRM in Central Asia

Our experimental setting described below aims precisely at this stylised level that allows validating behavioural assumptions in a given cultural context and tests their implications for the viability of policy approaches. We take issue with the second and third IWRM prescription by examining the willingness of water users to contribute to the maintenance of irrigation infrastructure in different policy and cultural settings. The experiments draw on the idea that water is an economic good the reliable access to which requires investment, involving costs and benefits. Specifically, we investigate how real water users engage in a process of local self-governance that is influenced by different policies. In our "communication treatment", we give farmers the opportunity to deliberate their options, revise their behavioural strategies based on new information and collective learning, and thus participate in local decision making. This process is "integrated" in the sense that it takes into account the water needs of both up-, mid-, and downstream users (Schlüter et al., 2010: 622). We test the effect of such a policy design against the alternatives of "no communication" and "penalties" levied by a local "enforcement agent". While this experimental setting abstracts from many complexities of real-world policies, we nevertheless believe that it provides useful insights into which policy principles do or do not lead to the desired results of decentralized water management in Central Asia.

2.5 Empirical approach

In Central Asia, attempts to analyze local cooperation have either focused on the description of social institutions such as clans or neighbourhood committees or, in rare cases, devised survey instruments (e.g. to measure "social capital" as in Radnitz et al., 2009). At the same time, in addition to inevitable logistical issues, these efforts are regularly hampered by problems of official censorship, the hostility of authorities towards independently conducted polls, and social expectations levied on respondents to please the authorities (Dadabaev, 2017b). Given these possible constraints, our empirical study described next is an attempt to utilize the methodological advantages of field experiments in a Central Asian setting[2].

2.5.1 Core hypotheses

Our review of the literature on the effects of policy treatments on cooperation levels leads us to the following hypotheses to be tested in a field experimental setting:

H1: Communication increases the cooperation of water users.

[2] In any of the post-Soviet republics, field experiments have rarely been used to investigate questions of natural resource management so far. In a pilot study of 20 farmers conducted in Uzbekistan, Roßner & Zikos (2018) provide evidence that group-endogenous rule formation may improve cooperative outcomes in a context of water management.

H2: Penalties increase the cooperation of water users.

Based on the idea that Uzbekistan has a much longer tradition of local water cooperation than Kazakhstan, we posit:

H3: Water users in Kazakhstan make lower contributions to the common pool than users in Uzbekistan.

However, as the literature considers Kazakhstan to be associated with a more liberal and decentralized regulatory environment, whereas Uzbekistan seems to host more citizens that could be labelled as "state-believers", we suggest that:

H4: Communication has a stronger positive cooperation effect in Kazakhstan.

H5: Penalties have a stronger positive cooperation effect in Uzbekistan.

In the following, we subject these hypotheses to empirical scrutiny by using unique experimental data from irrigated areas of Maktaaral (South Kazakhstan) and Samarkand (Uzbekistan).

2.5.2 Experimental design

We replicated the irrigation game experiments of Cárdenas et al. (2011) with a total of 235 farmers from twelve villages in pen and paper conditions (see appendix 1 in Appendix-I for details on the field setting). The framing of the experiment was around water management and we assume that it was not difficult for the participants of the experimental sessions to understand the task. The irrigation game captured the characteristic of the sequential access of users to nonstationary and storage-impossible canal irrigation systems. One session with one group consisted of five players and each game continued for 21 rounds in total. The anonymity of all players' decisions was provided with the use of experiment cabins, which isolated the players from each other. The participants noted their decisions on the decision sheet they had in their hands, which was collected after each round.

Before each round, we provided each player with ten coupons of endowment. In each round, the players had to make two decisions concerning the creation of irrigation infrastructure and water use respectively. Both their investments and their earnings based on their water use decisions were expressed in coupons. They were provided with information tables concerning the collective investment level implying a certain amount of "water minutes" made available to users and concerning the water use amounts with their respective crop-earnings in the form of coupons (appendix 2 in Appendix-I)

We instructed the participants to make decisions on the endowment allocation. They could allocate the coupons across two options, namely to their private account or to their collective "public fund" which would then be used for the maintenance of the water infrastructure they were using to extract water for their crop production. The returns from these two accounts were constructed in a way to ensure that the situation symbolized a public good dilemma with multiple equilibria. Higher collective investment means more water is available to the community of users. Under the experimental conditions, keeping everything in a private account is a best response Nash equilibrium, but if everyone contributes their endowments towards the public fund, then the socially optimum outcome is achieved. If the previous is the risk dominant equilibrium then the latter is the payoff-dominant equilibrium.

We announced to the players how much they had collectively invested and how much water was available for their aggregate use. Then the next stage of the game started, the "appropriation" stage, where participants needed to make independent decisions on water extraction. Players were randomly assigned locations, symbolized by the first five letters of the alphabet (A, B, C, D, and E). A was the head-end user, E the tail-end water user. These letters represented the order of the players' access to the resource. Water extracted by the head-enders was not available to tail-enders.

We assigned baseline and treatment groups. The baseline groups did not communicate and did not face penalties (see appendix 2 in Appendix-I for more details). Through these experiments, we studied the influence of communication and sanctioning on cooperation in the public good dilemma. The experimental groups were treated with communication, low and high penalties. In the communication treatment, the groups were allowed three minutes to talk to each other before each round. During the penalty sessions, equal water sharing norms were established and norm-obedience was monitored with a probability of one over six. If norm-violation was detected in a low-penalty treatment case, then one of the experimental administrators took the role of an "enforcement agent" and publicly withdrew the excess earnings from the player. In the case of a high penalty, the violator's excess earnings and an additional six coupons were subtracted from his or her revenue column. This procedure abstractly resembled the way WUAs were introduced in our study sites. While local users policed themselves under both treatments, they could engage in fully endogenous participation only in the communication treatment. The penalty level was dictated from outside, reflecting actual practice in Kazakhstan and Uzbekistan. Treatments started in the 12th round so that we were able to do both within group and between group comparisons.

2.5.3 Econometric model

To test our research hypotheses, we estimated the following regression model using ordinary least squares (OLS):

$$y_i = x_i'\beta + \varepsilon_i \quad ,$$

where y_i is the i'th player's cooperation level represented in the experimental observations as the share of his/her coupon endowment contributed to the public irrigation maintenance fund. x_i' includes treatments, country, and control variables described in Table 2-2. β is a vector of parameters to be estimated and ε is an independently and identically distributed error term.

Table 2-2: Definition of variables and descriptive statistics of the experimental data

Variable name	Maktaaral (Kazakhstan)				Samarkand (Uzbekistan)			
	mean	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**
Individual endowment share contributed to the public fund %	0.59	0.31	0	1	0.51	0.28	0	1
Round	10	6.03	0	20	9.95	6.07	0	20
Others' contribution in preceding round %	23.69	7.31	4	40	20.40	5.97	2	40
Relative share of extraction in preceding round %	0.20	0.17	0	2.17	0.20	0.25	0	1
Experimental location [5=A...1=E]	3.02	1.42	1	5	3	1.42	1	5
Individual deviation in cotton land share from the group average [a]	-0.04	0.30	-0.78	0.54	<0.01	0.09	-0.31	0.32
Individual deviation from group's average land size (ha)[b]	-0.08	11.30	-31.87	63.11	-0.02	22.92	-58.01	131.48
Actual position: Upstream (0/1)	0.27	0.45	0	1	0.33	0.47	0	1
Actual position: Midstream (0/1)	0.43	0.50	0	1	0.28	0.45	0	1
Education (years)	15.03	3.24	9	18	13.34	2.95	11	18
Household size (#persons)	6.50	2.86	2	20	6.61	2.51	2	21

Notes: N=2363 (2484) in Maktaaral (Samarkand), based on group-wise non-missing observations. [a] *Individual deviation in cotton land share from the group average*=$c_{ij} - \bar{c_j}$ where $c_i$is i's share of cotton in total land (in real life) and $\bar{c_j}$ is the mean cotton share in group j;[b] *Individual deviation from group's average land size* = $l_{ij} - \bar{l_j}$ where l_{ij} is i's farm land size (in real life) and $\bar{l_j}$ is mean farm land size in group j .

Source: Authors.

The coefficients of the treatment and country variables allow testing H1 – H3. We included interaction terms involving the treatment and country variables into one regression specification to test H4 and H5. All other variables serve as control variables which were partly taken from a post-experimental survey.

2.6 Results

2.6.1 Description of participants and outcomes

We conducted the irrigation game sessions among water users in six villages in Maktaaral and in six villages in Samarkand, from October to December 2016. Almost all of the participants were involved in crop production with an average farming land size of 10.5 ha in Maktaaral and 37 ha in Samarkand (Table 2-3).

Table 2-3: Description of the participants

Characteristics	Maktaaral	Samarkand
Upstream (%)	27.42	33.45
Midstream (%)	43.42	28.14
Downstream (%)	30.94	42.59
Male (%)	86.75	98.31
Education level:		
Incomplete secondary (9 year school, %)	0.85	0
Secondary general (11 year school, %)	18.45	35.19
Secondary professional (vocational school, %)	26.66	36.63
Higher (University degree, %)	54.04	28.18
Land endowment per farm (mean, ha)	10.57	37.00
Age (mean, years)	40.39	41.78
Household size (mean, people)	6.50	6.62
Count of observations	2363	2484

Source: Authors based on post-experimental survey data.

Out of 120 participants in Samarkand only two were women. In Maktaaral, 15 of the 115 farmers that took part in the irrigation game sessions were female. The average ages of the farmers in the Maktaaral and Samarkand sample were 40 and 42 respectively. More than 54% of Maktaaral farmers and 28% of Samarkand farmers possessed a university degree in our sample.

The average contribution patterns were different across different treatment sessions and rounds (Table 2-4). The contributions of the players decreased over time in both study areas when no penalties and no communication were enacted. When the players were allowed to communicate with each other, the average share of endowment contribution to the public fund increased. This was not the case for either of the penalty treatment games, but rather the average share of endowment contribution continued to decrease even after the introduction of equal sharing rules with low and high penalties (appendix 3 in Appendix-I).

Table 2-4: Average individual contributions to the public fund across session phases and treatments

	Maktaaral		Percentage change between two sets of rounds	Samarkand		Percentage change between two sets of rounds
Baseline sessions						
Baseline, rounds 1-11	0.64	**	-9.38%	0.52	***	-13.46%
Baseline, rounds 12-21	0.58			0.45		
Communication sessions						
Baseline without communication, rounds 1-11	0.63		4.76%	0.49	***	24.49%
Communication, rounds 12-21	0.66			0.61		
Low-Penalty sessions						
Baseline without low penalty, rounds 1-11	0.59		-5.08%	0.52	**	-9.62%
Low penalty, rounds 12-21	0.56			0.47		
High-Penalty sessions						
Baseline without high penalty, rounds 1-11	0.55		-9.09%	0.52	*	-7.69%
High penalty, rounds 12-21	0.50			0.48		

*Notes: t-test significance level: ***1%, **5% ,*10%: test on the equality of mean values of the 1-11 and 12-21 rounds of respective games*

The irrigation game sessions produced a total number of 4846 observations. These observations are nested within one player and players within sessions, sessions within villages and villages within countries. In order to capture these aspects of the data, we included fixed effects for countries and villages in the regression models. The identity and group layer variables-characteristics of players during the 21 rounds of the game do not change and they thus control for fixed session effects.

Table 2-5 presents the regression results of three OLS models. Model 1 represents the simplest specification including the treatments and a direct country effect. Model 2 adds country and treatment interaction effects to the specification. Model 3 keeps the treatments but replaces the country effects by village level fixed effects. All models generate insights about hypotheses H1 to H3, while model 2 specifically addresses H4 and H5. In the following, we discuss, in turn, the results on the core hypotheses, further determinants of cooperation, and village effects.

Table 2-5: Regression results of the individual endowment share contributed to the public fund

	Model 1: Pure country effects		Model 2: Interacted country & treatment effects		Model 3: Village effects	
Round	-0.003	***	-0.003	***	-0.004	***
	(-3.93)		(-3.80)		(-5.35)	
Communication treatment	0.100	***	0.118	***	0.134	***
	(6.37)		(5.66)		(8.87)	
Low penalty treatment	0.004		0.005		-0.002	
	(0.24)		(0.26)		(-0.14)	
High penalty treatment	-0.016		0.010		-0.020	
	(-1.11)		(0.56)		(-1.46)	
Others' contribution in preceding round %	0.007	***	0.006	***	>-0.001	
	(10.31)		(10.16)		(-0.41)	
Relative share of extraction in preceding round %	0.116	***	0.115	***	0.108	***
	(5.05)		(5.03)		(4.78)	
Experimental position [5=A...1=E]	0.018	***	0.019	***	0.017	***
	(5.29)		(5.30)		(5.12)	
Individual deviation in cotton land share from the group average	0.096	***	0.095	***	0.092	***
	(4.81)		(4.82)		(4.73)	
Individual deviation from group's average land size	-0.001	***	-0.001	***	-0.001	***
	(-3.36)		(-3.35)		(-3.46)	
Actual position: Upstream	-0.010		-0.010		0.004	
	(-1.00)		(-1.00)		(0.34)	
Actual position: Midstream	0.021	**	0.023	**	0.018	*
	(2.07)		(2.28)		(1.78)	
Education (years)	-0.005	***	-0.005	***	-0.007	***
	(-3.40)		(-3.34)		(-4.88)	
Household size (#people)	-0.002		-0.002		-0.002	
	(-1.45)		(-1.41)		(-1.08)	
Engbekshi Village (0/1)					0.145	***
					(6.50)	
Zhanazhol Village ((0/1)					0.313	***
					(13.64)	
Dostyk Village (0/1)					0.201	***
					(9.94)	
Intymak Village (0/1)					0.391	***
					(18.21)	
Maktaly Village (0/1)					0.145	***
					(7.12)	
Kyzylkum Village (0/1)					0.183	***
					(8.49)	
Eski Jomboy Village (0/1)					0.255	***
					(12.28)	
Juriat Village (0/1)					0.199	***
					(9.99)	
Qochqor-Torayev Village (0/1)					0.069	***
					(3.54)	
Aytamgali Village (0/1)					0.162	***

					(8.45)	
Dehkanabad Village (0/1)					0.136	***
					(7.00)	
Kazakhstan (0/1)	0.067	***	0.08	***		
	(7.62)		(7.55)			
Kazakhstan * Communication treatment			-0.037			
			(-1.37)			
Kazakhstan * Low penalty treatment			-0.004			
			(-0.15)			
Kazakhstan * High penalty treatment			-0.058	**		
			(-2.23)			
Constant	0.393	***	0.386	***	0.427	***
	(13.56)		(13.28)		(13.77)	
Observations	4,847		4,847		4,847	
R-squared	0.092		0.093		0.154	

Robust t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

2.6.2 *Communication, sanctioning and country effects*

In the context of our study, the communication treatment tests whether self-organized cooperation in irrigation water management evolves if participants are allowed to talk to each other (H1). We found a positive effect of the communication treatment on the individual's decision to cooperate in the form of investing more in the public fund. The significantly positive effect is observable in all three models presented in Table 2-5 so that H1 is clearly confirmed. The participants were hence able to use the repetitive interactions to enhance their understandings of the game settings, and devise informal and internal agreements on strategies for dealing with norm violations, with a direct effect size of between 10 (Model 1), 12 (Model 2) and 13 (Model 3) percentage points.

H2 entails the hypothesis that penalties induce cooperative behaviour. None of the three regression models allows rejecting the hypotheses that any of the direct low or high penalty effects were equal to zero so that the evidence speaks against H2.

Model 1 provides an estimate of the direct country effect undisturbed by interaction terms and village effects. It suggests that users from Kazakhstan were contributing 6.7 percentage points more on average than the Uzbekistani users. This result provides evidence against H3.

To test H4 and H5, we used the coefficients of the interacted variables from models 2 to estimate the treatment effects by country, employing the delta method to calculate the standard errors of the compound effect (Table 2-6)**.** In contrast to what we hypothesized, the effect of the communication treatment in Maktaaral was positive but smaller in size than in Samarkand (H4). Uzbekistani participants contributed 11.8 percentage points more under communication, whereas Kazakhstani players contributed only 8.1 percentage points more. That is, H4 is not supported by what we see in Table 2-6.

Table 2-6: Treatment effects on the individual endowment share contributed to the public fund, by country

	Model 2			
Treatments	*Maktaaral (Kazakhstan)*		*Samarkand (Uzbekistan)*	
Communication	0.081	***	0.118	***
	(3.93)		(5.66)	
Low penalty	0.001		0.005	
	(0.05)		(0.26)	
High penalty	- 0.048	**	-0.010	
	(-2.23)		(-0.56)	

Note: Effects based on coefficients of interacted variables shown in Table 2-5. Significance level: *** p<0.01, **p<0.05; t-statistics in parentheses.

We did not find evidence of sanctioning effects, whether positive or negative, on the decisions by Uzbekistani participants (H5). However, high penalties produced a significantly negative effect in the Kazakhstan sessions. Other than in Tenbrusel & Messick (1999) and Cárdenas et al. (2011), high penalties were thus less effective than lower ones.

Our evidence thus calls into question the validity of H5, positing higher contributions under penalties. While we detected no positive penalty effects on cooperation in Uzbekistan, high penalties even crowded out contributions by Kazakhstani users (Table 2-6). Therefore, the externally introduced equal resource sharing rules with imperfect monitoring and enforcement mechanisms did not improve cooperation among participants in Kazakhstan but rather deteriorated it.

2.6.3 Further determinants of cooperation

With more repetition of the interactions, the players learn about the rules and the material consequences of particular actions and, with time, what Cárdenas & Ostrom (2004) call internal game payoffs converge with the external game payoffs. The decisions of the individuals might hence move closer towards the self-regarding Nash equilibrium as the rounds continue (Isaac et al., 1985). We found evidence of a small learning effect across all three models in Table 2-5, around -0.3 and -0.4 percentage points.

According to estimates in models 1 and 2 when the participants experienced a higher contribution from the rest of the group in the previous round, they tended to increase their own contribution in the next one. This effect is very small in size although it is statistically significant. Players hence seem to behave reciprocally according to two models in Table 2-5, contrary to the results by Cárdenas et al. (2011). We tested for interaction with the country dummy, this effect proved to be significantly different from zero, but estimates were small in size ranging from 0.006 to 0.01. According to our data, players in Kazakhstan are more reciprocal than players in Uzbekistan. Moreover, we found that water users contributed more to the public fund when they received a higher share of water available to the group in the preceding round. We attribute this effect to reciprocating behaviour (tit-for-tat) or an increased certainty farmers perceive concerning the return on their own investment.

Furthermore, we hypothesized that individual decisions depend on how much the person knows about the other participants of the game. We expected that an individual farmer whose land endowment is higher (lower) than the group's average would be less (more) cooperative. We found that indeed such mechanism seems to be at play. On the other hand, farmers with an above average share of irrigation-dependent cotton in their crop rotation contributed more.

Players who were randomly assigned higher positions with respect to water tended to contribute more of their endowments to the public fund than players in lower positions, although the effect was quite small (Table 2-5). The upstream water users had better access to water than the downstream users. Therefore, they were surer that their investment in the infrastructure would pay back, as argued by Cárdenas et al. (2011).

The actual position along the canal also influenced the individual decisions to cooperate. Midstream farmers tended to contribute more than both the downstream and upstream water users in all three models. This finding supports Uphoff et al. (1990) stating that farmers will be more willing to participate in water self-management where water supply is relatively scarce rather than absolutely scarce or abundant. Farmers with more years of education contributed slightly less.

2.6.4 Village effects

In addition to the country effects, our data also allows a more fine-grained analysis of village-level variation in farmers' contributions to the public fund. The village fixed effects (model 3 in Table 2-5) include all village-invariant observable and unobservable factors. There are many possible factors contributing to a village's social capital, which are hard to define and measure. The village fixed effect captures those effects without having to define or measure them explicitly. While we cannot separately isolate the effects of such different factors, complementary information on the villages allows us to speculate about some of the driving forces, including the relative location at the canal, ethnic composition, the role of the cotton mandate, and other instances of local cooperation.

We list the average contributions by village relative to the lowest ranking village, Chimboy in Samarkand province, in Table 2-7. The average contributions are taken from model 3 in Table 2-5 and are thus purged from individual player characteristics as included in the regression. As Table 2-5 reports, the differences to the reference village are all significantly different from zero at the 1% level. The difference can be up to 39 percentage points (as for Intymak village). We ranked the villages according to their location along the canal, starting from the head end in both study sites, to qualitatively assess the relation between actual canal location and experimental cooperation levels. In fact, no clear pattern appears, thus calling into question arguments by Wade (1989, 163) that tail-end users are more inclined to cooperate as water is scarcer than at the head end.

Moreover, we added a couple of remarks on village characteristics that we discovered during the field study. Ethnically heterogeneous or distinct villages (Engbekshi, Dostyk, Qochqor-Torayev) tend to display lower cooperation scores, thus lending some support to the view that ethnic fractioning may jeopardize cooperation (Khwaja, 2009). The extent of ethnic heterogeneity and associated social distance among members may lead to a lower level of social interactions and thus weaker social capital. Ineffective mutual monitoring and difficulties in enforcing sanctions in ethnically diverse communities might encourage free-riding (Miguel & Gugerty 2005). The direction of causality can also be reverse, however, implying that ethnic homogeneity of a community results from historical patterns of social interactions and cooperation within that community. For example, ancient cooperation in irrigation led to the formation of Uzbek as a sedentary culture, whereas more autonomous Kazakhs remained nomads. Even in the short run, higher cooperation within a given community may result in ethnic sorting processes.

Engbekshi was called "Slavyanka" ("Slavic") until 1993. According to local sources, it was founded in 1900 under Tsarist rule, when Slavs, Tatars, Greeks, and Koreans were settling in the area. After the collapse of the Soviet Union, the share of the non-Kazakh population declined, although the old name remains in use among local people. We had particular difficulty in engaging players for the sessions in this village and even had to cancel one session (Table 0-1).

On the other hand, an ethnically homogenous village representing the majority group, Intymak (meaning "solidarity" in English), displays the highest cooperation score. Farmers voluntarily organized themselves into groups in front of the experiment venue, waiting for us to finish the session and asking us if we can run another session with them. In Chimboy, the low cooperation levels demonstrated during the experiments were also reflected in the exceptionally poor shape of the transport infrastructure. However, the absence of the cotton order in Eski Jomboy and Juriat did not seem to have a noticeable effect on cooperation levels. These observations don't provide conclusive evidence but should rather be taken to stimulate further research.

Table 2-7: Village effects

Villages listed according to their order along the canal, starting with the head end	Average contribution relative to the lowest ranking village (from regression table)	Remarks on village characteristics
Maktaaral		
Engbekshi	0.145	Slavic settlement established in 1900; relatively heterogeneous ethnic composition
Zhanazhol	0.313	
Dostyk	0.201	Ethnically homogeneous Tajik village
Intymak	0.391	Village name means "solidarity" in English
Maktaly	0.145	
Kyzylkum	0.183	
Samarkand		
Eski Jomboy	0.255	Free from state cotton order
Juriat	0.199	Free from state cotton order
Qochqor-Torayev	0.069	Ethnically distinct, called "Arab village" by outsiders
Chimboy	0 (=reference village)	Relatively poorest quality of roads among all villages
Aytamgali	0.162	
Dehkanabad	0.136	

Source: authors.

2.7 Conclusions

Based on unique field experimental data from agricultural water users in Maktaaral (Kazakhstan) and Samarkand (Uzbekistan), we found that endogenous cooperation can be stimulated by a regulatory environment that enables more autonomous decision making (as in post-independence Kazakhstan). An experimental treatment that proxies the participation principle of IWRM promoted cooperation both in Kazakhstan and Uzbekistan. Starting from a higher ex-ante cooperation level, the policy effect was lower in Kazakhstan. Under a treatment allowing face-to-face communication in the group, the players consistently contributed more than 60 percent of their endowment to the public fund. The average contribution level under communication among Kazakhstani water users (66 percent) was, in fact, identical to the one found by Cárdenas et al. (2011) for Colombia using the same experimental setting. While contribution shares in Uzbekistan were slightly lower (61 percent), they still exceeded the ones reported by Cárdenas et al. for Kenya (47 percent).

When farmers were allowed to self-organize, they achieved higher levels of cooperation as a result of bargaining during their group deliberation. Following our evidence, Central Asian farmers are able to design rules endogenously that lead to higher earnings and better enforce rules that induce cooperation. As in real life, where not all bargaining generates more effective rules, not all communication sessions resulted in enhanced cooperative outcomes.

Our findings do not support the idea that historic irrigation patterns or ancient management practices constitute long-term determinants of local water cooperation today. While Samarkand has a much longer tradition of decentralized water management, current cooperation levels were actually higher in our Kazakhstani site.

Our results imply that penalties have little effect in an environment described as paternalistic and state-centered (represented here by Uzbekistan). In a more liberal environment (as in Kazakhstan), high penalties for defectors may even crowd out voluntary contributions.

In addition, strong village-level effects suggest that idiosyncratic local characteristics such as ethnic composition or norms of cooperation may be more decisive for cooperative outcomes than policy blueprints imposed from outside.

The results presented here thus call into question emerging literature arguing that historic agricultural practices play a crucial role in understanding current-day cooperation outcomes (Talhelm et al., 2014; Carnap, 2017). However, the findings support the idea that policies entrusting local users with a degree of autonomy and scope for local interaction do work in Central Asia. As this effect was stronger in the Uzbekistani site characterized by a more constrained and hierarchical real-world policy environment, the results even suggest that the potential for local cooperation is similar in both places. While this finding is borne out by many empirical studies worldwide (such as quoted in Ostrom et al., 1994 or Cárdenas et al., 2011), we experimentally demonstrate here that it also holds for post-Soviet Central Asia.

International observers repeatedly recommend that Central Asian water administrators should strive to revive ancient principles of local water cooperation and management in the region (Abdullaev & Rakhmatullaev, 2013; O'Hara, 2000). In our Maktaaral site, the only notable tradition of water management is due to the Soviet water bureaucracy, but still, the cooperation levels are higher today than in ancient Samarkand. This insight suggests two conclusions: First, whatever historically beneficial management practices may have prevailed in Samarkand, they were muted or even revoked by a century of top-down administration and thus assimilated to practice elsewhere in the Soviet Union. Second, history is not predetermining the future; current water management can be policed and there are more or less conducive ways to do so.

In Central Asia, it appears that productive ways of water governance need to be re-invented and turned into going practice once again. As shown above, twenty-five years after national independence, both Kazakhstan and Uzbekistan display a decisively mixed record of experimenting with such new (or renewed) practices and policies. The results of a single experimental study are in no way sufficient to fully identify the behavioural trend of Kazakhstani or Uzbekistani water users as a whole. Our results, however, provide us with a basis for informed speculation. The evidence provided here supports the view also advocated by international donors that decentralized and participatory water management for example in WUAs under a regime of IWRM can be viable. While the complexity of administering such governance systems greatly exceeds the stylised forms of interaction captured in field experiments, our results nevertheless convey the message that greater autonomy for water users enabling their truly endogenous organization will evoke higher individual contributions to the local common good. However, the substantial heterogeneity in individual contributions apparent at the village level also signals a warning that one-size-fits-all approaches to local cooperation are unlikely to succeed.

3 INVESTMENT TRAPS IN COLLECTIVE WATER GOVERNANCE: THEORY AND EXPERIMENTAL EVIDENCE FROM CENTRAL ASIA[3]

3.1 Introduction

Surface irrigation water management faces two major challenges (Ostrom & Gardner, 1993): a farmer who has not invested in the infrastructure cannot be prevented from enjoying its benefits (non-excludability), whereas one farmer's use of water will diminish another farmer's access to the commonly available water resource (rivalry). In such social dilemma, the actions of rational economic agents carry external effects on other actors leading to the degradation of the common resource, which is said to result in Hardin's (1968) "tragedy of the commons".

Many analysts have modelled interaction among water users as a Prisoners' Dilemma game with a dominant strategy to free ride. However, if we take into account the accumulated experimental evidence that roughly 40-50 percent of the human population reveals reciprocal rather than purely self-regarding preferences (Fehr & Fischbacher, 2005), the same interaction can also be modelled via alternative approaches entailing multiple equilibria. These approaches, which are framed in terms of conditional reciprocity by involving concepts such as reciprocal altruism, tit-for-tat, iterated Prisoners' Dilemma or strong reciprocity, will turn the interaction into an Assurance game (Friedman, 1971; Trivers 1971; Axelrod & Hamilton 1981; Taylor, 1987, Cosmides & Tooby 1989, Bowles, 2004).

In an Assurance game, in general, mutual cooperative and mutual defective equilibria can result from best-response play. However, reaching a socially preferred, mutually cooperative convention is still problematic, due to independent decision making and imperfect information or a lack of trust among real-world decision makers (Ostrom et al., 1992; Madani, 2010).

[3] This chapter draws on a journal manuscript written jointly with Martin Petrick and Nodir Djanibekov

The present study considers the creation of irrigation infrastructure as a potential social dilemma. We analyze this dilemma both theoretically and empirically. In the theoretical section, we develop a non-cooperative game to represent farmers' decision making in irrigation management. We add multiple iterations and multiple players and incorporate the logic of dynamic evolutionary game theory. In this way, we derive testable hypotheses on the dynamics of farmers' interaction. In the evolutionary irrigation investment game, initial conditions determine whether the interaction will converge to a high or low-level investment convention. In other words, the interactions are subject to lock-ins (traps). We then ask whether pre-play communication and penalty treatments can overcome such investment traps. These peer-monitoring and sanctioning arrangements reflect the notions of self-governance and exogenous (top-down) rules, respectively (Amirova et al., 2019).

In the empirical part of our study, we examine the results of a field experiment on irrigation management conducted among real-world farmers in two regions of Central Asia. We use the experimental outcomes to test for the presence of autoregressive lock-ins in collective investment. Non-parametric auto-regressive regression results confirm the existence of multiple equilibria, consistent with an N-person Prisoners' Dilemma supergame including retaliating and self-regarding players. Our analysis reveals that peer-monitoring facilitated by a communication treatment of the players resulted in higher collective investment outcomes. While communication generally established higher levels of collective investment, it did not completely eliminate the low-investment (defective) equilibrium. Sanctioning arrangement (penalties), on the other hand, seemed to crowd out the intrinsic motivation to cooperate, as they decreased collective investment levels.

The use of game theory in water governance analysis is not novel. For example, the general applicability of game theory to water governance, with range of stakeholders' participation, was the focus of study by Madani (2010). He illustrates some simple two-by-two water resource games not only as Prisoner's Dilemma but also as Chicken and Assurance games, and by doing so supports the idea that not all water resource games are Prisoner's Dilemma with deadlock (with only an inferior convention) and accordingly shows that theoretically water interactions can have several Nash equilibria (conventions). Furthermore, studies by Cárdenas et al. (2011), Janssen et al. (2012), Javaid & Falk (2015), and Amirova et al. (2019) use irrigation game experiments with Colombian, Kenyan, Thai, Pakistani, Kazakhstani and Uzbekistani water users to explore the provision of irrigation infrastructure and water use decisions under asymmetric appropriation respectively. All of these game theory-based experimental studies try to get more empirical insights and assess the effect of different institutions of coordination on individual decisions to cooperate in water management.

By using field experimental data described in Amirova et al. (2019), the current study integrates the game theory into empirical analysis such that the corollaries of the theoretical model are straightforwardly verified with the experimental database. We thus provide novel insight into the processes of cooperation or non-cooperation in irrigation water management. Amirova et al. (2019) answer the question of **why** cooperation happens among water users in Kazakhstan and Uzbekistan subject to layers of information (short-term determinants) and (long-term) cultural determinants. The current work answers the question of **how** cooperation or non-cooperation occurs and can be locked in at one or another convention. Rather than on the determinants of cooperation, we trace the inherent dynamics of reaching different cooperative equilibria.

This chapter is organized as follows. Section 3.2 models collective investment in irrigation infrastructure. Section 3.3 presents the logic of multiple dynamic equilibria and integrates the interplay of stylized institutional arrangements with the self-reinforcing investment traps into the model. Section 3.4 summarizes the main hypotheses of the study. The next section describes the experimental database of the study. Section 3.6 elaborates on non-parametrical graphical analysis. Section 3.7 present the results of the analysis. Section 3.8 concludes. The results of additional robustness checks are provided in the appendix.

3.2 Modelling interaction in irrigation water management

We model the investment decisions of water users in irrigation infrastructure in a highly stylized game setting. Investing or abstaining from investment are the strategies available to each player. The decision of investment is made simultaneously. We start with the simplest case of a one-shot, 2x2 Prisoners' Dilemma setting and then add additional elements to the model that increase the consistency with actually observed outcomes.

3.2.1 One-shot, 2x2 Prisoners' Dilemma

Table 3-1 illustrates the payoff profiles of two farmers' irrigation investment interaction (Bowles 2004:238-242). This interaction resembles a Prisoners' Dilemma, as with payoffs $a > b > c > d$, each farmer's best choice is free riding on the fellow farmer's effort, by letting the fellow carry the full burden of the irrigation infrastructure and then reap the benefit of the system all the same. The best response for each individual farmer is abstaining from investment, consequently abstaining is the dominant strategy (the only Nash equilibrium) for each farmer in such context. Equilibrium strategies are denoted with bold letters in Table 3-1. However both farmers would be better off if they invested. Individually optimal choice might not be optimal from the perspective of society (i.e., the water users' group). The social surplus is maximised when the sum total of the interacting farmers' payoffs is maximised. In the current case thi,s occurs when both parties invest ($a + d < 2b$) (Dixit & Skeath, 2004: 384).

Table 3-1: Payoff table of one shot, two farmer interaction and their investment decisions in irrigation infrastructure (Prisoners' Dilemma)

	Farmer 2 invests	Farmer 2 abstains
Farmer 1 invests	$b; b$	$d; a$
Farmer 1 abstains	$a; d$	$\boldsymbol{c}; \ \boldsymbol{c}$

Note: $a > b > c > d;$ Source: adopted from Bowles, 2004: 239

3.2.2 Contradictions with the expected outcomes

Albeit the dominant free riding outcome in such irrigation investment social dilemma, empirical evidence reveals both cooperation and defection patterns among water users. Uphoff (1990) found evidence of broader participation of Sri Lankan farmers in self-governance process of irrigation water systems than predicted by pure free riding. Lam (1999), Bardhan (2000) and Fuijie et al. (2005) studying water users in Nepal, South India, and Philippines, respectively, show that local water users successfully engage in collective action.

Real-world cooperation in situations apparently characterized as a Prisoners' Dilemma in irrigation, as in Table 3-1, suggests that something important is missing in the model. The model may thus be modified as follows.

First, the assumptions about the ranking of payoffs may be wrong. If the payoffs in Table 3-1 took the following conditional values: $b > c > a > d$, the game turns into an Assurance game, not a Prisoners' Dilemma. In reality the, costs and the benefits associated with building (maintaining) the irrigation infrastructure can depend on which players participate. That is, when only one farmer carries the burden, such infrastructure might not provide as much water as when both farmer invest. Moreover, the two-person project might be of better quality due to a larger pool of investors (Dixit & Skeath, 2004: 384). In such circumstance, there is no tendency to free ride, as the payoff for abstaining is low and does not depend on what the other farmer does. Therefore, if one farmer feels confident with the other farmer's cooperative action this farmer then will cooperate. Consequently, the Assurance game has two Nash equilibria: one where both farmers invest and the other where neither of the farmers does. The convention where both farmers invest is the socially optimal outcome, because both players would be better off when they invest ($a + d < 2b$). The Assurance game is still a dilemma as it is not guaranteed that the players always achieve the cooperative convention. Indeed, players sometimes might opt for defection probably due to lack of trust which then leads the interaction toward a Pareto inferior outcome (mutual defection; Madani, 2010: 233).

Secondly, the one-shot Prisoners' Dilemma's defective outcome, as in Table 3-1, may disappear if the game is played iteratively. In that setting mutual cooperation can become rational at individual levels as well, according to the supergame argument of Taylor (1987). One of the conditions for achieving a cooperative outcome in a Prisoners' Dilemma supergame entails that at least some players are conditional cooperators (or tit-for-taters): they cooperate only if the other player does in the preceding round, and defect otherwise. Furthermore, if each player's discount rate is sufficiently low, the conditional cooperators' mutual investment equilibrium will eventually prevail. If the players value later payoffs as much as the earlier ones such that the free-rider's gain in the first period does not outweigh the losses in all preceding periods of mutual defection, then the tit-for-tat (retaliation) strategy would induce individual cooperation and hence stabilize a cooperative convention (Taylor, 1987).

3.2.3 N-person, multi-period, meta-preference Prisoners' Dilemma in an evolutionary game setting

In the real world, most of the interesting public goods provision dilemmas, including irrigation interactions, involve more than two actors. N-person games, therefore, could produce more practically relevant insights. We thus model water users' interaction by considering a water using farmers' population composed of N individuals who interact in pairs to engage in irrigation investment activities. We simultaneously introduce **repetition** (of the same game), **retaliation** (tit-for-tat preference) and **replication** (of the norms of the successful players) to the N-person Prisoners' Dilemma and hence show how it leads the interaction to multiple equilibria of both mutual defection (abstaining) and mutual cooperation.

Our modelling strategy follows evolutionary game theory, which is a modified version of the classical game theory that takes into account people's limited cognitive capacities. Hence individuals, according to evolutionary game theory, update own beliefs, and accordingly decisions, using imperfectly observed local information. Evolutionary game theory can describe adaptive water users who might not necessarily be forward-looking, and whose interactions' direction is determined by differential replication which then determines the population structure with preferences including both self-regard and reciprocity (Bowles, 2004). More details about evolutionary game theory can be found in Weibull (1995), Bowles (2004) and Dixit & Skeath (2004).

In an evolutionary game setting, the adaptive agents keep updating their choices of traits, and they do it in accordance with differential replications. We assume that at each period of the interactions some ω fraction of water users' population update their choice of strategy. The updating dynamic favors successful strategies over less successful strategies. The fitter strategies with higher expected *payoffs*, as a result, get more replicas (Weibull, 1995). These expectations are simply the payoffs that would obtain if the previous period's state remained unchanged (Bowles, 2004: 408). This replication dynamic gives direction to the evolutionary processes (Bowles, 2004: 62)

We illustrate this extension of the game, with repetition, retaliation (tit-for-tat) and replication, in Table 3-2, which is adopted from Bowles (2004).

Table 3-2: Payoff table of iterative, multi farmer irrigation investment interaction with retaliation preference possibility

	Tit for tat	**Abstain**
Tit for tat	$\frac{b}{\rho};\frac{b}{\rho}$	$d+(1-\rho)\frac{c}{\rho};\, a+(1-\rho)\frac{c}{\rho};$
Abstain	$a+(1-\rho)\frac{c}{\rho};\, d+(1-\rho)\frac{c}{\rho}$	$\frac{c}{\rho};\quad \frac{c}{\rho}$

Note: $a > b > c > d;\ \rho \in [0;1];$ Source: adopted from Bowles, 2004: 242

We assume, for simplicity, that the N-person population of farmers is endowed with two preferences only. One is tit-for-tat (T), i.e. the player with such a trait will cooperate in the initial period and in all subsequent periods will do what the counterpart did in the preceding period of interaction. The second preference is unconditional abstaining (A) from investment. We suppose that the players are randomly paired to play after each period of play. Extension of the model also captures the iterative nature of interactions, and it is reflected in a newly introduced element to Table 3-2, that is the probability of interaction to terminate (ρ). The range of ρ varies between 0 and 1. The closer it is to 1, the higher is the probability of termination, and the interaction illustrated in Table 3-2 will tend to resemble the one illustrated in Table 3-1. On the other hand, if ρ is closer to 0, the higher is the probability of the game to be repeated and the resulting game resembles an Assurance game. We assume that the repetitions take place over appropriately brief periods and hence justify our ignorance of the players' discount rates.

We normalize the size of the farmers' population to unity and denote the fraction of farmers who are retaliating (play tit-for-tat strategy) type with τ. Consequently, $(1-\tau)$ is the fraction of farmers' population who are (unconditionally) abstaining. The expected payoffs for tit-for-tat and unconditional abstaining players are denoted with π^T and π^A, respectively, and they take the following values:

$$\pi^T = \tau \frac{b}{\rho} + (1-\tau)\left\{d + \frac{(1-\rho)c}{\rho}\right\} \quad (1)$$

$$\pi^A = \tau \left\{a + \frac{(1-\rho)c}{\rho}\right\} + (1-\tau)\frac{c}{\rho} \quad (2)$$

By equating (1) and (2) we get τ^*, i.e. the interior equilibrium share of tit-for-tat playing farmers:

$$\tau^* = \frac{c-d}{2c-a-d+(b-c)/\rho} \qquad (3)$$

Figure 3-1illustrates (1), (2) and (3). In this model, we represent water using individuals as bearers of their adopted strategies (tit-for-tat or abstain). However, the distribution of chosen strategies varies within the population. While analyzing the change in a single period ($\Delta\tau$), we follow the assumption of monotonic updating of the individual strategies. This, in turn, implies that $\Delta\tau$ takes the signs of $(\pi^T - \pi^A)$ (as in Bowles, 2004:409).

Figure 3-1: Expected payoff to strategies.
π^Aline: expected payoff to abstainers. π^T_C line: expected payoff to tit-for-taters

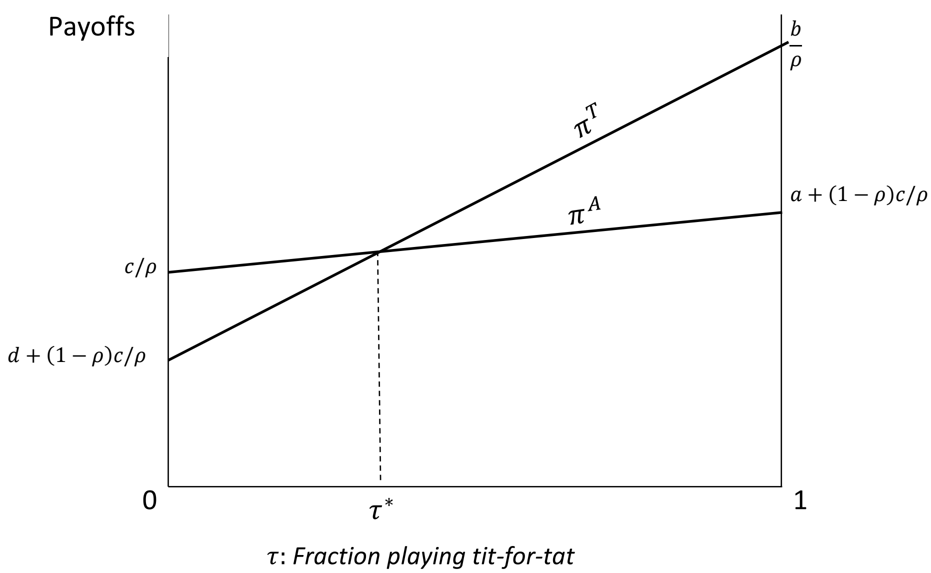


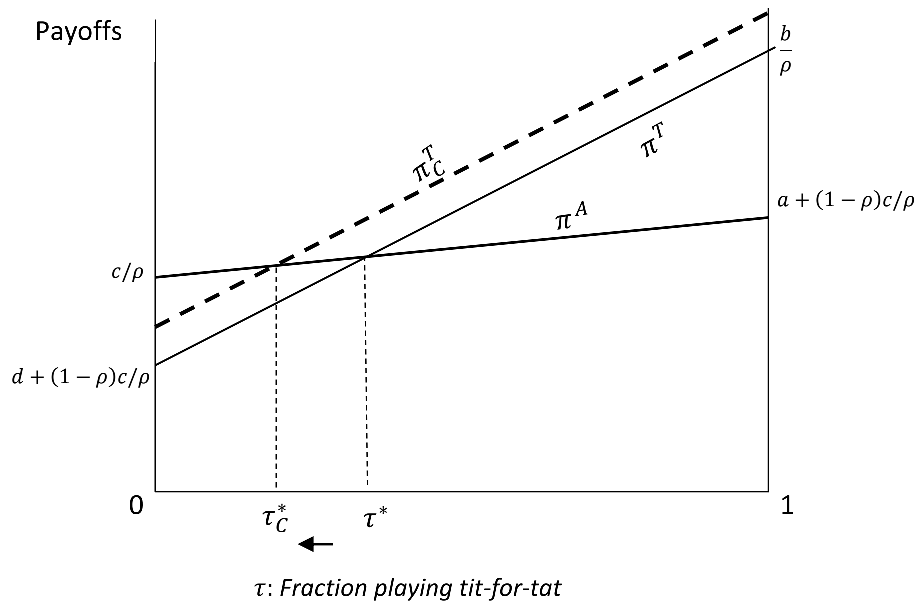
Figure 3-1 is *non-ergodic* or path dependent, as there are two stable equilibria both of which are *absorbing*. Which equilibrium is attained by the population depends on the initial state (Young, 1998:48). This situation is subject to *positive feedbacks* as the payoff to either strategy (to invest or abstain) is increasing in the number of people taking the same action. Moreover, there is a threshold (τ^*) amount of tit-for-taters, i.e. an unstable equilibrium, beyond which tit-for-tat becomes more successful than abstaining. This is because when the fraction of farmers playing tit-for-tat is more than that threshold, the payoffs to tit-for-tat become greater than the payoffs to unconditional abstaining ($\pi^T - \pi^A > 0$). In this setting with positive feedbacks, small chance events usually have continuous consequences. Initial conditions produce persistent 'lock-in' effects and lead the population into multiple equilibria or 'traps' as in Figure 3-1. In such traps (absorbing stationary states at $\tau = 0$ and $\tau = 1$), small deviations in strategies ($\Delta\tau$) are not sufficient to shift the interaction from one state to another, unless $\Delta\tau > \tau^*$ or $\Delta\tau > 1 - \tau^*$ respectively. The steady states (equilibria) are self-correcting. However, the multiple stable equilibria can still be displaced by means of exogenous shocks, mutations and non-best response play (Bowles, 2004:12).

3.2.4 Arrangements (treatments) facilitating cooperation

Achieving a cooperative outcome in smaller groups is more realistic than in bigger groups. Taylor (1987:105) justifies the size effect with the argument of peer monitoring, as it is a major enabling factor for players to sustain conditionally cooperative interaction. With increasing group size, however, it becomes a tedious task for the interactors to engage themselves in mutual monitoring, as a result, sole peer-monitoring might lose its worth as cooperation inducing arrangement. Consequently, in groups of intermediate size, positive and negative sanctioning mechanisms could be essential to facilitate the self-reinforcing cooperative outcome.

Until now we have seen how a multi-period, N-person Prisoners' Dilemma with retaliation turned into an Assurance game-like interaction with multiple Pareto ranked (superior and inferior) equilibria. The Assurance game which is also known as a Trust Dilemma (Grimm et al., 1998:163) can be locked into a defective convention due to a lack of trust among players, as the alternative name might suggest.

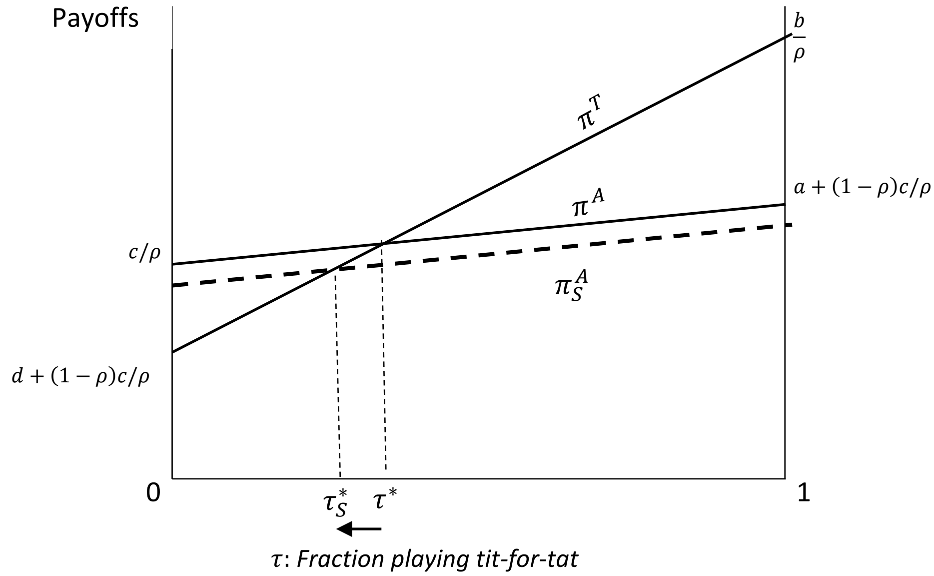
Figure 3-2 Expected payoff to strategies. Communication treatment (dashed π_C^T line: expected payoff to tit-for-taters in Communication treatment)



Pre-play communication may provide the players with trust and hence reputation building opportunity. Communication among players enables them to behave conditionally cooperative which then (in the following round of interaction) increases the proportion of tit-for-taters in the population. This effect of communication, through its peer-monitoring specification, is reflected in Figure 3-2 by an upward shift in the expected payoff for tit-for-tat denoted with π_C^T. Such shift decreases the threshold amount of the population fraction of tit-for-taters ($\tau_C^* < \tau^*$). It implies that the basin of attraction for the cooperative (mutual investment) convention is increased.

Sanctions, on the other hand, diminish the payoffs for unconditional defectors. Figure 3-3 conveys this notion by shifting down the expected payoff of unconditional abstaining ($\pi_S^A < \pi^A$). This shift, in turn, increases the basin of attraction of the cooperative convention: $(1 - \tau_S^*) > (1 - \tau^*)$. This implies that sanctioning also facilitates the cooperative convention.

Figure 3-3: Expected payoff to strategies. Sanctioning treatment (dashed π_S^Aline: expected payoff to unconditional abstainers from investment in sanctioning treatment)

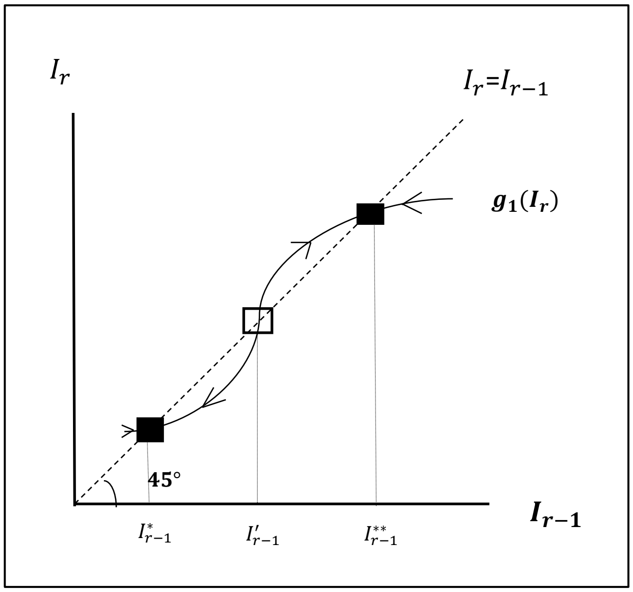


There are hence five major insights to take from our theoretical discussion so far. First, that the repetition of the one-shot Prisoners' Dilemma makes cooperation possible as a best-response play of rational individuals. Second, the existence of conditional cooperators playing a tit-for-tat strategy is another factor enabling cooperation. Third, the repeated Prisoners' Dilemma can end up in multiple equilibria. Fourth, the initial state of interaction plays a key role in determining the final equilibrium (i.e., history matters). Finally, peer monitoring (Figure 3-2) and sanctioning (Figure 3-3) may enable conditional cooperation as they make the cooperative convention more attractive (by increasing its basin of attraction).

3.3 Multiple equilibria

3.3.1 Multiple dynamic equilibria

Figure 3-4: Stylized investment diagram with multiple stable and unstable equilibria



Source: adopted from Carter &Barret (2006)

In order to prepare for the empirical analysis, Figure 3-4 presents a recursion diagram in players' investment space, which we adopt and adjust from Carter & Barret (2006). The recursion function denotes expected collective investment decision path. The vertical axis shows collective investment per session at the current round (I_r) and the horizontal axis illustrates collective investment per session in the previous round (I_{r-1}). There is a dashed (45-degree) line, which illustrates total lock-in (trap) of investment decisions where current round collective investment equals the previous round. Any point on the 45-degree line represents a dynamic investment equilibrium. The function $g_1(I_r)$ represents the case of multiple dynamic equilibria where the dynamic investment decision path crosses the 45-degree line several times. I'_{r-1} indicates a dynamic (unstable equilibrium, saddle point) collective investment threshold. If collective investment decisions are above this threshold, players can be expected to increase their collective investment decisions (i.e. more than in previous rounds) until they reach the stable equilibrium I^{**}_{r-1} .

Figure 3-4 illustrates interaction with two absorbing (non-ergodic) investment conventions [low (defective): I^{*}_{r-1} and high (cooperative): I^{**}_{r-1}], as in Figure 3-1.

We will analyze the curvature of the recursion diagram using experimental data from a field experiment. The shape of the graph of a function visually illustrates where it is concave or convex and where the local extreme points are to be found.

3.3.2 Treatments (arrangements) and dynamic equilibria

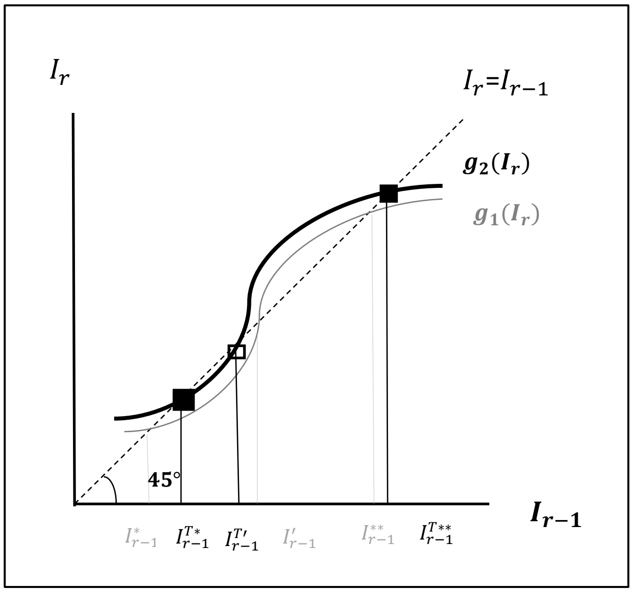
The deliberate introduction of non-best response play (intentional collective action) into the game could break the deterministic dependence of the outcomes on the initial state (Bowles, 2004: 419). We consider two types of treatments: peer-monitoring enabling communication and the deployment of sanctions (penalties) against defectors.

Pre-play communication gives a chance to devise, though non-binding, agreements on group-interest favouring decision making and strategies to tackle the defectors (Ostrom & Walker, 1991). In other words, the communication treatment provides the opportunity for the players to collectively decide to change the mode of play by increasing mutual trust. Given a "bad" (low investment) equilibrium, self-organized (intentional) non-best responses by players are necessary to navigate into the basin of attraction of the "good" (high investment) equilibrium (Bowles, 2004).

Penalty treatments are also assumed to induce non-best response play among farmers and move their interaction toward a mutually beneficial convention. In their experimental research, Tenbrusel & Messick (1999) reveal that defection took place more often when a sanctioning scheme implied lower levels of penalties. This finding motivated us to employ both low- and high-penalty treatments.

The analytical framework for both communication and penalty treatments is demonstrated in Figure 3-5, where the $g_1(I_r)$ (baseline) function shifts upward [$g_2(I_r) > g_1(I_r)$]. The resulting I_{r-1}^{T*}, $I_{r-1}^{T\prime}$ and I_{r-1}^{T**}

Figure 3-5: Stylized investment diagram for games with treatments



respectively depict the stable low level of collective investment, an unstable threshold equilibrium and a stable high level of collective investment for all treatments.

In case of the communication treatment, the payoff to the retaliation strategy increases due to positive feedbacks, as pre-play communication and hence peer monitoring serve to increase the fraction of tit-for-taters through trust-building mechanism, which then increases the basin of attraction of the cooperative (high investment) convention. Regarding penalty treatment circumstances, because the payoff to the abstaining strategy decreases as a result of penalties (as in Figure 3-3), the basin of attraction of the investment strategy increases. These increases of the basin of attraction (of communication and penalty treatments) is accordingly spelled out in the upward shift of the investment path in Figure 3-5.

3.4 Key hypotheses

According to the lock-in effect, we predict that if a game starts with a low level of joint contributions, this type of interaction will be locked in (trapped), and the interacting parties stay in a no investment (or low joint investment) convention until the end of the game. Following the same logic, if a play starts with a high level of joint contributions, there is a high probability that this interaction will continue with a high level of cooperation (mutual investment) till the end. While this belief is supported theoretically, the data at our hands derived from the irrigation game experiments allows us to empirically address the question of whether there are self-reinforcing traps (dynamics) at play.

Hypothesis 1 (H1): *There are multiple equilibria in interactions. Among those multiple equilibria, there are low and high stable equilibria (collective investment levels), towards which the interactions move; at which the interactions can be locked-in depending on the level of collective investment in the previous round.*

Furthermore, building on our arguments above, we hypothesize that peer-monitoring or sanctioning (pre-play or penalty treatments) affect the self-reinforcing investment traps.

Hypothesis 2 (H2): *Communication treatment increases the level of cooperation compared to a baseline without treatment*.

Penalties decrease the payoff to the abstaining strategy which then increases the basin of attraction of high-investment (cooperative) strategy (in Figure 3-3, Figure 3-5).

Hypothesis 3 (H3): *Penalty treatment increases the level of cooperation compared to a baseline without treatment*. *Both low-investment (defective) and high-investment (cooperative) levels are higher under penalties.*

3.5 Experimental design: rules of irrigation game

In the following, we aim to test the key hypothesis using field experimental data collected among agricultural water users in Kazakhstan and Uzbekistan. The experiments were conducted in twelve villages in Maktaaral district of South Kazakhstan (now called Turkistan province) and Samarkand provinces in 2016, involving 235 farmers in a total of 47 sessions (see Amirova et al. 2019 for a detailed description of the data). Villages were selected according to their up-, mid-, and downstream location along major irrigation canals. Based on experimental protocols developed by Cárdenas et al. (2011), farmers obtained an endowment to be allocated either for private consumption or to a public irrigation fund. Depending on the size of the irrigation fund, water availability and thus returns from farming for individual farmers increased. Each session comprised five players; each participant was randomly assigned with a particular location with respect to the water resource, in order to imitate head and tail-end users. Each session continued for 21 rounds, however, the players did not know when the game would end so as to avoid end-game effect. In every round every participant had to make two decisions, concerning: (1) investment in irrigation infrastructure and (2) water use. We established a direct relationship between collective investment and water available for the group of water users to irrigate their respective fields. Individual water use translated into earned income from irrigation. Both of these relationships are presented in Table 3-3 below. The information in Table 3-3 was available to every participant and was accordingly explained. Both investment and water use decisions were made anonymously. The investment decisions were simultaneously made by all five players. Afterwards the amount of collected coupons was announced to the group. No individual investment of the players was known to any of the players. Then, the players in accordance with their water locations sequentially made their water use decisions.

Table 3-3: Collective investment (a) and individual water use (b) outcomes

(a) Investment		(b) Water use	
Group investment (in coupons)	Water available for collective use (in minutes)	Individual water extraction in minutes	Coupons earned
0-10	0	0-5	0
11-15	5	6-7	2
16-20	20	8-10	5
21-25	40	11-12	10
26-30	60	13-15	15
31-35	75	16-17	18
36-40	85	18-20	19
41-45	95	21 -25	20
46-50	100	26-28	18

Note: 1 coupon is ~0.02Euros (equivalent in local currencies: Tenge (Maktaaral) and Soums (Samarkand).

We conducted irrigation games either according to a baseline scenario, or according to one of three treatments, i.e. communication, low penalty, and high penalty scenarios. We did not change anything during the 21 rounds of the baseline games. If the group was playing treatment games, the first 11 rounds were held as in the baseline, afterwards we introduced respective new rules to the game (treatments). In the communication game, after the 11th round, the players started to have a pre-play cheap-talk opportunity for 3 minutes before each round until the end of the game. In case of penalty games, after the 11th round, we introduced an equal sharing rule to the players, with one-sixth probability of each water user's water extraction decision being inspected. When the equal-sharing rule was violated, the violator's excess earning would be confiscated in the low-penalty game. In the high-penalty game, on top of the confiscation of excess earnings, the detected rule-breaking player was forced to pay a fine equal to six coupons as well (Amirova et al., 2019).

The water users face circumstances where they need to make decisions of irrigation infrastructure maintenance, i.e. public good generation and water use within the same group context. Sequential access gives the upstream water users higher chances of water stealing. In the same time, it also gives the downstream water users the opportunity of "sanctioning" the head-enders by not contributing to the infrastructure maintenance if the upper ones do not leave sufficient amount of water to them (Janssen et al., 2012)

3.6 Graphical analysis

In the remainder of the chapter, we employ non-parametric local regression to investigate the dynamic properties of collective investment choices depicted in Figure 3-5, based on the experimental data introduced before. Local regression is an approach to fitting curves and surfaces to data by smoothing. The fit at a particular independent variable is the value of a function fitted only to those observations in the neighbourhood of that variable (Cleveland & Loader, 1996).

With I_r the collective investment level of session s at round r, equation (4) depicts the dynamic auto-regression of a session's average investment non-parametrically for some unknown mean and variance function $\mathrm{g}(\cdot)$, without making assumptions about the functional form of $\mathrm{g}(\cdot)$.

$$I_r = \mathrm{g}(I_{r-1}) + \varepsilon_r \quad (4)$$

Smoothing via local polynomials is one method among many others and estimators fall into the category of nonparametric regression. Local polynomial regression involves fitting the response to a polynomial form of the regressor via locally weighted least squares.

In local polynomial regression, the choice of the polynomial degree and the bandwidth (how wide the local neighborhood should be) is crucial and involves a trade-off between bias (misreporting the shape) and variance (lack of precision). A higher degree will generally produce a less biased, but more variable estimate than a lower degree. It has been stated that odd-degree polynomials outperform even degrees, but totally ruling out even degrees is also not recommended (Cleveland & Loader, 1996).

In the following, we use the "lpoly" algorithm in Stata 15 to analyze our data. By default, Stata's lpoly uses the rule-of-thumb (ROT) method to estimate the bandwidth used for the smoothing. Plug-in or default bandwidth estimates are, usually, not the best choice. Therefore, one approach of optimal bandwidth selection is to select the bandwidth by visual inspection of the data. This method is named as *eyeball method*. It implies starting with a rule-of-thumb (Stata's default) value and then assess the sensitivity of the resulting estimate to alternative values of bandwidth (smaller and larger) until the data do not appear either over-smoothed or under-smoothed (StataCorp 2017). We employ such visual sensitivity analyses for the selection of both bandwidth and polynomial degree for baseline, communication, low-penalty and high-penalty irrigation game sessions in Figures A1, A2, A3, and A4 respectively (see APPENDIX-II).

Table 3-4 provides a summary of the chosen polynomial degree and bandwidth to model data from baseline and treatments of irrigation game experimental sessions. (see the APPENDIX -II for robustness checks).

Table 3-4: Our chosen polynomial degree and bandwidth values to model data generated in irrigation game sessions

	Using the eyeball method we choose:	
Irrigation games' rounds 12-21	**Polynomial degree**	**Bandwidth**
Baseline (Figure A1 in APPENDIX-II)	3	3.23
Communication (Figure A2 in APPENDIX-II)	1	2.07
Low-penalty (Figure A3 in APPENDIX-II)	1	1.18
High-penalty (Figure A4 in APPENDIX-II)	2	1.65

3.7 Results

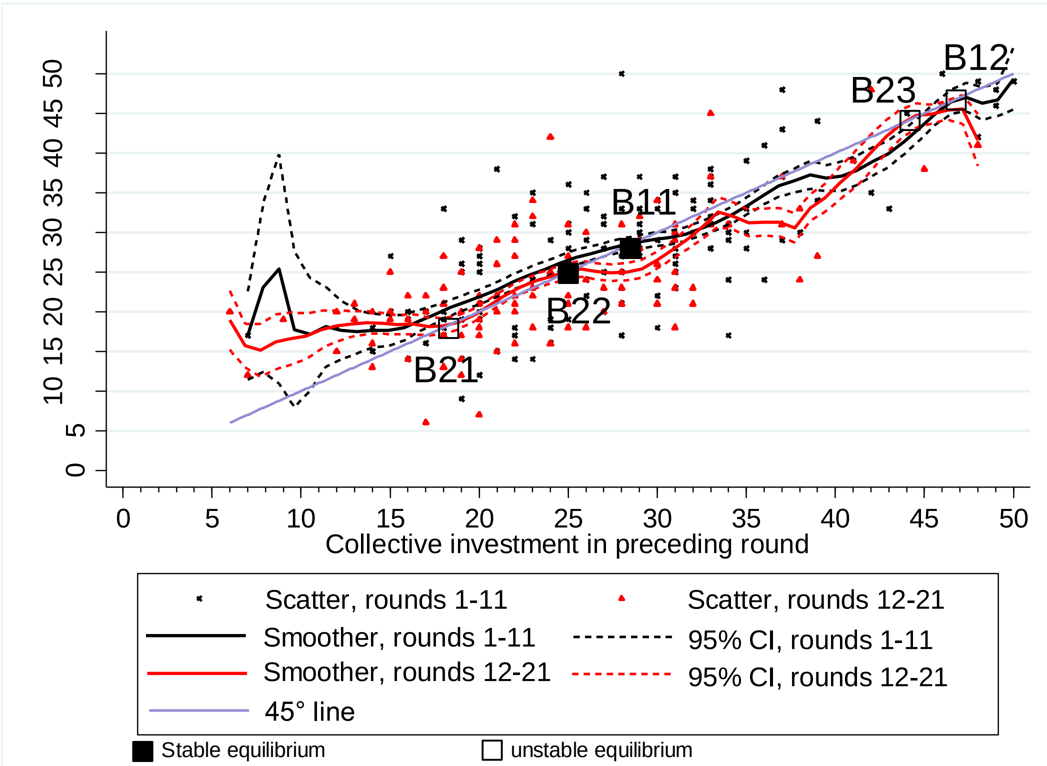
3.7.1 Overview

We analyze each game session, including baseline sessions, by dividing the observations into two stages: the first stage captures observations generated between rounds 1 and 11; the second stage captures observations generated between rounds 12 and 21, i.e. the treatment rounds. We also compare the first and second stage for the baseline observations. Isaac et al. (1985) explain that with more iterations of interactions participants start to understand (learn) the rules of the game better and as a result, the interaction could move toward the convention representing narrow self-interest (low levels of collective contributions). Inter-stage comparison of the observations in baseline games allows us to capture this pure learning effect. Similarly, inter-game comparison of the second stage of the baseline with the second stage of treatment games allows us to capture treatment effect across games.

Figure 3-6, Figure 3-7, Figure 3-8 and Figure 3-9 present the autoregressive non-parametric model of investment relationship for baseline, communication, low-penalty, and high-penalty irrigation games respectively. Figure 3-6 is an empirical representation of Figure 3-4. Figure 3-7, Figure 3-8 and Figure 3-9 are empirical representations of Figure 3-5.

Baseline irrigation games: A closer look at the scatter plot of the first stage (rounds 1-11) and the second stage (rounds 12-21) of the game shows that black dots (representing rounds 1-11) were more dispersed than the red dots (representing rounds 12-21), though one might find it hard to detect. This implies that with more rounds of interaction the decisions of investment are path dependent. Because the red dots, representing the later stages, come very close to the 45-degree line, and this means with more rounds the probability of current round's decision being pre-determined by previous round's decision increased. The decisions were locked in. Previous round decisions were pivotal in the current round's level of investment in the second stage of baseline games. Moreover comparing the relative location of the scatter plot we can see the amount of black dots above the 45-degree line is greater than the amount of red dots. With this, we capture the learning effect in our experiments, as with more rounds the aggregate amount of investment started to lower toward conventionally forecasted Nash equilibrium (Figure 3-6).

Figure 3-6: Collective investment outcomes in baseline game

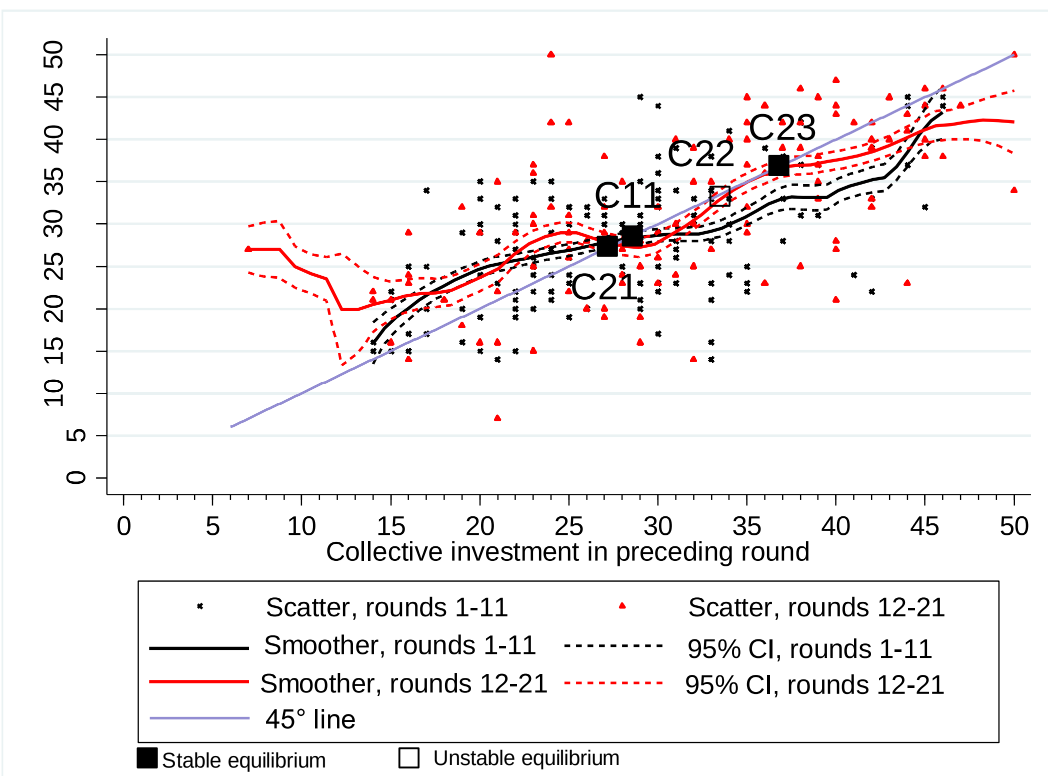


The local polynomial smoothing curve crosses the 45-degree diagonal line once in the first stage and several times in the second stage. Those intersections are denoted with alphanumerical labels, from B11 to B23, where the first number after the letter denotes the stage of the game (baseline vs. treatment) (Figure 3-6). Moreover, the intersections are indicated with filled square and hollow squares, they symbolize stable equilibrium (convention) and unstable (interior) equilibrium respectively.

Communication irrigation games: In the first stage of the game, when no communication was allowed, the local polynomial smooth line of collective investment crosses the 45-degree line once, denoted with C11 (a stable equilibrium) in Figure 3-7. However in the second stage, when a pre-play communication opportunity was given, the respective local polynomial smooth line of collective investment crossed the 45-degree line several times (C21 stable equilibrium, C22 unstable equilibrium, and C23 stable equilibrium). These points are also referred to as C11-equilibrium; C21-equilibrium; etc.

There are two parts of the smoother (local polynomial smooth curve) of the communication treatment (rounds 12-21). The first part, left of the C21-equilibrium, is located northwest of the 45-degree line, and the second part is beyond the C21-equilibrium. In the first part, the curve is not closely located to the 45-degree line. In the second part of the smoother, the curve crosses the 45-degree line and the position of the whole smoother line is generally located very close to the 45-degree line. This means that when people communicated, they were able to overcome crisis (extreme poor investment) as their current round investment decision was not pre-determined by previous round's low levels of collectively invested coupons. That is, when farmers faced a crisis of investment in irrigation infrastructure and hence crop productivity, they were able to improve their state by pushing their aggregate investment up in the next round of their interaction. The local decision making (in the form of pre-play communication) was indeed serving to overcome the vicious circle of extreme underinvestment.

Figure 3-7: Collective investment outcomes in communication game

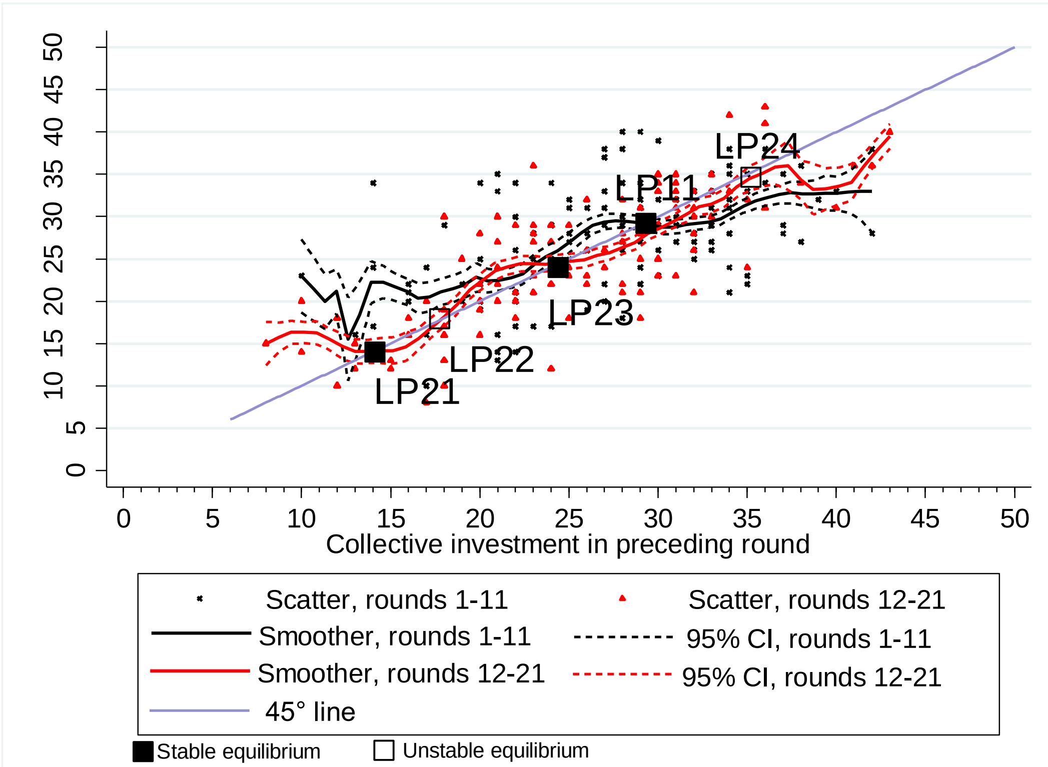


The figure also shows that high collective investments in previous rounds create positive spillover effects. The second part of the smoother pivots inwards and comes very close to the 45-degree line. This means that beyond the C21-equilibrium, the investment decisions were mostly path dependent (Figure 3-7). The communication opportunity provided space for both reciprocation-based cooperation and crisis-overcoming cooperation.

Low-penalty irrigation game: When no treatment was introduced, the local polynomial smooth line of collective investment crossed the 45-degree diagonal only once in Figure 3-8 (in LP11, a stable equilibrium). In the second stage, when the weaker sanctioning rule for the equal sharing rule violators was introduced, the respective local polynomial smooth line of collective investment crossed the 45-degree line several times, those intersections are LP21-stable equilibrium, LP22-unstable equilibrium, LP23-stable equilibrium and LP24-unstable equilibrium (Figure 3-8).

As in the baseline game, the scatter plot of rounds 1-11 (black dots) is more dispersed than the scatter plot of rounds 12-21 (red dots) in Figure 3-8. With time or due to the weak sanctioning treatment, the decisions became more path dependent. Because the previous rounds' decisions were more pivotal in the second half of the games' investment decisions (rounds 12-21) when the treatment was effectuated and the players were more used to the rules of the game. A learning effect coupled with a treatment effect made the collective investment decisions similar to the Nash solution in the low-penalty irrigation games' treatment stage.

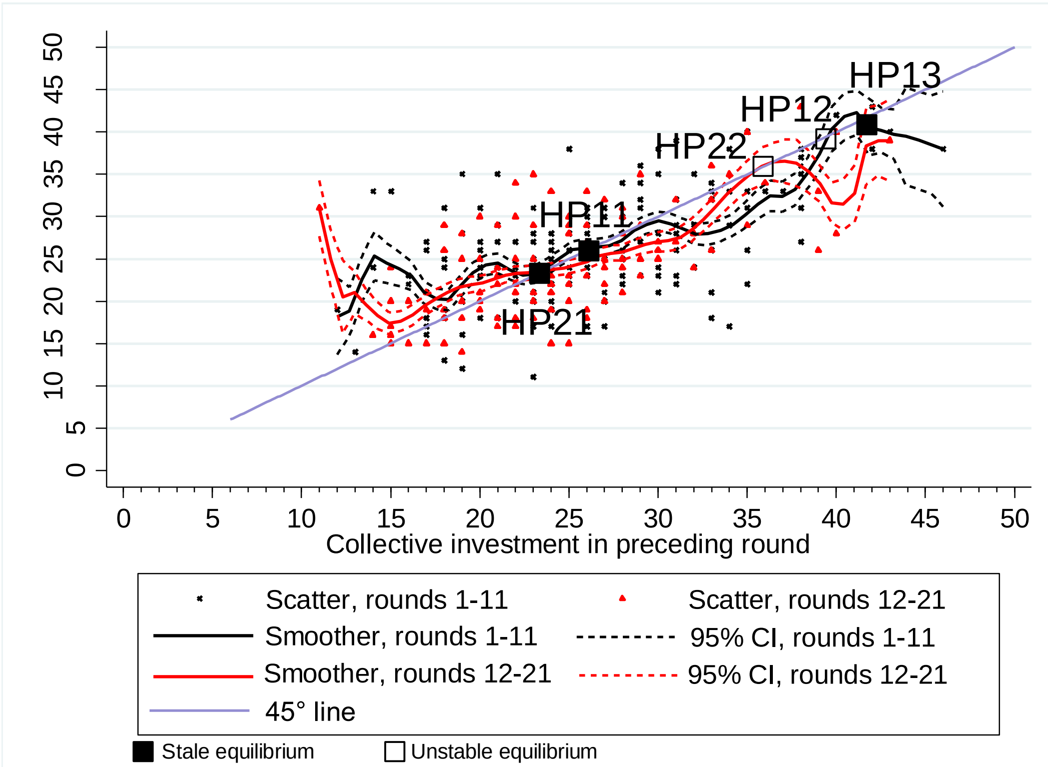
Figure 3-8: Collective investment outcomes in low-penalty game



<u>*High-penalty irrigation game*</u>*:* Unlike in low-penalty (or any other) games' first stage, in the baseline setting (first stage) of the high-penalty irrigation game we detected three intersections of the local polynomial smooth line of collective investment with the 45-degree diagonal in Figure 3-9 (the HP11 stable, HP12 unstable, and HP13 stable equilibria). In the second stage, when the severer sanctioning rule was introduced, the local polynomial smooth line of collective action crossed the 45-degree line at the HP21 -stable-equilibrium and HP22-unstable equilibrium points (Figure 3-9).

In the North-Western part of Figure 3-9, we can see a higher number of black dots than red dots. Consequently, the local polynomial smooth curve of the High-penalty treatment narrows in dispersion and comes close to the 45-degree line. These details provide evidence for the inability of the High-penalty treatment to enhance collective investment in irrigation infrastructure.

Figure 3-9: Collective investment outcome in high-penalty game



3.7.2 Baseline: H1

The baseline game demonstrates that there are multiple equilibria (at B11, B12 B21, B22, and B23) in the investment decision path. Among those equilibria, some are stable (B11 and B22) and some unstable (B12, B21, and B23). Equilibria B11 (in the first half) and B22 (in the second half of the baseline game), denoted with filled squares, depict situations of lock-in in the baseline setting. Consequently, we **confirm H1**.

Table 3-5 summarizes the approximate numeric values of the denoted points of the local polynomial non-parametric regression across baseline and treatment games. In baseline games with more rounds of interactions, the equilibrium level of investment decreased from 29 to 25 (Table 3-5). This finding supports Isaac et al (1985), regarding the learning effect, that with more iterations of interaction, people learn the setting better and their decisions start to approach the Nash solution.

Table 3-5: Summary of local polynomial non-parametric autoregressive regressions' selected points

	Baseline					Communication				Low-penalty					High-penalty				
Points in the figures	B11	B12	B21	B22	B23	C11	C21	C22	C23	LP11	LP21	LP22	LP23	LP24	HP11	HP12	HP13	HP21	HP22
Approximate location (amount of collected coupons of investment)	29	47	18	25	44	29	27	34	37	29	14	18	24	35	26	40	42	23	36
ESS (Y: Yes; N: No)	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	N	Y	N	Y	N	Y	Y	N

Note: Key to equilibrium labels Xij: i is the stage of the game (stage 1: rounds 1-11; stage 2: rounds 12-21) and j is the position of equilibrium in ascending order from left to right (with respect to 45 degree line).

3.7.3 Communication treatment: H2

We test our hypothesis 2 **(H2)** via the graphical multiple dynamic equilibria analysis as well. Figure 3-7 presents the autoregressive non-parametric model of the investment relationship for communication irrigation games. We compare the amount of collective coupons of investment denoted with respective alphabetical letters in the baseline as opposed to the communication game when we are comparing inter-game results. We consider collectively invested coupons in the communication games' first stage (rounds 1-11) with the second stage. H2 can accordingly be tested in both inter- and intra-game context. We refer to Table 5 in these comparisons.

The value of the B22-stable equilibrium (baseline) is compared with the value of the C21-stable equilibrium (communication). As 27 is greater than 25, we confirm H2 in the inter-game comparison. The magnitude of cooperation in communication treatment games is higher than in baseline irrigation games. There is a clear red (scatter) dominated cloud of dots on top of the C23-equilibrium and a black dominated one below, establishing the upward shift due to the pre-play communication treatment (Figure 3-7).

In intra-game comparison, because C21-equilibrium's collective coupons (27) are less than at the C11-equilibrium (29) we cannot confirm H2. However, there are two stable equilibria in communication treatment sessions, denoted with C21 and C23. C23-convention's coupons (37) are more than in the C11-

equilibrium (29). Accordingly, we confirm H2. When farmers had the opportunity to self-organize through group deliberation and bargaining, they were attained higher levels of collective investment. As Amirova et al (2019) found, rural Central Asian water users could achieve endogenous cooperation (higher investment). However, just like in reality where not all deliberations lead to better rules, not all communication opportunities led to higher cooperation levels. Some interactions converged toward the C23-equilibrium (high) and others converged toward the C21-equilibrium (low).

3.7.4 Penalty treatments: H3

We hypothesized that penalties decrease the payoff to the abstaining strategy which then increases the basin of attraction of the high-investment (cooperative) strategy, therefore the cooperation level in penalty games is higher than in baseline games (**H3**). **Figure 3-8** presents the autoregressive non-parametric model of investment relationship for low-penalty irrigation games. It is an empirical representation version for low-penalty treatment of the stylized investment diagram illustrated in Figure 3-5.

In *intra-game* comparison, it is clearly seen that neither of the stable equilibria (denoted with LP21 and LP23) are more efficient than the LP11-equilibrium. Consequently, we **reject H3** in this particular setting. Moreover, we **also reject H3** when we do *inter-game* comparison, as both LP21- and LP24- equilibrium values of investment (14 and 24) are less than the B22-equilibrium (25) value (Table 3-5, Figure 3-6 and Figure 3-8). Our finding is consistent with the findings of Andreoni & Varian (1999).

Following the results of Tenbrusel & Messick (1999), regarding the severe versus weak sanctions' respective stronger and weaker effects on cooperative behaviour, we separately test H3 for low- and high-penalty treatments. For low-penalty we failed to confirm H3 in both inter- and intra-game comparison. **Figure 3-9** presents the autoregressive non-parametric model of investment relationship for High-penalty irrigation games.

In intra-game comparison, we observe that high-penalty treatment did not improve the cooperation level. Instead, as the values of the HP11- and HP13-equilibria (26 and 42 respectively) are greater than the HP21-

equilibrium (23), the treatment worsened the cooperation. In other words, in the first stage of the game, when there was no treatment at all, there was a possibility to converge toward a high level of collective investment because of the HP13-equilibrium (Figure 3-9). But when the treatment was effectuated that possibility disappeared. Accordingly, we reject H3 for high-penalty games in intra-game comparison. Our finding supports the argument about third-party induced (or economic) incentives' counterproductive effect on cooperation motives of individuals (Bowles, 2008).

When we compare the high-penalty treatment with the second stage of the baseline game, we see that the B22-equilibrium amount (25) is greater than the HP21-equilibrium amount (23) of collective investment in irrigation infrastructure (Table 3-5). This, in turn, induces us to reject H3 for high-penalty games in inter-game comparison context as well.

To sum up, we **reject H3** for low- and high-penalty treatment games based on both within- and between game comparisons.

3.8 Conclusions

Investment in irrigation infrastructure has widely been described as a social dilemma, suggesting that water users end up in a "tragedy of the commons" characterized by low investment outcomes. In this chapter, we argue that the dilemma may actually exhibit multiple equilibria, in which case the seemingly inevitable tragedy is turned into a coordination problem that may be easier to solve. We establish this possibility theoretically and provide supporting evidence from a field experiment among Central Asian water users. In our setting, the initial conditions are decisive for identifying to which (low or high) level of joint investment the interaction will eventually converge. In other words, the interactions are subject to lock-ins (traps). In a further step, we show theoretically how endogenous or exogenous rule-setting may overcome low-level investment traps.

As a logical continuation of Amirova et al. (2019), we use data from irrigation game experiments to study whether the interactions of players representing the same rules are consistent with the theoretical model.

We asked whether a self-reinforcing investment dynamic with low-investment and high-investment traps (stable equilibria) could be observed. As that was the case, we were also interested to see how those traps were affected by institutional arrangements (treatments) with peer-monitoring (communication) and third-party sanctioning (low- and high-penalty) attributes. We hence examined the dynamics of collective investment decisions and tested for autoregressive lock-ins.

Non-parametric auto-regressive regression results indicated the existence of multiple equilibria in baseline games similar to the evidence revealed in poverty trap studies by Carter & Barret (2006) and Naschold (2012). Our findings thus confirm that the interactions represented by the experimental irrigation game carry the nature of a self-reinforcing multiple equilibria dilemma, with positive and negative feedbacks. Our findings regarding the negative feedbacks allowed us to capture the learning effect in our experiments, as with more rounds the aggregate amount of investment started to lower toward conventionally forecasted Nash equilibrium as it was claimed in the study of Isaac et al. (1985) for instance. In the same time, we also found that the current state of interaction is heavily dependent on the interacting parties' initial decisions. As a result, to surpass that stationary state there is a need for a great portion of idiosyncratic play, which is unlikely to occur spontaneously. Consequently, the interactions among the players are trapped in either low or high level of joint investment conventions as foreseen by Grimm et al. (1998).

Our results show that players reached a stable, high-level investment equilibrium if they were allowed to communicate before each round. However, the opportunity to communicate did not eliminate the inferior (low joint investment) convention altogether. Our interpretation is that the irrigation game with a communication opportunity still requires costly coordination to reach the socially preferred (high investment) equilibrium. Coordination through the bargaining process which was enabled during pre-play communication led the interaction to either inferior or superior conventions with low- or high-collective investment levels respectively. Which outcome (inferior or superior) would prevail depended on the ability of the players to reach effective agreements among themselves. Moreover, in communication sessions, farmers were better able to overcome extremely low investment outcomes, as in those situations the users' decisions were little predetermined by their previous rounds' low collective investments. Self-organization thus created room for cooperation based on motives of reciprocity and crisis-mitigation.

The penalty treatment with a weak sanctioning mechanism could not achieve better cooperation levels than the baseline games. Instead, both the low-investment and the high-investment stable equilibria in the low-penalty treatment were less than in no-penalty (baseline) circumstances, both in inter- and intra-game comparisons. It suggests that this type of intervention mechanism, with the objective to coordinate the interaction, resulted in an opposite effect. This weak external rule apparently crowded-out the players' motivation to cooperate. Even the external rule, penalizing heavily the defectors (high-penalty treatment), with its imperfect monitoring attribute, could not establish a higher investment level than in the baseline. Moreover, we observed that the cooperative behaviour of the players was suppressed after the introduction of the new rule (intra-game comparison). This evidence suggests that even a severe (external) sanctioning rule does not increase cooperative behaviour, but rather had a crowding-out effect on the voluntary cooperation preference of the water users. Both incentives provided in low- and high-penalty treatments were found to reduce the intrinsic cooperation potential of resource users (Bowles, 2008).

The existence of multiple equilibria in the irrigation game experiments provides us with the hope that cooperation in water governance can be the outcome of best response play. However, because inferior conventions are not eliminated altogether, the water users are still at risk of being trapped in low-joint investment conventions. There is a range of institutional arrangements with the theoretical potential to coordinate the users to achieve the cooperative solution. Given such settings of potential lock-ins, institutional arrangements which allow user participation; give users the power to bargain and provide opportunities to devise endogenous rules seem to be promising candidates for breaking the vicious circle of underinvestment in irrigation infrastructure in a region as Central Asia.

4 AN ANALYTIC APPROACH TO THE HISTORICAL EVOLUTION OF WATER GOVERNANCE IN CENTRAL ASIA[4]

4.1 Introduction

Water is an economic resource for agricultural development, which is contested, controlled and sometimes fought about (Bichsel, 2016: 359). In Central Asia, water governance has entailed all those activities since many centuries (Lewis, 1966). It is a region where the traditional institutions of residence self-governance (mahalla) and Islamic endowments (waqf) with the capacity of producing many forms of public goods in water management emerged and prevailed for a long time (McChesney, 1991; Sievers, 2002). The region's water users, indeed, reaped the combined benefits of such traditional institutions, which were also enriched with election-sanctioning mechanism in coordination of both water users' participation and irrigation officers' continuous decent service (O'Hara, 2000; Abdullaev & Rakhmatullaev, 2015).

However, Central Asia's landscape considerably changed between the 1860s and the 1990s when the region was under the rule of firstly Tsarist Russia and then the Soviet government. The invading nation, as a rule, perceived the new colony as backward and introduced its development program which mainly aimed to solidify the regional specialization via extending irrigated land area and cotton production (Obertreis, 2017).

Our objective here is to provide an analytical model of evolved history that allows identifying key behavioural mechanisms that potentially explain the historically observed outcomes in water governance of Central Asia. Our study asks how and why the institutions of water governance in Central Asia changed over time. The objective to model institutional evolution requires us to depict institutions not as a set of exogenous constraints, but rather as the outcome of water user's interactions. The underlying game we specify can have several outcomes (also termed conventions or equilibria) as a result of individual interaction. These conventions actually are institutions. Consequently, we explain the institutional change of Central Asia's water governance as a problem of convention (equilibrium) selection, and explain why

[4] This chapter draws on a journal manuscript written jointly with Martin Petrick and Nodir Djanibekov

one equilibrium emerged and persisted for long, when other alternative equilibria were possible in the framework of water users' best response play, and why those long time persistent arrangements then eclipsed. To answer our question we refer to an extension of the evolutionary "Hawk-Dove game" with individual water users' preferences in water appropriation, sharing and their civic engagement (participatory with sanctioning attribute) (Bowles, 2004:382-386). We refer to the game strategies as the cultural traits which can be learned and/or updated following certain copying behavior (replication dynamic). The replication dynamic can be described by both payoff monotonicity and a conformist transmission process.

We consider this sort of explanation of water management history to be instructive for various purposes. It does not solely describe the former water management practices but it additionally presents insight about the mechanisms (games) behind those practices. By doing so, we ease the understating of, possibly, reciprocal cause and effect relationship between endogenous preferences (strategies or traits) and institutions (conventions) along with the role of chance events (exogenous shocks) in water management. With the reference to history we evaluate water coordination mechanisms such as community and bureaucratic arrangements. By using a counterfactual approach we present a scenario of market arrangements in irrigation water governance. Such synopsis, while not exhaustive in outlining a whole set of possible outcomes (consequences), should be useful for both social scientists and policymakers to get novel and stimulating insights into the problems and possible solutions of current water governance practices in Central Asia.

We illustrate that pre-Tsarist water governance entailed a coexistence of several arrangements, including state and several (parallel) self-governance institutions such as water users' federation with its accountable irrigation officers, neighborhood communities and charitable endowments. They jointly instilled conditional cooperation in water into the strategy profile of rational water users. Moreover, we show why and how the lowering of payoffs for civic-minded water users eventually led to their disappearance, so that they were replaced by unconditionally defecting water users, after the Russian invasion and then during

Soviet rule. Moreover, our analytical framework allows us to sketch a possible scenario of market arrangements in the irrigation sector. We claim that private property rights could have solved Central Asian water users' long-standing issues with unsustainable water use practices. However, the absence of essential preconditions for water privatization could have led the water users' society towards a regressive convention as well.

Based on a suggestive literature review, section 4.2 recalls the historical facts of water governance in Central Asia. Section 4.3 provides the analytical framework, that is, the evolutionary game model, the lens through which the chapter, in section 4.4, re-iterates the historical events and explains the evolution of water governance from the perspective of behavioural preferences, replication dynamics, conventions, and drifts. Section 4.5 examines what we call the "Kaufman drift," i.e., the corruption of decentralized water governance, and its repercussions in the long term. Section 4.6 elaborates on what could have happened if the water resource was privatized, drawing on historical plans to do so under Tsarist agricultural minister Krivoshein. Section 4.7 provides a final discussion and concludes.

4.2 *Historical epochs of irrigation governance in Central Asia*

4.2.1 *Traditional governance prior to the Tsarist invasion of Central Asia*

An exceptional geographic feature of Central Asia is its aridity. This feature implies that agriculture and hence constant food supply were, normally, impossible without irrigation, after the region's wider shift to a sedentary way of life in irrigated oases. The history of irrigation practice of the region dates back to, at least, the Bronze Age and it was initially based on piedmont irrigation. On the piedmonts, there was an evolution from naturally-formed irrigated basins to artificial basins fed by small irrigation systems. Only small and scattered areas could be irrigated along the piedmonts due to an inadequate water supply capacity of the respective system. To ensure adequate water supply across scattered irrigated areas, the settlers introduced dams and embankments along small streams derived from rivers (Lewis, 1966).

Central Asia's communities used various artificial forms of irrigation, including exclusively sedentary agriculturist to small groups of nomads utilizing small canals (aryks) carved out in the steppe for infrequent agricultural cultivation. Fully sedentary communities could be exploiting both large irrigation systems and small isolated systems as well. Communities used irrigation in conditions of extreme drought as well as in quite humid foothills. Such diversity of irrigation types and practices illustrates the individualistic response of Central Asian communities to fit their respective environmental context (Matley,1994: 277; Fourniau, 2000).

Both the social organization and the physical system of irrigation differed across periods, regions and localities. The system, its management and governance styles were interwoven with the social and political organization of the respective societies (Obertreis, 2017: 29). In the following, we review some of the basic institutions influencing water governance in Central Asia.

4.2.1.1 Actors and social institutions of traditional water governance

Usually, networks of *aryks*, which fed farms, villages, and towns, were constructed and managed locally by communities of peasant farmers (*dehqans*). However greater feeder canals (*nahars)* required greater resources and hence were subject to more complex coordination (Morrison, 2008: 202). This role of a coordinator for the construction and maintenance of a large net of *nahars* and installations alike, the country-wide water allocation and distribution, was taken by the central water authority, which was led by a *Mirab-bashi,* the chief water master. Water users' communities who consisted of dehqans elected the Mirab-bashi and paid his remuneration, known as *Kipsen*. Kipsen was never some constant percentage from the grain harvest, but rather it depended on the satisfaction level of dehqans concerning the irrigation service quality they received. Furthermore, there were *mirabs* and their assistants called as *aryk-amins,* who supervised the secondary canals' maintenance, water allocation and distribution. They were also, like Mirab-bashi, elected and paid by the dehqans based on the same principle. There were *ketmans* (water users' associations) comprised from three to four villages. The ketman was responsible for the village level constructions and maintenance of irrigation systems. One ketman would have three to four elected elders (*aryk-aksakals*) who represented their respective villages' interests. There were even further smaller management components (tops) consisted of either few streets or family units (O'Hara, 2000: 373).

4.2.1.2 The charitable endowment (waqf)

The charitable endowment (waqf) was a complementary institution to the above-mentioned water self-governance arrangements. "[A] … waqf is an unincorporated trust established under Islamic law by a living man or woman for the provision of a designated social service in perpetuity. Its activities are financed by revenue-bearing assets that have been rendered forever inalienable" (Kuran, 2001:842). In other words, this was a private institution for providing public goods. The *waqf* was an important institution for the provision of community social services in Islamdom and it was woven into the fabric of daily life of Muslim Central Asian societies. Financing public buildings and facilities like irrigation infrastructures, supporting education, providing welfare for the poor and the like were the variations of waqf actions of community members which undeniably was one of the major producers of the public good of its time (McChesney, 1991:3). Kuran (2001) suggests that the waqf system was a credible commitment device which provided the property owners (usually land and immovable assets) economic security and reduced taxation in return for an investment in a public good. In other words, this system was a kind of maneuver of the property owners against rent-seeking rulers which in the same time closed holes in social security. Kuran also posits the waqf system as a practice which could have been more flexible over the centuries to fit the dynamically changing societies after the industrial revolution. It may hence have served the respective societies to develop economically and might well have generated a vigorous civil society. The waqf was still widely practiced when Russians arrived at the region. For example, a Russian survey of 1886 revealed that around half land of today's Uzbekistan was under waqf arrangement (Sievers, 2002).

4.2.1.3 The neighborhood community (mahalla)

Mahalla is an indigenous institution of neighborhood community of Central Asia which was managed by a group of community's chosen elders (*mahalla-aksakals*). In pre-Soviet Central Asia the role of elders, and hence mahallas included a range of functions, such as the collection of taxes, delivery of orders, provision of security, residents' dispute arbitration and the guardianship of orphans and widows (Dadabaev, 2017a). In mahallas, social norms were and are still applied to a broad range of social interactions which are often interlocked. For example if an individual failed to cooperate (contribution in either monetary or labor form) in maintenance of road he might face ostracism in a particular form such that he might not be invited to morning ritual feasting next time or "toi" (social gathering to celebrate positive events such as wedding and etc.) or other events (Sievers, 2002). One might also interpret the existence of waqf and mahalla settings as an order of some sort in the world where there is rudimentary government as it is mentioned in Posner (2009: 3).

4.2.1.4 The collective community service (khashar)

Irrigation systems in pre-Tsarist Central Asian localities were, usually, not fixed. Whenever there was a need, new derivations could be built. Such flexibility, however, came with a price. It required constant regulation and continuous manual work. Also, these systems were prone to risks of destruction due to possible high levels of water streams. This implied that in every crop season large amounts of resources were mobilized to clean the canals from siltation and sometimes for reconstruction of destroyed canals or for building new ones. Such grand resource mobilization took place as a result of coordinated cooperation of water users' groups. The communities of dehqans assigned a particular amount of laborers to collective work tasks, directed by water officials, such as the Mirab-bashi, Mirabs or Aryk-amins. This practice was known as *khashar* or *kazu*, and they could imply huge amounts of workers, involving up to thousands of men, for several weeks (Obertreis, 2017: 30-32).

Soviet time researchers such as Tolstov (1948) explained such grandiose resource mobilization with persisting practices of slavery in pre-Tsarist Central Asia. However, there is insufficient evidence to support the idea that Central Asia was a hydraulic society with a strong centralized state, as postulated by Wittfogel (Stride et al., 2009). Instead, we are inclined to believe that the khashar or kazu practices which turned into a custom or tradition (norm), describes the dehqans' self-organization, or cooperation potential and the realization of that potential in water governance of the region. In the same time, the state in the region had always played a prominent role in water distribution, and the ability of a ruling dynasty to exercise control over water was a crucial measure of its power and effectiveness (Morrison, 2008: 202). The profitability of the land of their respective kingdom (khanate) and hence power depended on the number of peasant farms and their income due to the tax or rent dehqans paid to khanate (Abdullaev & Rakhmatullaev, 2015). In its own turn, the aridity of the region determined irrigation water as a major factor of those dehqans' revenue. This means the state was highly interested in keeping a high number of dehqans, while the social and technical organization of irrigation matters were a crucial aspect for dehqans to stay in one or another khanate of the region. In other words, dehqans had the lever, reflected in their exit choices from the khanate, which was the very mechanism enabling the persistence of responsive water governance arrangements supported (complemented) by the centralized government (khanate) level coordination.

4.2.2 Tsarist irrigation governance

Meanwhile Russia, since the time of Peter I, held the illusory belief that Central Asia was a new El Dorado, a region with plentiful natural resources (Thurman, 1999:19). In the second half of the 19th century, this faith of Russia was decisive in the act conquering Central Asia. However, initial imperialistic expeditions made it clear that the dreams of copious natural resources of Central Asia were false. Hence by the time of the invasion, the economic value of the conquest turned out to be unclear (Obertreis, 2017:52). Instead, Tsarist Russia was disappointed by both a false belief regarding the resources and the discovery of a merely "“empty” and “lifeless” desert and steppe landscape” (Obertreis, 2017: 56). The cost of the conquest, nevertheless, had to be justified. Cotton seemed to be a good way of extracting additional revenue from the new colony (Obertreis, 2017). The cotton autonomy objective emerged as a result of the American Civil War, which interrupted Russia's cotton imports from the United States (Beckert, 2014). Consequently, Central Asian cotton production expanded and hence irrigation projects became a major concern in Russian policy over the next century (Obertreis, 2017).

Consequently, Central Asian cotton production expanded and hence irrigation projects became a major concern in Russian policy over the next century (Obertreis, 2017). The introduction of American cotton varieties that produced higher yields than traditionally cultivated Central Asian seeds as well as the dependence of cotton on more frequent periods of intensive labor triggered so-called ‘technology treadmill’ dividing peasants into better-off farmers and landless sharecroppers and introducing so-called ‘plantation economy’ (O’Neill, 2003).

The Russian rule forcefully asserted that Tsarist Russian civilization was superior with respect to both nomadic and settled Central Asian populations. Russian officials and authors portrayed previous rule, under khanates as arbitrary and cruel. The progress of the irrigation system was equated to the progress of the region’s civilization. As a result, economic and civilizing motives concerning the supposedly backward Central Asia were legitimizing the Empire’s development projects regarding cotton production expansion via “blossoming” deserts. Engineers’ fantasies were orchestrating the irrigation infrastructure and hence cotton growing (Barts, 1910; Obertreis, 2017). Ultimately, the greater Russian regulation of Turkestan and investments into irrigation and cotton expansion along with the migration of peasant colonists will turn the region into an economically integrated part of the Empire (Peterson, 2016).

In the process of those projects’ implementation, the Russian Empire kept traditional water governance arrangements to guide the regional water administration. However, the traditional local water administration, now under Russian rule, became corrupt. Graf Konstantin Konstantinovich Palen (senator), who was responsible for the senatorial audit of Turkestan region with the decree issued by the Tsar, remarks that by 1908 it was already a usual practice that wealthy users were getting more water, although there was a ban on water buying and selling (Palen, 1909-1910). The local water administration assisted those wealthy water users. Most of the *aryk-aksakals* turned into professional rent-seekers, and as a result, the irrigation management became inefficient. These changes point to the collapse of established non-state arrangements in the water governance (Obertreis, 2017: 110). We can only guess that this was the consequence of either a lack of insightful knowledge of Russian officials of the local arrangements and hence misuse of the system. Or else it was because of “minor” interventions such as the replacement of election-sanctioning mechanism with state-appointment of various rank irrigation officers (mirabs, aryk-aksakals) and a fixed salary system instead of one that was contingent on the quality of service delivery (O'Hara, 2000).

The Ministry of Agriculture of Tsarist Russia was aware of the breakdown of well-established non-state water governance structures. Moreover, there were financial difficulties in the implementation of irrigation projects in Hungry Steppe. For example, the final cost of the Romanov Canal which was originally projected at 2.5 million rubles, in fact, amounted about 8 million rubles. This difficulty induced the central government to turn to the private sector for assistance. The Tsarist government approached textile industries and requested them to invest in irrigation (Joffe, 1995:372). So the breakdowns in customary water governance and the financial issues with the grandiose irrigation projects were accordingly reflected in the new water legislation proposal of the Minister of Agriculture Alexander Vasilyevich Krivoshein. According to that newly suggested water legislation the state was still supposed to dominate the management. However, Krivoshein proposed to establish a priority ranking of access to free water in the region. The first priority would belong to the state and public needs and the second priority to drink and domestic usage. The third priority would go to irrigation works and industrial-technical enterprises (Pierce, 1960: 151-152). According to the newly proposed water legislation, private capital was to be engaged in the irrigated water sector only, and the state dominated the management.

Nevertheless, the private initiative was integral to the realization of cotton autonomy objective of Tsarist Russia (Joffe, 1995: 381-382). The water law would legalize the water trade that was already taking place in Fergana valley (Morrison, 2008:235; Obertreis, 2017:110). But Tsarist Russia dismantled shortly after Krivoshein submitted this law proposal to the Duma (Joffe, 1995). Consequently, it is hard to guess the possible consequence of this legislative innovation in water governance of Central Asia. In section six, however, we simulate the introduction of private property rights in irrigation water. By applying an extension of the evolutionary Hawk-Dove game, we model the setting and predict the counterfactual outcomes.

4.2.3 Soviet Central Asia

The collapse of the Tsarist regime in Russia and its colonized Central Asia was the result of civic turmoil which eventually transferred power to the political fraction of the Bolsheviks. Former Tsarist administrative borders were erased, and new national borders were instead drawn. It led to the establishment of the Union of Soviet Socialist Republics (USSR) in the respective territories through revolution, civil war, and famine. In Central Asia, under Bolshevik rule, the ideas of cotton autonomy, the defeat of backwardness, the transformation of agriculture and the modernization of irrigation, were adopted from the Tsarist regime without much scrutiny but instead, these ideas took much stronger impetus than it used to be in Tsarist periods (Obertreis, 2017).

The introduction of cotton production plans associated with the increase of cotton yields via higher fertilizer applications and better seed selection, and with continuous planting of cotton on the same fields were among such so-called transformational and modernizing ideas (Matley, 1994). The Soviet period can be marked by the announcement of cotton the King or White Gold of irrigated Central Asia engraved into social, economic and political lives and in new irrigation projects. However, the format of Soviet rule changed throughout the 74 years of its existence. Based on the attention to the Central Asian irrigated agriculture and infrastructure, we distinguish three phases of Soviet rule in the region: early (1917-1944), mid (1945-1969) and late Soviet rule (1970-1990).

4.2.3.1 Early Soviet rule

The division of Central Asia into separate republics was a major step which shaped Soviet Central Asia in the early years of Soviet rule. This separation then facilitated the conversion of the Uzbek Soviet Socialistic Republic (SSR) into a member republic with a special duty to supply the USSR with cotton, despite resistance from local peasants and functionaries (Obertreis, 2017).

Reforms in land and water arrangements began in 1925 and were followed by the involuntary collectivization of agriculture. The collectivization broke the existing power relations and instead created a novel system run by state and coercive collective efforts. Arrests, executions, massive evacuations, and forced deportations were the detrimental consequences of the collectivization. Although there was unrest due to the collectivization campaign, cotton production increased and the Tsarist then Soviet objective of cotton autonomy was becoming more realistic (Obertreis, 2017). For this, the Josef Stalin's government implemented vast irrigation projects across Central Asia, such as the Great Fergana Canal.

Equal opportunities in educational empowerment of both men and women from villages and cities of Central Asia and Russia was the worth mentioning aspect of the Bolshevik regime which was the significant difference from the Tsarist regime. The emphasis of the Soviet government to withdraw from religious traditions has affected the social organization in irrigated agriculture in the region where Islam was a main social force. This related firstly to the abolishment of the traditional land tenure system to induce collectivization in agriculture (O'Neill, 2003).

Water administration, however, on the ground remained in the hands of traditional (customary) water management system's officers, namely *mirabs* and *aryk-aksakals.* This did not significantly change until the 1940s because of a lack of technical training of the new system's personnel. Already in Tsarist Russia, this customary arrangements became corrupted and hence inefficient, and this seemingly continued in the early years of Soviet regime. The state of irrigation was at a dissatisfactory level, moreover, the drainage systems were in even worse condition.

World War II caused perturbations in cotton production, as a result, private and subsistence farming returned and prevailed during the war period in the region. Consequently, after the war, the Bolshevik regime had to take measures to re-establish the collective farm (kolkhoz) system and return the crop choice toward the cotton again (Obertreis, 2017).

4.2.3.2 Mid-Soviet rule

In this period collectivization was completed, and the World War II and its consequences were mitigated, therefore "high modernism" became a top priority (Obertries, 2017: 366).

The electrification of rural areas and mechanization of all cotton cultivation processes, in particular, harvesting process were among such high-modernistic development path of the region. The first was combined with investments into the regional electricity grid and the latter with the construction of an agricultural machinery plant in Tashkent. This period is also associated with a search among various economic and organizational measures to introduce structural transformation in agriculture after the death of Stalin. In this period new agricultural lands were opened up, and massive irrigation installations, e.g. the Karakum Canal, kept emerging. Collective and state farms were usually blamed for water wastage, while inefficient large-scale infrastructure responsible for water distribution from the rivers were also causing water loss and as a result rivers could not reach the Aral Sea. For example, the Karakum Canal, which diverted water from the Amu Darya River, was estimated to be accountable for 40% of shrinking of the Aral Sea between the years 1978 and 1991 (Obertreis, 2017: 369).

Furthermore, though the initial experiments with large scale irrigation installations in desert zones of Hungry Steppe proved difficult financially, socially and environmentally, this model of "development" was replicated in other steppe areas of the Union such as Karshi, Djizak, Surkhan-Sherabad Steppe and the lower reaches of the Amu-Darya River after 1960 (Fayzullayev, 2015). This, in turn, exacerbated problems with water distribution, neglected drainage constructions, and salinization (Obertreis, 2017).

4.2.3.3 Late-Soviet rule

Large-scale irrigation installations, ever-increasing cotton acreages and scientific recommendations that were insufficiently related to local conditions were leading the region toward a state of crisis.

Though the crisis was hidden in the beginning, it became more obvious during the 1970s and 1980s. Water scarcity, exhausted soils, and stagnated cotton yields were symptoms of that crisis. Also, the local population's health was at colossal risk due to water pollution, the spread of toxic substances from agriculture and a drying Aral Sea (Micklin, 1988; Obertreis, 2017).

Due to the lack of experts and poor coordination, the construction and effective use of drainages remained neglected. Consequently, amounts of saline land increased which then lowered the cotton yields and triggered even more water use, leading to higher salinization. That is, it was a vicious circle of water users' and bureaucrats' unsustainable actions over water use and its management (Obertreis, 2017: 357).

The distinctive element of this phase is that it was the first time when the Soviet citizens (mainly scientists) challenged the Soviet projects such as the Hungry Steppe or the Virgin Lands. It was in 1977 when the Soviet constitution incorporated aspects of environmentalism in its content. It is an open question if that inclusion triggered the debates among scientist (a top-down initiative which is typical to the bureaucratic regime), or the debates led to the changes in the Union's constitution. Obertreis (2017:459) supposes that the constitutional change caused the civil discussions (eco-criticism).

Now after living through all those phases and the collapse of the Soviet rule in Central Asia, one might suppose that this final phase of Soviet government was indeed a start of the (early) proliferation of civic-mindedness among Central Asians. In this sense, the socio-environmental crisis of Central Asia was leading toward yet another turmoil in the region. We could even speculate that this was the perturbation which contributed to the shift of the institutional setting from the bureaucratic toward the decentralized one eventually.

4.3 Evolutionary game theory as an analytic narrative

In this section, we will equip ourselves with the instrument through which we reiterate those historical events and derive insights regarding the mechanisms at play, game changers and drifts from one convention into another. To do so, we model water users' interaction in an evolutionary hawk-dove game with three alternative strategies to share a common good. In our particular case, the common good is the water available to one village (a symbolic group) as a whole.

According to evolutionary game theory, interacting parties are a priori programmed to play one or another strategy, while some strategies earn more than others (Dixit & Skeath, 2004). Successful strategies with higher payoffs are replicated more than unsuccessful ones. As a result, successful strategies proliferate in the population (Weibull, 1995)

4.3.1 *Hawks and doves as an elementary model of resource governance*

The original hawk-dove game entails two strategies: *hawk* and *dove*. The underlying context of such interaction is the competition for a resource. The hawk-strategy is aggressive and fights to get the whole resource, while the dove-strategy is peaceful (does not fight) and offers the whole resource to the hawk-strategy player. When only dove-strategy players interact, they equally share the resource. When only hawk-strategy players meet, they both fight (Dixit & Skeath, 2004: 447). In this classic game, the best-response play resulting equilibrium is the Hawk-Dove (Dove-Hawk) strategy profile. The Hawk-Dove game is characterized by a waste of the resource. This characteristic stems from Hawks' fighting, not from their exploitation of Doves. The solution, in this kind of setting, is to find a way which would diminish the number of disputed interactions (Bowles, 2004:85).

We adopt this game with its *hawk* and *dove* strategies, but alter the strategies' names into *defect* and *cooperate* respectively. Besides, following Bowles (2004) and Bowles & Choi (2013) we introduce a third *punishing* (civic) strategy to this classic game, as an option to solve it.

Let us suppose that n farmers (peasants) of a village, who are engaged in irrigated crop production, are randomly paired to share a common water resource. The value of the water is denoted with v. The water users can adopt three strategies: (unconditionally) *defecting*, (unconditionally) *cooperating*, and *punishing* (or conditionally cooperating). It is not possible to detect the behaviour (type) of an individual before interaction.

When cooperating water users interact, then they will share the available water among them equally ($v/2$). However, when a defecting type farmer interacts with a cooperating type, then the defector gets all water (v) and leaves no water (0) to the colleague; when defectors meet each other they fight where the winning party gains the water (v) and the losing side faces the cost of fight (c), both sides of the interaction assumedly have an equal probability of defeat and victory.

A fight is a within-group conflict among water users over water use or over a common investment project. Consequently, our interpretation of the cost of the fight among peasants is their effort invested in stealing water by a variety of means (including bribing the irrigation staff or subjective costs of damaged reputation). In case the defector is successful and obtains that extra portion of water (or free rides the common investment project), the counterparty carries the whole burden (cost). For the counterparty that cost of a defeated fight is the effort, they invested in order to guard their water turn (or the investment contribution which did not generate a return as the defector reaped that potential benefit). Hence their effort was useless as the water was stolen (or the share was not contributed) by the successful defecting type peasant.

When punishing types are paired with either a cooperating type or a punishing type, they share water equally ($v/2$). When punishing strategy playing individuals interact with the defecting type, then all of the punishing type water users (of the village) try to punish that defector. In case of victory, punishing water users share the water among themselves (all punishers), however, in case of the defeat of punishing farmers, the punishing farmer bears the burden of failure (c).

The punishing strategy is a collective strategy because punishing-type individuals support other punishing-types who are interacting with defectors. Consequently, the success of a defector in an interaction with a punisher depends on the fraction of punishers in the village population (n). We can also term the punishing type as "civic" as in Bowles & Choi (2013). This type highly values the social norms (e.g. water sharing) and opt for punishing when that norm is violated.

In order to make it simpler to analyze, we normalize the size of village-farmers' population to unity and denote the fraction of punishing-type of farmers as β. Furthermore, we denote the fraction of cooperating water users in the village with α, and the fraction of defecting water users of the village with $(1 - \alpha - \beta)$.

Payoffs of the interaction of water users, described above, is accordingly illustrated in Table 4-1.

We calculate the expected payoffs to the three strategies as below:

$$\pi^{coop} = (\alpha + \beta)\frac{v}{2} \quad (1.1)$$

$$\pi^{defect} = \alpha v + \beta\{(1-\beta)v - \beta v\} + (1-\alpha-\beta)(\frac{v-c}{2}) \quad (1.2)$$

$$\pi^{punish} = (\alpha + \beta)\frac{v}{2} + (1-\alpha-\beta)(\beta v - (1-\beta)c) \quad (1.3)$$

Table 4-1: Payoffs in the Water Users' Civic Game

	Defect	**Cooperate**	**Punish**
Defect	$(v-c)/2$; $(v-c)/2$	v; 0	$(1-\beta)v - \beta c$; $v/n - (1-\beta)c$
Cooperate	0; v	$v/2$; $v/2$	$v/2$; $v/2$
Punish	$v/n - (1-\beta)c$; $(1-\beta)v - \beta c$	$v/2$; $v/2$	$v/2$; $v/2$

Source: adopted from Bowles, 2004: 383

4.3.2 The evolution of group interaction in the triangular state space

Figure 4-1 presents the graphical illustration of the state space for this system of interactions (ignore vectors and all other details inside the figure for now). Figure 4-1 depicts the distribution of strategies in the village. Any combination of preferences (types) is possible, and the range can vary from extreme (all cooperators or all defectors or all punishers) to anything in between. Figure 4-1 was generated by assuming the values of v and c of Table 4-1 to be 2 and 3 respectively.

The vectors in Figure 4-1 indicate the direction of movement in the region defined by the loci along which α, β and γ are stationary (note that: $= 1 - \alpha - \beta$). These movements (to either side) occur as a result of an updating of preferences (i.e. the choice of strategies). The choice-updating process is payoff-monotonic and follows a replicator dynamic as in (1.4), and (1.5).

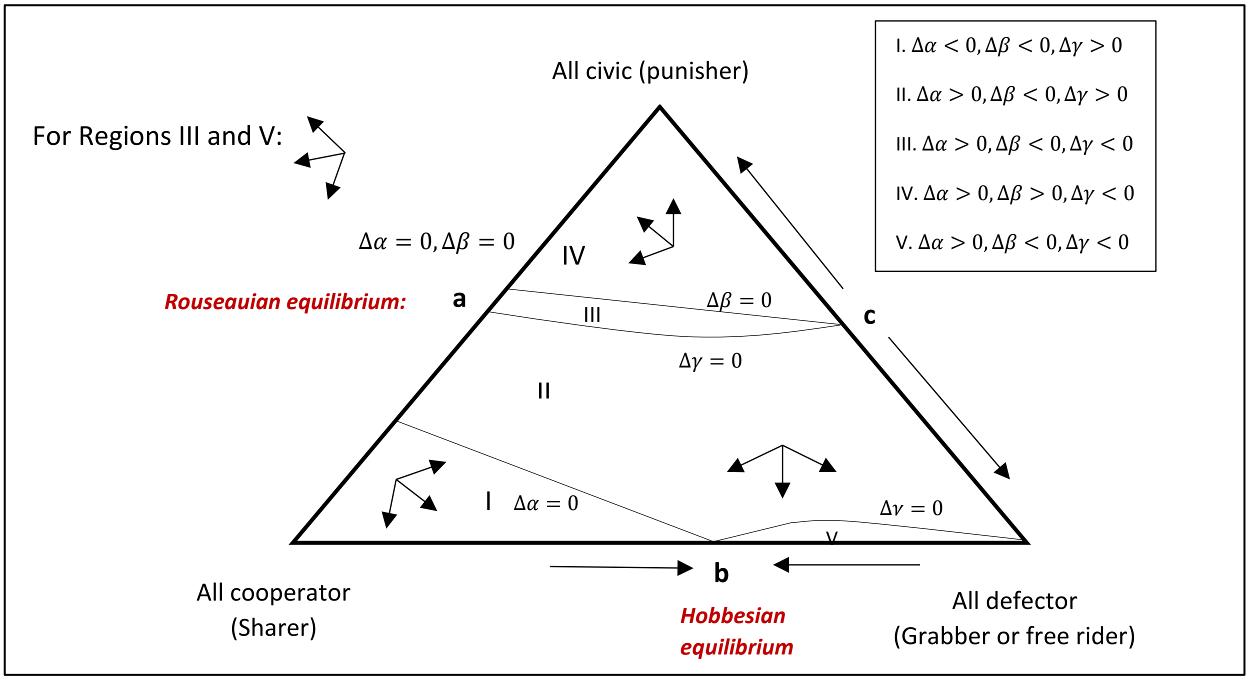
$$\frac{d\alpha}{dt} = \alpha(\pi^{coop} - \underline{\pi}) \quad (1.4)$$

$$\frac{d\beta}{dt} = \beta(\pi^{punish} - \underline{\pi}) \quad (1.4)$$

$\underline{\pi}$ is the average payoff to all three strategies, with $\underline{\pi} \equiv \alpha\pi^{coop} + \beta\pi^{punish} + (1-\alpha-\beta)\pi^{defect}$.

Figure 4-1 is divided into five (I, II, III, IV, and V) regions. Vectors in each region indicate the forthcoming proliferation of strategies. For instance, in region IV both α and β are increasing but γ is decreasing. This means that if water users' interaction occurs with any combination of preferences falling in this region (IV), eventually defecting-type individuals will disappear, as a result of the updating process initially defecting players opt for cooperating or punishing strategies instead. In this particular region the payoff to a punishing or cooperating strategy is higher than to the defecting strategy.

Figure 4-1: State space. Within-group dynamics.



Source: adopted from Bowles, 2004: 385

Bowles (2004) calls this equilibrium the *Hobbesian equilibrium.* The aggregate payoff of such equilibrium is low due to frequent fights over water (among defecting types of farmers) and hence costs (also called a deadweight loss). This then decreases the aggregate benefit of water use in such a setting. The Hobbesian equilibrium is *evolutionarily stable strategy* (ESS). That is, the population all playing ESS will resist an invasion of individuals playing some other strategy. Small perturbations around ESS are self-correcting. On the other hand, the point **a**, another stable stationary outcome (but not ESS), is a combination of cooperating and punishing preferences. This equilibrium, following Bowles (2004), is also denoted as *Rousseauian equilibrium*[5].

4.3.3 Theoretical equilibrium solutions vs. historical reality

The theoretical prediction dictates that water users' society should have spent most of their time in a Hobbesian type of convention, not in a Rousseauian because the former is ESS and the latter one is not. However Central Asian water management history along with other societies of the world (as in Sri Lanka, Pakistan, India, Nepal and etc.) provides us with evidence that, in fact, most of the epochs of water users' interactions could be characterized by conventions resembling a Rousseauian equilibrium.

In general, there are several documented instances of successful water self-governance history with long term persistence records in other parts of the world, although the evidence might sometimes be mixed (Bardhan, 2000: 847).[6] However, the key message is clear, that all those cases from different parts of the world show that water (local) self-governance arrangements were possible and persistent for long. Those self-governance arrangements, which were ubiquitous over long time, emerged independently, persisted in varied locations and cultures, indeed suggest that most water users' groups spent most of the times in an interaction approximating a Rousseauian equilibrium which combines the unconditional co-operators and collective upholding social norms (civic-minded water users).

In the next sections of our analytical narrative, we depart from the point where we consent that traditional (pre-tsarist) water governance arrangements of irrigated Central Asia induced prevalence of unconditional cooperation and a civic pairing of strategies. After that, we show why and how the Central Asian version

[5] Jean Jacque Rousseau admired such collective upholding of social norms (Bowles, 2004: 385).

[6] Sri Lanka, for example, had a very productive system of irrigated agriculture, which supported impressive ancient cities and large kingdoms. The island's traditional irrigation system, which relied on self-governance (collective action) via village councils and irrigation headmen (vidanes) mechanisms, emerged and persisted for thousands of years until the island's colonization by Western nations (Uphoff, et al. 1990: 28). Panchayats, which played significant role of coordinator in self-water management at community level in India and (today's) Pakistan, prevailed for many centuries until Western colonization, as well (Wade, 1989; Javaid & Falk, 2015).

of the Rousseauian equilibrium in water governance faced drift and eventually converged toward a Hobbesian equilibrium.

4.4 Evolutionary game theory at work

This section analyses the Central Asian epochs of water governance through the prism of the evolutionary Hawk-Dove-Civic game model.

4.4.1 A Rousseauian equilibrium in the pre-Tsarist period

In pre-Tsarist Central Asia, water management and governance were organized in the *latent* or *federal* group style, where each group was divided into a number of small groups. Each group had reason and interest to join with the others to form a federation representing a large group as a whole (Olson, 1965). We do not want to idealize pre-Tsarist Central Asian irrigation governance arrangements, as it was not free from deficiencies and inefficiencies. For example, flexible infrastructure required grandiose resources (mostly labor) to reconstruct each season and also after every flood. However, it was an *inclusive* setting, the term described by Acemoglu & Robinson (2012), which was sufficiently centralized, where interests of every single dehqan (member) and community of dehqans (groups) were accordingly represented. In other words, the setting had also certain pluralistic attributes.

In the same time, the supply-side of the water was, also, well represented and carried significant weight in decision making. For example in oases like Merv, dams were equipped with gauge. The gauge was used to identify the level of water and consequently determine whether there would be a surplus or deficit of water that year. There was a certain threshold level; if the water level was more than that threshold, then water would be abundant that year, and hence the state would permit to increase the amount of land cultivated. On the contrary, in years of water scarcity, the state would induce peasants to reduce the cultivated land areas, and only best quality lands would be used (Barthold, 1914 cited in O'Hara, 2000: 372).

Election-sanctioning mechanism of traditional water self-governance enhanced the civic-mindedness of the dehqans (increased number of punishing type peasants). The state was held accountable due to competition among khanates for more dehqans which also sustained responsiveness toward environmental dynamics. The waqf institution of comprehensive charity and mahalla arrangement where second-order punishment was possible in everyday life against deviating and in favor of cooperating members of the community in punishing the Hawk type water users, that is, against Sharers in Rousseauian equilibrium. These all were the bundle of arrangements in irrigation water governance, which synergistically prevailed and provided the asymptotically stable equilibrium, which was composed of mostly punishing (civic) type of water users, before the arrival of the Russian Empire. However, ultimately it was meant to eclipse in the coming century from the region's practice altogether.

4.4.2 The slide towards a Hobbesian equilibrium during Tsarist and Soviet water governance

The eclipse of traditional water governance is linked to the epoch of Russian invasion of Central Asia. The period between 1860 and 1917 was associated with the expansion of cotton production via the extension of irrigated land areas at the expense of converted deserts (Obertreis, 2017). A sanctioning mechanism via elections was the distinguishing attribute of the traditional (pre-Tsarist) water governance (O'Hara, 2000), and it was one of the major causes of a long-time persistent asymptotically stable state with a civic majority of the peasant population.

The history of irrigation water administration in Tsarist Central Asia, in general, was slightly more than the widely mentioned laissez-faire attitude. For example, Konstantin Petrovich von Kaufman, Governor General of Russian Turkestan, disposed most powerful irrigation officials and replaced them with Russian irrigators. In cases where he retained traditional water officers (such as mirabs, aryk-aksakals) he imposed tight Russian supervision. Central department in Tashkent appointed an irrigator, an assistant and a group of conductors to each province (Morrison, 2008: 210). In other words, the synergy of water governance arrangements faced a metamorphosis, and it was losing its pluralistic attribute. This, in turn, made the traditional water governance slide toward the alternative Hobbesian evolutionary stable state's basin of attraction, entailing a defecting majority of dehqan types. This drift consequence decreased the efficiency of the irrigation system, and it was reflected in physically deteriorated irrigation infrastructure and a waste of resources on many failed irrigation infrastructure projects. In section five we analyze this drift as a possible cause of negative repercussions which longed for more than a century.

The Soviet regime took over the general policy of Tsarist Russia regarding Central Asian irrigation infrastructure and cotton production. Besides, forced collectivization of agriculture involved trespassing, confiscations of private possessions and coercive resettlements. Eventually, the state arrangement turned to be the only institution to govern irrigation water management. The centralization of water governance, actually, started already in Tsarist Russia, with the Duma's water law of 1916, but it was finalized and enforced during Soviet rule (Obertreis, 2017). As a result, the state became the provider of an unprecedented number of public goods including irrigation infrastructure at all levels (Sievers, 2002). The shift of governance towards the state was in accordance with either of Hardin's (1968) recommendation. Hardin refers to two extreme possibilities of averting the tragedy of commons: one is relying on the institution of private property (market mechanism), and the other is through the coercive function of the state. The latter option assumes self-regarding preference as rational and empirically dominant. However, the picture we are drawing is an attempt to show why water users' preferences (cultural traits) as punishing (civic) did disappear first of all and how that process happened.

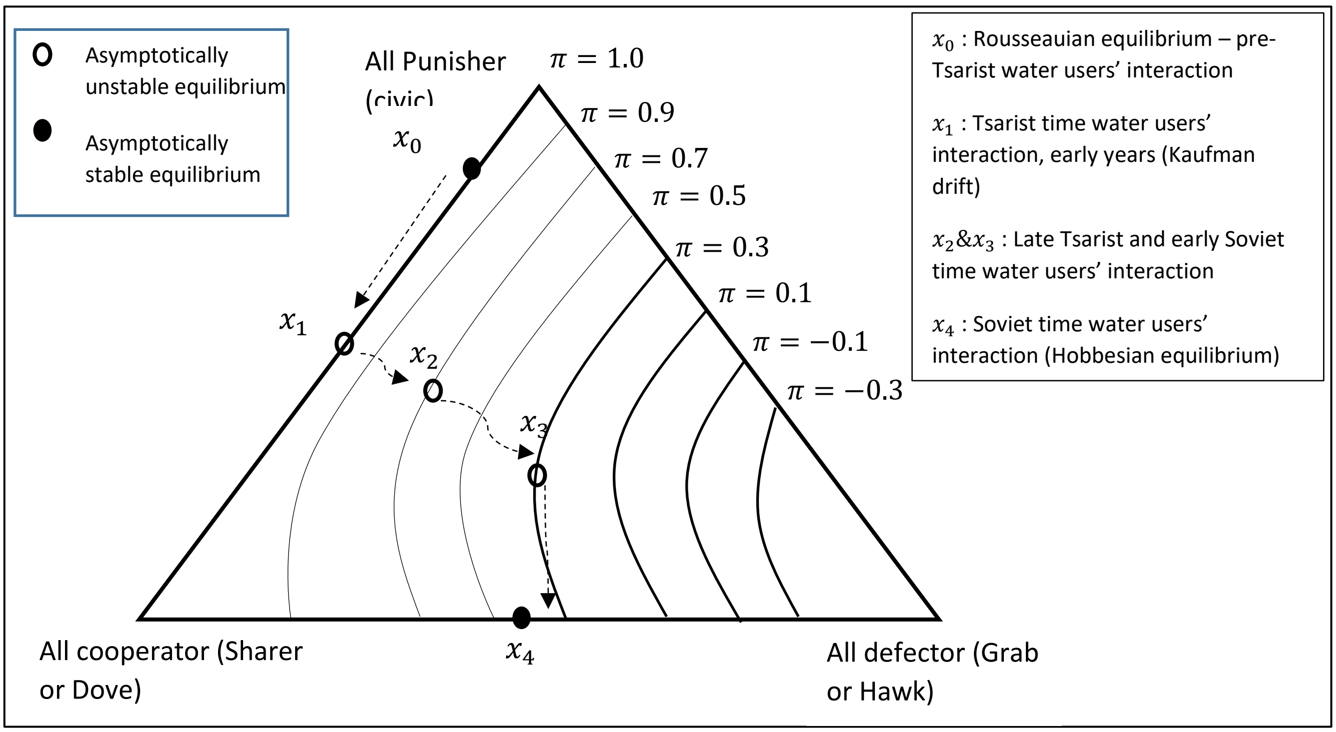
4.5 *The "Kaufman drift" corrupts decentralized governance as an unintended consequence of Russian regulation*

Figure 4-2, which we adopted from Bowles (2004), illustrates the average payoffs of the water users with meta-preferences (sharing, defecting and civic) of water user society's composition in the simplex. This is the graphical illustration of the game payoff table provided in Table 4-1. In Figure 4-2 we attach hypothetical values to the available total water value.

The solid contours show iso-average-payoff loci, every single of which is associated with a particular average payoff (π) ranging from -0.3 to 1. The higher the fraction of civic individuals in the water users' population, the higher is the average payoff level. The average payoff level reaches its maximum when all members of the population are either punishing or unconditional cooperating types, with no defecting peasants at all.

Figure 4-2 shows, though abstractly, the dynamic of water users' preferences and the interactions' payoffs attributable to the three epochs briefly covered in previous sections. They are illustrated with five points denoted with x and subscripts ranging from 0 to 4 in Figure 4-2. Pre-Tsarist traditional water governance induced the dehqans' interaction to locate close to Rousseauian equilibrium, which Figure 4-2 roughly depicts with x_0.

Figure 4-2: Average payoffs through epochs of water governance of Central Asia between 1860 and 1990 [Kaufman drift]



Source: adopted from Bowles, 2004: p388

Note: the efficiency which was enhanced due to technological shifts across the epochs are ignored, but instead the focus is given to the efficiency rate sourced from institutional settings

Then Tsarist water governance intervened into the election-sanctioning mechanism of the traditional water governance. This intervention was revealed in von Kaufman's policy in 1877 which implied massive disposal of customary water management officers, who were elected, and their replacement with the irrigators of state choice. This changed the setting of the interactions (Morrison, 2008; Rysbekov & Rysbekova, 2016). In the previous scenario, the possibility of electing the aksakals, aryk-amins, and mirabs served as leverage, in the hands of dehqans, which, then, induced accountable water administration. Because the punishing trait (through not electing and, or paying low amounts of remuneration) had its consequences, the payoff to the respective strategy could be assumed to be higher than co-operators and defectors, therefore it was ESS. The payoff level to the punishing strategy (in our model), after the Tsarist-Russia's de-facto appointing attitude, was reduced and more peasants although could be still sharing water (cooperating) less and less of them were punishing. This, in Figure 4-2, is reflected in the movement of the convention from x_0 to x_1. This movement, from x_0 to x_1, we decided to call the "Kaufman drift". Because after this movement the state at x_1 was prone to further invasion of defecting dehqans who would steal the water or bribe the mirabs. Due to the invasion of defectors, x_1 shifts toward x_2, a (nonstationary) population state where defectors along with punishers and co-operators coexist. Due to the path dependency among the dehqans and mirabs, aryk-amins and aksakals there could still be punishing type strategies ($\beta > 0$) in this unstable equilibrium.

The drift took place until the interaction of water users attained an evolutionarily stable state at x_4: with only defectors and co-operators and no civic fraction in water users' population, that is a Hobbesian equilibrium.

Let us derive parallels from Soviet epoch, which then could serve to support our idea about the prevalence of a Hobbesian-like interaction among Central Asian water users which carried destructive socio-economic consequences into the 20th century. During the 1970s, over-appropriation of irrigation water at the state and collective farms turned into a typical and widely recognized practice, and hence was usually harshly criticized by scientists, politicians, and engineers in the country (Obertreis, 2017). Throughout the region, it was documented that many irrigation canals lacked a cement lining, hence significant amounts of water was also lost in the transportation process (Kovolenko & Mulliev, 1974). Widespread secondary soil salinization, organizational inadequacies, and inefficient technologies were a commonly accepted plague of the Soviet irrigated agricultural sector as a whole (Micklin, 1978). There were no effective means of fighting water wastage both at the farm and higher levels. Though several services were organized to control the water use in the 1960s, they could not change the ever deteriorating unsustainability in water usage patterns. Instead, irrigators were constantly losing their reputation and hence were not able to penalize the illegal water users (Obertreis, 2017:369). We interpret these qualities (plagues) as symptoms of the convention where the defectors prevail, as farms constantly over-appropriate water resources and irrigation systems remain unmaintained. Defection occurs at such frequencies that civic (punishing) behaviour cannot proliferate. In other words, the x_4 (Hobbesian equilibrium) point in our Figure 4-2 could have been firmly established by the 1960-1970s.

The Tsarist intervention which then was finalized by the Soviet regime changed the payoffs of the game by altering the gains of strategies. It, then, led to a complete disappearance of civic (punishing) preferences, and by doing so led to a fundamental decay (reduced average payoffs) of the system (Figure 4-2). In our model context, this outcome is perfectly consistent with a view that Russian regulation had only the best intentions. In fact, the model suggests that the deterioration of civic-mindedness was an *unintended* side effect of the centralization of water governance.

4.6 The "Krivoshein game": potential effects and limitations of a water privatization scenario

The coordination of natural resource governance can be implemented via the market, bureaucratic or users' self-organization (community management) mechanisms (Ouchi, 1980). If the water governance arrangement that prevailed in the pre-Tsarist epoch closely resembled a synergy of community and hierarchical mechanisms, then the Soviet epoch introduced solely bureaucratic arrangements into water governance of Central Asia. If to simplify, in water governance of Central Asia, we now have historical evidence concerning two out of the three coordination mechanisms mentioned by Ouchi. Our analytical survey so far allowed us to compare them along the efficiency spectrum. The third arrangement, the market mechanism, however, is missing in the catalogue of observed water coordination institutions of the region.

4.6.1 Merits of treating water as a private good

Water markets could stimulate flexibility in water use and establish a widely acknowledged value of water which then provides incentives for more efficiency in resource use (Saliba & Bush 1987). This then would incentivize the farmer to invest in improved irrigation systems, including infrastructure and technology. Moreover, such markets encourage farmers to pay for the safe disposal of drainage produced in their fields. We could also consider other societal benefits such as a reduction in environmental pollution and benefits to the urban sector from additional water for its consumption (Dinar & Latey, 1991). With such increased efficiency and sustainability, the privatization of irrigation water resource can mitigate many pitfalls like water stealing or corruption in water governance, the very problems the Central Asian water users' society has been facing for a long time now (Morrison, 2008; Obertreis, 2017; Wegerich, 2008). At the same time, such an arrangement is not free from downsides due to incomplete information, which is private and unobservable. The incomplete information on the marginal value and use of the irrigation water, as the farmers might have an incentive to underreport actual usage of water (in the case of volumetric pricing). These are distinctive issues of irrigation water resource pricing that are stemmed from socio-economic and biophysical attributes of the water (Johansson et al., 2002). For that reason, the complexity of water privatization beats the complexity level of land privatization.

Probably that difficulty is the major suppressing factor of the irrigation water privatization process in developing countries. More research needs to be done in this field. In times of increasing levels of anarchy in the water sector partly due to the increased complexity of water governance (Wegerich et al., 2014), perspectives of launching functioning tradable water rights could be one solution to enhancing the efficiency and sustainability in water use in developing countries at large (Rosegrant & Binswanger, 1994). There is broad interest in, and support for, the idea of treating water as an economic good which is one of the prerequisites of water markets. This very attribute is the primary principle of Integrated Water Resource Management (Woodhouse & Muller, 2017), a policy framework current Central Asian countries are attempting to apply in their water governance (Zinzani, 2015). In other words, although the market mechanism in its pure format is not introduced into the setting, its elements are already taken up, and implementation trials are in progress since 2003 in the region, with unclear consequences though. Access to water is a basic need, and it is categorized as a merit good. Besides, the flow of water through a basin is complex, and it provides a range of externalities, market failures, and high transaction costs. All of these characteristics coupled with a weak institutional setting make the selection of an appropriate set of prices for water exceptionally difficult (Rosegrant & Binswanger, 1994; Perry et al., 1997). Consequently, converting water into an economic good is a tedious job, the countries of the region need to deal with.

4.6.2 Krivoshein and the Bourgeois strategy of water privatization

Recalling the history allows us to discover that, indeed there were attempts of shifting the water governance of the region toward market setting. Tsarist Russia's Minister of Agriculture, Krivoshein, suggested privatizing the irrigation water resources as part of the program to fight documented incompetency in Turkestan's (traditional) water governance, such as water theft and bribery. That is, the proposed water law along with other propositions, was supposed to legalize water trade and succeed the prevailing traditional water governance arrangements (Palen, 1909-1911; Gins, 1910; Joffe, 1995; Morrison, 2008). We found this story of water privatization attempt still very relevant to current-day debates about water as an economic good, water pricing, and privatization. Because of this relevance, we provide a counterfactual analysis of a water privatization scenario and its outcomes through our evolutionary game theoretic prism.

So, what if Krivoshein's suggested water privatizing law was indeed enacted by the Soviet regime? Or else, what if Tsarist Russia was not dismantled, and the water was privatized? In this section, we explore an alternative scenario for Central Asia's water governance with the help of yet another extension of the evolutionary Hawk-Dove game.

The Hawk-Dove like interactions, with the hawk-dove (defect-cooperate) strategy profile being an ESS, are destined to result in resource wastage due to the contestations. The fights in the water management context could imply water stealing, the costs associated with guarding the water turns would then be the cost of the fight. One of the solutions to this waste is a private ownership mechanism (Bowles, 2004). Consequently, in the game setting, we adopt a new strategy which Maynard Smith (1974) called a "Bourgeois" strategy.

This new strategy implies that if the peasant *owns* the (water) resource, then he will behave like a Hawk (unconditional defector=does not share). If, however, the (Bourgeois) peasant is not the owner of the resource, he would share the water resource with the interacting party (behave like Dove). In each interaction, we assume that half of the time the Bourgeois player is the resource possessor and hence claims for it, and the other half of the time he is a non-possessing Bourgeois, hence does not claim the water. The assumption is that the ownership is never questioned among Bourgeoisies and sharers.

Table 4-2: Payoffs in the Water Users' Bourgeois Game – the "Krivoshein Game"

	Bourgeois	**Cooperate (Share)**	**Punish (Civic)**
Bourgeois	$v/2$; $v/2$	$3v/4;\ v/4$	$\frac{1}{2}[(1-\beta)v-\ \beta c]$; $\frac{1}{2}[v/n-(1-\beta)c]$
Cooperate (Share)	$v/4$; $3v/4$	$v/2; v/2$	$v/2; v/2$
Punish (Civic)	$\frac{1}{2}[v/n-(1-\beta)c]$; $\frac{1}{2}[(1-\beta)v-\ \beta c]$	$v/2; v/2$	$v/2; v/2$

Source: adopted and adjusted from Bowles, 2004 and Bowles & Choi, 2013.

A sharing (Dove) farmer submits half of the resource available to them to the fellow interacting party or even the whole resource in case that the fellow peasant claims ownership, that is, if the interacting side is the resource possessing Bourgeois.

The Punishing (civic) type peasant behaves like Dove and shares the resource when he is interacting with a self-like or sharing type peasant. However, when a civic farmer is paired with a peasant who does not share (resource possessing Bourgeois), the civic peasant joins with other civic type water users in the group to contest the claim of the resource owning Bourgeois. In the case of the civic peasants' success (with a probability which increases with the increasing fraction of civic users), the civic type users allocate the resource among themselves and leave the losing Bourgeois to carry the cost of the fight (contest) all alone. Alternatively, if the contest is lost by the civic peasants, they bear the cost of fight themselves.

Here as well, we assume that there is payoff monotonic updating (higher payoff earning strategies are replicated) and conformist cultural transformation at play, implying that peasants are more likely to replicate the revealed behavior of the more numerous peasant types.

For the setting where the population is consisting of three types, cooperators (sharers), civic (punishers) and bourgeois as in Table 4-2, we can reproduce the state space similar to the one in Figure 4-1, where we replace all-defectors with all-bourgeois. This is logical because, as with Krivoshein's story, the water privatization carries the potential (or at least aims) to mitigate the water user groups' issues associated with water stealing (defecting). In this dynamic, the stationary and stable states are the all-civic group of water users and combinations of bourgeois with cooperators (Bowles & Choi 2013).[7] Just like in Figure 4-1, the all-civic state represents a relatively conflict-free social system but it is not ESS, that is, it is subject to drift. The group representing pairs of bourgeois and cooperators, on the other hand, is self-correcting (i.e. it is an ESS). It is an interesting implication of such a set of interaction possibilities that in any stationary state (all civic or combination of bourgeois with sharers) the social surplus size is the same (sum of payoffs is equal to v). That is, both stationary states are equally (comparably) efficient. However, the surplus distribution of the mixed state with bourgeois and cooperator does not represent egalitarian principles as it is the case in athe ll-civic state, where each member of the group gets an equal share of the resource.

The mixed state of bourgeois and cooperators is ESS because when few civic types are introduced to the mix, they have to bear the cost of the many fights with the water possessing bourgeois peasants. As a result, these civics' net payoff is diminished and hence in the updating process they are not replicated but fade out.

[7] The difference between Bowles &Choi (2013) and us is that we assume a scenario where a Bourgeois peasant preference is triggered by an external policy environment, namely by the (hypothetical) Krivoshein's irrigation water privatization law. Bowles and Choi, on the other hand consider a setting where such preferences (strategies) evolve themselves (endogenously) among foragers.

If water resource ownership was legalized, as it was promoted by Krivoshein after traditional water governance arrangement's metamorphosis and respectively associated issues, the water users of the region could indeed have a utilitarian (because of the total surplus size) and a viable (as it is a Nash equilibrium) solution for the emerging problem in the irrigation water sector. At the same time, we acknowledge that the principal problems with water privatization could probably also withhold the successful implementation of Krivoshein's privatization law. Indeed, the pursuit of such approaches in the absence of the required preconditions may possibly have even negative effects (Perry et al., 1997).

4.7 Discussion and implications

A *Rousseauian equilibrium,* with coexisting co-operators and punishers, could have persisted in Central Asia due to reasons as following. Firstly, because of the prevalence of second order punishment cultural trait, which induced individuals to punish co-operators for not punishing defectors; secondly, the group-selection mechanism was at play among users' community who had shared fates in times of adversity; thirdly, because the conformist cultural transmission was accordingly functioned (Bowles, 2004: 388)

Alternatively, if the water resource was privatized as a result of either spontaneous evolution of a Bourgeois trait or regulation by the state, Central Asian water users could have enjoyed higher levels of social surplus instead of regressing into conventions characterized by lower levels of aggregate payoffs (e.g. as in the Hobbesian equilibrium). However, principle problems associated with water privatization due to biophysical attributes of water could along with the absence of required preconditions indeed serve to fail privatization reforms as well.

Two major external shocks, with lasting spillovers, took place in Central Asia between the 1860s and the 1930s: the invasion of Tsarist Russia and the regime shift towards the Bolsheviks. The Tsarist rule in the region is associated with the deterioration of traditional water governance, which relied on both centralized and decentralized governance principles. Meanwhile, Soviet rule is associated with the full abolishment of self-governance in the irrigation water management and its full replacement with a water bureaucracy.

Entirely centralized water management bodies eventually reduced the role of mutual monitoring and peer-based enforcement mechanisms attributable to the traditional water management of the region. Furthermore, coercive collectivization of agriculture was the manifestation of the new communist ideology and related institutional arrangement in the Central Asian Soviet Republics.

Preferences and institutions are assumed to coevolve. That is, preferences influence the development of institutions and vice versa (Bowles, 2004: 401). Consequently, the preferences regarding water sharing are subject to updating via copying behaviours that are widespread and successful. Invading, arresting, executing, massively evacuating, resettling and forcefully deporting – were distinctive behaviours of the ruling regime in Tsarist and later Soviet Central Asia (Morrison, 2008; Obertreis, 2017). These manners could also be interpreted as being one possible option of the Hawk (grabbing or unconditionally defecting) strategy in Hawk-Dove-Civic game-like interactions. Consequently, the continuous rule of the Russian Empire and then of the Bolsheviks could serve as a role model (widespread and/or with higher payoffs) for the water users of the region. Their endogenous preferences could be updated and payoff monotonic and, or conformist updating could have induced the Central Asian water users to opt for defecting in interactions over water as part of the best-response play. This behavioral update happened amidst the traditional self-governance losing its levers and being corrupted. Changes resulted from interventions in the prevailing arrangements led to efficiency issues. These issues coupled with the role model (Hawks being more successful and numerous) could explain the rationale behind the apathy of water users, irrigation officers, and engineers in the 20th century. These attitudes accumulated and eventually resulted in one of the greatest anthropogenic catastrophe of our civilization, namely Aral Sea's (Lake's) transformation into Aralkum Desert.

We are far from the idea that the extensions of Hawk-Dove models presented in this study fully explain the history of Central Asian water governance. As Bowles (2004) rightfully acknowledges, simple models such as Hawk-Dove-Civic or Civic-Dove-Bourgeois games are not able to provide a sufficient framework for understanding the complex history of water governance. However, they provide us, both researchers and policymakers, with more insights and tell us where to look if we are interested in understanding the cause of the matter. They make all of us aware that seemingly minor chance events (initiated from outside or evolved from inside) such as Kaufman's administrative intervention in Central Asia in 1877 can have historically fatal consequences.

5 GENERAL CONCLUSION

The current chapter starts with the synthesis of the research findings of the main chapters (two, three, and four) of the dissertation. Afterwards, it discusses the thesis findings in the context of international academic literature. Then the chapter elaborates on policy implications of the dissertation findings. In the end, it presents research limitations along with a few selected research questions for the future. Empirical findings of the work are related to experimental observations obtained from farmers of Turkistan's (Southern Kazakhstan's) Maktaaral and Uzbekistan's Samarkand regions.

5.1 Synthesis of research findings

The thesis presents its analyses by utilizing theory focusing on how individual behaviours (to cooperate, reciprocate, defect or punish) and institutions interact to generate aggregate outcomes (conventions). The theoretical (evolutionary) framework of the dissertation signifies the role of adaptive agents with realistic cognitive capacities who base their own decisions on local information.

Moreover, the underlying theory implies the importance of cooperation coordination institutions, such as self-governance and state (third-party) rule (treatment). The findings in Chapter 2 confirm that the regulatory environment (treatment) that enabled more autonomous decision making stimulates endogenous (bottom-up) cooperation among water users (participants in the experiments). Because when both Kazakhstani and Uzbekistani farmers were allowed to self-organize, they achieved higher levels of cooperation as a result of bargaining during their group deliberations which influenced their mutual trust. Furthermore, the irrigation game experiments with Central Asian water users revealed the existence of social preferences such as reciprocation and retaliation. These (pro-) social preferences contribute to understanding better why individuals (in general) decide to cooperate even when it is more (materially) beneficial to free ride (defect). Furthermore, these social preferences assist us in explaining why incentive schemes like penalty treatments, which focus on stigmatizing self-regarding preferences, sometimes go wrong and crowd-out the intrinsic motivation to cooperate, instead. Such a crowding-out effect was observed in Kazakhstani sessions of irrigation game experiments (Chapter 2).

Moreover, the theoretical framework of this study suggests the pervasive influence of positive feedback effects, which then explains why both cooperative and defective outcomes are cumulative (Bowles, 2004:6). These positive feedbacks create an environment where initial actions are decisive and lead to lock-in effects. The "investment traps" faced in collective water governance in experimental sessions with rural Central Asian water users with vicious (virtues) circles of low (high) levels of joint investment exhibited the lock-in effects due to positive feedbacks (Chapter 3). These positive feedbacks are the reason for having multiple stable equilibria where small perturbations are self-correcting. These type of equilibria are named as evolutionarily stable strategy (ESS). That is, the population all playing ESS will resist an invasion of individuals playing some other strategy. Our findings in Chapter 3 confirmed the existence of such multiple equilibria in collective investment decisions of Central Asian water users. In theory, these multiple equilibria, as they are ESS, can only be displaced as a result of some external shocks or a substantial portion of the idiosyncratic play. Because we follow Bowles (2004: 412) and assume the idiosyncratic play not as accidental but rather as an intentional collective action, we assessed the influence of institutional arrangements (treatments) on the ability of the users to cooperate intentionally. The results indicated that among two types of tested coordination institutions (communication and penalty), the one which allows user participation, provides the user with the power to bargain and gives the chances to design own (endogenous) rules seem to be more promising in destroying the vicious circle (trap) of underinvestment, which is the long-standing issue in the contemporary Central Asian irrigation sector.

Finally, the study presented how and why water using individuals' preferences (behaviours) and water governance arrangements changed over time by focusing on three historical (pre-Tsarist, Tsarist and Soviet) epochs of Central Asian water governance (Chapter 4). In this process, we considered heterogeneous people. That is, our analytical framework allowed some water users to be more self-interested, others more civic-minded, who support social norms' enactment via collective punishment actions, and some to be more altruistic that is, of the unconditionally sharing type. We also allowed the preferences to be flexible that is, to be endogenous. Because of heterogeneous and endogenous preferences, which can change as a result of behavioural updating, seemingly small changes in institutional design can lead to significantly varying conventions. Replacement of the election-sanctioning elements of federative water governance with de-facto appointment system with fixed wages to irrigation officers metamorphosed the pre-Tsarist (traditional) water governance practice. This minor change in the traditional setting led to tremendous differences in outcomes with regressed efficiency, which then prevailed for a long time in Central Asia. We attributed the continuous success of Central Asian traditional water governance, which kept generating increasing returns (through positive feedback) to the society's wellbeing, to institutional synergy (of community and state) and pluralism (inclusivity).

5.2 Research findings in the context of the international academic literature

Major ideas of the analyses, presented in this study, are based on concepts borrowed from Taylor (1987), O'Hara (2000), Bowles (2004), Cárdenas & Ostrom (2004), Carter & Barrett (2006), Ostrom (2010), Madani (2010), Cárdenas et al. (2011), Naschold (2012) and Bowles & Choi (2013). The dissertation draws on notions from evolutionary game theory, the theory of economic institutions, and experimental economics.

Chapters two and three analysed data generated from the replicated irrigation game experiments due to Cárdenas et al. (2011). Chapter 2 tests the effect of two treatments on the share of farmers' budget dedicated to the irrigation fund: group-internal communication during the experiments as a facilitator of self-governance and penalties for defectors as a form of external regulation. The same chapter confirms that within-group communication (self-governance) of Central Asian users increased individuals' commitments to the common pool in a statistically significant way. Consequently, this chapter became one of the first such studies in Central Asia and the post-Soviet realm in general.

In the past few decades self-governance real world solution to the collective action problem, with both successful and failing consequences, has been widely studied. Such a study by Cárdenas & Ostrom (2004), which experimentally attempts to understand how the tragedy of the commons could be averted, suggests a framework that explains how individuals come up with self-governed solutions maneuvering that tragic ending. According to the framework, the participants of the experiment transform the material payoffs into a subjective-internal game in the field, driven by three categories of variables: (i) the material payoff of the game, (ii) the group-context and (iii) identity layer variables. The second chapter of the thesis adopts this analytical framework and finds that indeed such a mechanism was at play in the experimental sessions conducted with Kazakhstani and Uzbekistani water users. Moreover, Cárdenas & Ostrom (2004) recognize that the field experimental setting abstracts from the real life of participants. Therefore they argue that complementary data about the participants may loosen the analytical constraints due to the experimental abstraction. Following Cárdenas & Ostrom (2004) chapter 2 also includes data from post-experimental surveys into the regression analysis of experimental cooperation outcomes and confirms that contextual variables such as demographic or group characteristics influence the way people make decisions during the experimental sessions. Cárdenas & Ostrom (2004) found that participants who indicated that the state organizations should take care of local CPR management (state-believers) behave more cooperative under the externally introduced rule. Determined by this finding, we tested the hypothesis that Uzbekistani users that could be labeled as "state believers" (relative to more liberal Kazakhstani users) would be more cooperative than the users from Kazakhstan. However, we did not find supportive evidence for such cultural predisposition.

Following Henrich et al. (2004), who conducted experimental work in fifteen societies and found enormous variation in the levels of individual willingness to cooperate, the current research work used field experiments to study the effect of varying cultural context explicitly. In both Kazakhstan and Uzbekistan the same irrigation game experiments with the same protocol were conducted. Consequently the study (chapter 2) was able to find that water users in Uzbekistan were relatively less cooperative than the users from Kazakhstan. This finding accordingly enabled the work to claim that while history might matter, it does not predetermine the success of current water decentralization in ancient (in Uzbekistani study site) as compared to relatively recently established irrigation sites (study site in Kazakhstan). This result disagrees with studies such as by Talhelm et al. (2014) trying to establish a "rice theory of culture" but supports von Carnap (2017) arguing that there was no systematic causal relationship between historical agricultural practices (long-term determinant) and current levels of social capital in India.

Chapter 3 integrated the evolutionary theory into an empirical analysis to answer the question of how water cooperation (or defection) does occur and how the interactions are locked in one or another equilibrium. Taylor (1987) and Madani (2010) are the studies which motivated the theoretical model of the third chapter, and the detailed specifications of the model were adopted from Bowles (2004). The chapter followed Taylor's supergame argument when the one-shot Prisoners' Dilemma's dominant defective outcome disappeared once the game was played iteratively. The supergame argument entails that to achieve a cooperative outcome in a Prisoner's Dilemma at least some players need to be conditional cooperators (or tit-for-taters). Hence Chapter 3 in its theoretical model mixes the tit-for-tatters into the self-regarding population of water users. By doing so, Chapter 3 supports the idea endorsed by Madani (2010) that not all water resource games are Prisoner's Dilemma with deadlock (with only an inferior convention), but rather water interactions theoretically can have several Nash equilibria just like in Assurance game, for instance. The chapter refers to Taylor (1987) in modelling the communication treatment effect on the water users' (non-) cooperation decisions. The modelling of the (communication) treatment effect is motivated by the idea that achieving a cooperative outcome in smaller groups is more realistic than in bigger groups. Taylor justifies the group size effect with the argument of peer monitoring as a significant enabling factor for players to sustain conditionally cooperative interaction. With increasing group size, however, it becomes a tedious task for the interactors to engage themselves in mutual monitoring. As a result, sole peer-monitoring might lose its worth as cooperation inducing arrangement.

Furthermore, studies by Cárdenas et al., (2011), Janssen et al., (2012), and Javaid & Falk (2015) use irrigation game experiments with Colombian, Kenyan, Thai, and Pakistani water users to explore the provision of irrigation infrastructure and water use decisions under asymmetric appropriation respectively.

So we have a group of studies separately working on theoretical prepositions as Taylor (1987) and Madani (2010), and another group of studies like Cárdenas et al., (2011), Janssen et al., (2012), and Javaid & Falk (2015) trying to get more empirical insights and assess the effect of different institutions of coordination on the individual decisions to cooperate in water management. The objective of the third chapter was to integrate these two sides (theory and empirics) of the same coin. To test the corollaries of the theoretical model for the empirical analysis we, in chapter 3, adopted a recursion diagram in players' investment space from Carter & Barret (2006). The recursion function denotes the expected collective investment decision path. That diagram is a result of a non-parametric auto-regressive regression. Our analysis indicated on the existence of self-reinforcing multiple stable equilibria in Central Asian experimental irrigation session with positive feedback effects similar to the evidence revealed in the poverty trap studies by Carter & Barret (2006) and Naschold (2012).

The objective in chapter 4 was to provide an analytical model of evolved history that allows identifying key behavioral mechanisms that potentially explain the historically observed outcomes in water governance of Central Asia. The chapter investigated how and why the institutions of water governance in Central Asia changed over time. We recall the historical facts of water governance of the region based on Lewis (1966), McChesney (1991), Matley (1994), Joffe (1995), O'Hara (2001), Kuran (2001), Sievers (2002), O'Neil (2003), Morrison (2008), Abdullaev & Rakhmatullaev (2013) and Obertreis (2017).

We referred to two varieties of the evolutionary "Hawk-Dove game" extensions (Haw-Dove-Civic and Bourgeois-Dove-Civic games) with individual water users' preferences in water appropriation, sharing and their civic engagement. These extensions were the analytical framework, the lens through which the chapter re-iterated the historical events and explained the evolution of water governance. We adopted the specifications of the models from Bowles (2004) and Bowles & Choi (2013) respectively.

The chapter, by adopting the Hawk-Dove-Civic game from Bowles (2004), finds that the Tsarist Russian regulation that replaced the election-sanctioning element with a system appointing the irrigation staff and paying them fixed wages as a reason which corrupted the well-established traditional decentralized water governance in the region. We referred to this seemingly small change as a drift (we symbolically termed as "Kaufman drift") which eventually led the water interactions in Central Asia toward a "Hobbesian equilibrium", characterized by chronic underinvestment in irrigation infrastructure and water overuse. The difference between the "Bourgeois game" (or Bourgeois-Dove-Civic game) of Bowles & Choi (2013) and the "Krivoshein game" (a counterfactual analysis) of chapter 4 is that we assume a scenario where an external policy environment triggers a Bourgeois peasant preference, namely by the (hypothetical) Krivoshein's irrigation water privatization law. Bowles & Choi (2013), on the other hand, consider a setting where such strategies evolve endogenously among foragers.

The dissertation presented a different style of analysis and perception of water governance in the Central Asian context. Taken together the chapters of the thesis eventually cumulated in the greater idea regarding the endogenous institutions and preferences in water governance of the region. The thesis gradually endogenized the institutions of water governance. In chapter 2 we merely look at exogenous factors affecting water cooperation. Chapter 3 included endogenous dynamics with exogenously determined (given) institutions (treatments). In chapter 4 we endogenized the institutions as well. So the models in the thesis eventually (chapter after chapter) became more encompassing and dynamic which better reflects the complexities of reality rather than the static settings with exogenous institutions and behavioral preferences. The research work, unlike the mostly empirical literature on Central Asian water management, presented insights about the mechanisms (games) behind the water governance practices. This, in turn, should help both researchers and policymakers with more insights and tell us where to look if we are interested in understanding the cause of the matter in a broader picture.

5.3 Implications for policymakers

Three analytical chapters of the thesis (2, 3, and 4) rely on experiments on water users' potential to self-organize, a reconstruction of historical water governance practices through the evolutionary game prism, and a simulation of a counterfactual setting for private property rights in water. These ways of analyses, taken alone, are not able to tell generalizable conclusions or theorems. Preferably the best use of them can be achieved when other well-established methods of analyses complement them. In the same time, we cannot deny that these methods of analyses (individually) give us hints and insights on the matter of irrigation water governance and indications for researchers which aspects of water interactions to focus on. Challenging (or confirming) theories, searching for facts, and informing policymakers are the primary uses of experiments (Roth, 1995). The experiments, although at different levels of abstraction, can inform policymakers. The fundamental theories, like the universal self-regarding preference of *homo-economicus*, are confronted with experimental outcomes claiming that around 40-50% of human individuals are reciprocators (Fehr & Fischbacher, 2005). Such massive observation, in turn, questions the foundations of particular policy approaches, which are based on the assumption of self-regarding preference being the only behaviour of a rational individual, and consider any deviation as irrational and merely an exception. Consequently, the effectiveness of the policies which are only focusing on the self-regarding type of citizens (around half of the population on average) remains unclear. Therefore for policymakers knowing which sort of stylised intervention (reflected in experimental treatment) promotes pro-sociality in a given context may give valuable hints for specific policy instruments to be developed.

The water users' ability to organize collective action in water management will be determining whether the Central Asian institutional transition toward decentralized water governance succeeds or not.

The experimental finding of the thesis provides supportive evidence that the local water users, both in Maktaaral and Samarkand, possess such cooperative potential and hence can design their water self-governance institutions. This finding, in turn, calls into question whether the contemporary Central Asian WUAs' are actually grass root organizations. Instead, the experimental finding of an external (top-down) rules' crowding-out effect is explaining why those WUAs are dysfunctional. Furthermore, seemingly small changes in institutional design could lead to totally different aggregate outcomes. For example, minor chance events such as Kaufman's regulatory intervention in Central Asia in 1877 led to historically tragic consequences. Therefore any administrative intervention into the governance should always be weighted and carry minimal distorting characteristics, and the best thing is usually evidence-based policymaking.

The pluralistic attribute of the (pre-Tsarist) traditional water governance's federative structure was one of the decisive factors of the system's efficiency and its longevity. Therefore the legal environment of water governance should support the pluralism and inclusiveness of self-governance where the water users have the leverage which is reflected in the power to elect their local irrigation officer (or self-governance organization's administration/mirabs), and locally decide on the water fees.

The study revealed the existence of self-reinforcing multiple stable equilibria in water users' interdepend collective investment interactions. It is true that the pre-play communication (mimicking self-governance rule) shifted both cooperative (good) and defective (bad) conventions upwards. This finding revealed the higher potential of the self-governance setting than the no-rule or external rule settings to break the chronic underinvestment circle in irrigation infrastructure. In the same time, the treatment which imitated self-governance could not abolish a low investment equilibrium altogether. Based on this evidence the model predicts that decentralized water governance could be locked (trapped) in multiple equilibria. That is, the water decentralization in the region might lead to a coexistence of both prospering and deteriorating water users' self-governing communities. The difference between the successful and failing communities and their respective infrastructure will not tend to come closer to each other in terms of aggregate economic gain. In other words, water users will face a coordination problem.

Here I follow Petrick (2013) and claim that the Central Asian water users' interaction will also need a "local governance mechanism" (organization or platform) that will assist the users in solving their coordination dilemma. This local governance mechanism might imply actions like meetings of water users where self-governance rules are deliberated, respective training and education are disseminated, networks with other working (functional) water self-governance practices are established, and local action groups are set up. At the same time, the local governance mechanism, the thesis is proposing, should not be confused with the mechanisms inherited from Soviet times which were initiated by the state and were inflated by exhausting speeches of state officials with no concrete use, or the meetings undertaken by the international donors once or twice during a three year project, for instance. Central Asia has already experienced all these, and hence the region is well aware of the loose ends of such artificial incentives.

Furthermore, it is important to remember that these actions until they bring their results will require time to make the water decentralization process irreversibly successful. Therefore the political will regarding the establishment and sustainment of that local governance mechanism needs to be continuous enough so that to ensure no immature break-downs are the case. That is, based on current research analysis, I am claiming that there is a possible need for an external coordinator which would organize (assist) the intentional collective action of the water users and hence overcome the hurdle and help the users to navigate into the basin of attraction of the prosperous equilibrium. However, that assistance should not be confused with coercive means of cooperation inducement.

To summarize, in contemporary post-Soviet Central Asian irrigation water governance, there is a need for a legal environment supporting inclusiveness and pluralism in water decentralization. There is a need for a policy which would stimulate the water users (individual farmers mostly) to help themselves. In the same time, the state support (that is, state-supported platforms or local governance mechanisms in the forms of continuous training, network engagement, etc.) should be provided for a long time enough so that the water users' communities could achieve their sustainably cooperative convention. Besides the state support (intervention) instruments should be adequately modest so that no crowding-out effect with damaged community institution's governance potential is the consequence.

5.4 Research limitations and future research

The significant shortcomings of the dissertation are the limitations which are endemic to the employed analytical tools (or methods). All three (major) chapters have already mentioned those limitations previously. Here, I would only like to provide a summary of those significant limitations.

Experiments have strong internal validity, due to which we were able to replicate the experimental findings and the protocol developed by Cárdenas et al. (2011) in Central Asia. However, results from field experiments, alone, cannot themselves be generalized. Therefore, the conclusions which we drew in Chapters 2 and 3 carry more speculative nature and need to be further investigated with the use of other empirical, analytical methods such as case studies and, or large N-studies.

Moreover, our analytical modelling chapter by using simple extensions of Hawk-Dove evolutionary games investigated the historical water governance institutions of Central Asia and compared them in the efficiency spectrum. We acknowledge that this way of analyses cannot generate a full-fledged framework for understanding the complex (real) history of water governance.

These limitations of the research work point toward the further research agenda and questions in related matters. That is, there are some questions the current research work poses as food for thought for a further research agenda.

While it is simple to recommend avoiding a one-formula fits all approach in water governance because we find substantial heterogeneity in individual contributions to common pool apparent at the village level, the interesting question stems from such finding is:

1. How to operationalize such an individualistic approach in water decentralization?

Section 5.3 of the dissertation provides a part of the answer to the question above. However, it could only benefit the research pool if insights are enriched, which then would lead to policy implications that are based on more evidence.

Besides, we found that the traditional water management of Central Asia entailed higher cooperative behavior because of its pluralistic and synergetic aspects, such as the existence of traditional institutions as mahalla. Civic-mindedness, was found to be the behavioral preference and the fundamental trait granting the continuous accountable traditional (pre-Tsarist) water self-governance. Civic water users highly value the social norms (e.g. cooperation) and opt for punishing when that norm is violated. Such punishment attitude targets not only the defectors but also the co-operators who choose not to punish the defecting type users (second-order free-rider problems in collective sanction systems). From this finding the following question emerges:

2. Is the role of second-order punishing significant in self-governance of resources in Central Asia?

The peer-monitoring attribute of the community mechanism is the arrangement's principal factor sustaining conditionally cooperative interaction among CPR users. Consequently, it is the arrangement international donors often recommend developing countries to opt for as a tool of achieving sustainable resource management. However, it is also worthwhile to consider that it is not the only institution which has the capacity of attaining higher efficiency in water management. For example, water markets could stimulate flexibility in water use and establish a water value which then provides incentives for more efficiency in resource use (Saliba & Bush 1987). The private property rights over water would then incentivize the farmer to invest in improved irrigation systems, including infrastructure and technology. In legal water ownership, the Central Asian water users could indeed have a utilitarian (because of the total surplus size) and a viable (as it is a Nash equilibrium) solution for the problems in the irrigation water sector. At the same time, we acknowledge that the principal problems with water privatization could probably also withhold the successful implementation of water privatization. Indeed, the pursuit of such approaches in the absence of the required preconditions may have even adverse effects (Perry et al., 1997). More research needs to be done on the irrigation water privatization perspectives in Central Asian countries.

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APPENDIX - I

to

LONG- AND SHORT-TERM DETERMINANTS OF WATER USER COOPERATION: EXPERIMENTAL EVIDENCE FROM CENTRAL ASIA

Appendix 1: Field and project setting, selection of regions, villages, participants

We selected twelve villages in total for the experimental sessions. The selection of the villages in both Maktaaral and Samarkand was based on one common criterion: the relative location of the village with respect to the main surface irrigation source (Table 0-1).

Table 0-1: - Study sites and session schedule

Province	District	Relative location within the study area	Village	Average contributed share of endowment	Number of sessions per village	Number of participants per village	B	Sessions per treatment		
								C	L	H
South Kazakhstan	Maktaaral	Head	Engbekshi	0.506	3	15	1	1	*0	1
		Head	Zhanazhol	0.674	4	20	1	1	1	1
		Mid	Dostyk	0.546	4	20	1	1	1	1
		Mid	Intymak	0.739	4	20	1	1	1	1
		Tail	Maktaly	0.507	4	20	1	1	1	1
		Tail	Kyzylkum	0.548	4	20	1	1	1	1
Samarkand	Jomboy	Head	Eski Jomboy	0.627	4	20	1	1	1	1
		Head	Juriat	0.562	4	20	1	1	1	1
	Pastdargom	Mid	Q. Torayev	0.441	4	20	1	1	1	1
		Mid	Chimboy	0.371	4	20	1	1	1	1
	Payarik	Tail	Aytamgali	0.527	4	20	1	1	1	1
		Tail	Dehkanabad	0.503	4	20	1	1	1	1
			TOTAL		**47**	**235**	**12**	**12**	**11**	**12**

Notes: B: Baseline; C: Communication; L: Low- penalty and H: High-penalty.

* One low-penalty session was cancelled in Engbekshi. We scheduled 3 times, but we could not attract enough farmers every time.

We conducted the experiments in Kazakhstan during October and November of 2016 and in Uzbekistan during November and December of 2016. The team of experimenters consisted of the first author and a local moderator who explained the rules and regulations of the game to the participants and assistants.

After deciding on the particular village set in each country, we met with district level authority representatives to introduce ourselves and explain our objectives and request official permission for our activity in their territory. Once the formal matters were resolved, we paid a visit to all the villages on our list. During these initial introductory visits, we contacted local village leaders and explained them the context of our study and requested their support in communicating this message to local farmers. In this way, we created a preliminary schedule of our field trip, during which the experimental sessions needed to be accomplished in each village. Essentially, recruitment took place through word of mouth, but it was always sourced from the local leader. That is, we requested the village leader to announce our experiments to the farmers in his village on a particular date. This was especially useful to organize initial sessions in a new village. Then most of the times farmers, who participated in the experiments, supported us by engaging fellow farmers to take part in the next sessions in the villages.

The experiments were conducted in various locations in the villages. Sometimes it was classrooms of the village schools and technical colleges. Occasionally local village authority representatives provided us with a space from their own buildings. All sessions were conducted with the permission of the respective local-district authorities.

Locations where experiments were conducted

Engbekshi – village school assigned a classroom for the experiments. It was equipped with a sufficient number of tables and chairs and a whiteboard.

Zhanazhol – village authority allocated a room from the aul-akimat (village authority) building.

Dostyk – half of the sessions were conducted in a room located in a local WUA office. The other half of the sessions were run in a local village school classroom.

Intymak – the village authority allocated a room for us in its building for all sessions.

Maktaly – we conducted the sessions in a village authority building. The sessions which were run during the weekend were held in the private house of a local farmer.

Kyzylkum – we received a hall in the building of the village authority (aul-akimat).

Aytamgali – a classroom in a village school was assigned by the district authority (Payariq hokimiyat)

Dehkanadbad – a classroom in the local agricultural technical college was assigned by the district authority (Payariq hokimiyat).

Qochqor Torayev – a meeting room of a local machine tractor park (MTP) building was assigned by the director of the MTP.

Chimboy – a classroom from a service college was assigned by the local MTP director of the village.

Juriat – a classroom from a village school was assigned by the district authority (Jomboy hokimiyat)

Eski Jomboy – a classroom from a village technical college was assigned by the district authority (Jomboy hokimiyat)

Appendix 2: Experimental Protocol

Irrigation Game

BASELINE

1. Dear farmers, thank you very much for accepting our invitation and coming to this place.

2. This is Iroda Amirova from IAMO (Leibniz Institute of Agricultural Development in Transition Economies) in Halle, Germany. And this is the group which has gathered to assist Iroda Amirova in conducting the experiment. I am _______, and I will be explaining all the instructions to you today. And these are __________ (names of other assistants) who will be assisting in the experiment.

3. This is a voluntary session. If you do not want to participate you can leave our session, but our request is to do so before we start the process.

4. We have gathered you here with the aim of conducting a research experiment. This is an exercise to understand the potential of farmers to manage irrigation systems in your area. Since Kazakhstan/Uzbekistan became independent, things have been gradually changing. Different reforms are being implemented. Such reforms are implemented in the irrigation water management sector of the country. The country is moving towards passing water management into the hands of water users like you. Because of these ongoing changes and processes in Kazakhstan/Uzbekistan, we are interested in studying the potential of water users.

5. Each person who takes part in the experiment will receive 2 euros (equivalent in local currency: KZT/UZS) for his/her participation. It is a payment for showing up here to the experiment.

6. You can earn more during the course of the experiment; the money you earn today comes from the research institute.

7. Why have we introduced a payment mechanism to this experiment? We wanted to have a realistic environment. We want to know what irrigation water means for crop production in Maktaaral/Samarkand. It means: if irrigation is applied appropriately, the farmer/peasant obtains a better harvest, and this means that he/she obtains better earnings. Am I right?

8. So our experiment wants to capture this real-life-aspect, though in a very simplified way. All details we receive today in this session will only be used for research purposes. No part of them will be available to any government agencies either in here or in ZZZ (country).

9. We request you to listen to the instructions very carefully. Whenever you do not understand, please just ask your question immediately, by raising your hand. Also, if you do not hear the instructions very well, let us know.

10. Each round of the experiment is expected to last 3-4 minutes. We are expecting to take 2 to 2.5 hours of your time today.

11. Imagine all of you are farmers with the same sized land. And you cultivate the same crop.

12. In real life we know that in order to be able to irrigate our fields we need to have an appropriate irrigation system. In order to have an appropriate irrigation system we need to invest either in the form of money or labour. So this experiment is based on such real-life scenarios which are usually faced in making decisions about irrigation.

13. You – all five – are one group of water users, who use the same watercourse. You will play several rounds. Each round is equivalent to one irrigation season (figuratively).

14. Within this group of five, each player is randomly assigned a unique position identified in alphabetical order (Cyrillic): А, Б, В, Г, Д. (then converted in - A, B, C, D, E equivalent in Latin)

15. By drawing concealed envelopes [an assistant distributes five envelopes to the participants in this moment] you will receive those letters. Please, without showing to others, open your envelope and see what letter of the alphabet you have received. See it and remember it please.

16. Now, as you may have noticed, there are folders in front of each player (on your tables). Please open that folder and you will see a first page which is a **yellow** colored piece of paper with the title “Player’s decision and earnings in coupons”. On the top of this yellow sheet you will see a line where it says: “player’s position”. If you remember what letter you received in the envelope (if not, then please look back and see again) please write that letter there (on the yellow page).

17. In the folder, you will see a name-badge with some numbers, could you please attach it so that we can see them clearly.

18. Before starting each round, we will distribute 10 coupons to each player. To save time, we will not distribute them physically, but they are inserted in your yellow paper. Look at that yellow paper and see the second column, there is “10” in every row. So this means that we are distributing them to you each round.

19. What do those coupons mean? They are our currency in the experiment. One coupon means 0.02 euro (local currency equivalent). Each round we are actually distributing to each player (0.02*10) 0.2 euro. What to do with those coupons (with such monetary value)?

20. Each round you are asked to make two decisions: The **first decision** is about **investment.** That is investment of the coupons we distribute to you each round. You should decide where to invest.

21. There are two options of investment for every player. **One** is to keep in your private account. Another is to invest in the Public Fund, which will be used for the maintenance of irrigation infrastructure. Basically, whatever (amount of coupons) is not invested in the public fund it is kept in your private account.

22. Why do you need to invest in irrigation infrastructure? The amount of water available for you to irrigate depends on your collective level of investment. Investment in the maintenance of irrigation infrastructure means that less water is wasted. More water is available to you.

23. Collective investment for a group is calculated by adding the individual investment of each of you. The sum of the contribution will affect the amount of water available to the five players. Now I want to show you how it happens.

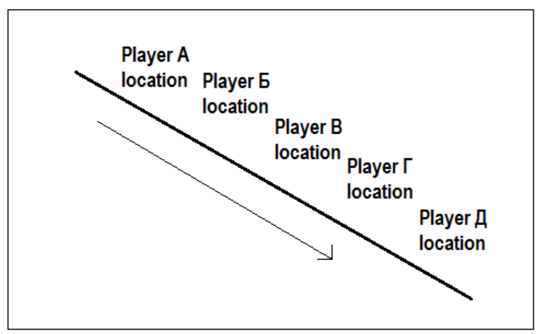
24. Again, look back to your folder. There you find a **blue** paper. In that paper you will see a table and graph. They both have the same information. Let’s, for convenience, choose one of them, let’s go to the table. There you will see two columns. One is the collective amount of investments made by your group. The second column illustrates the total water available to your group (in minutes). Let’s say: if you altogether invest 41 coupons (all five of you) then you will have 96 minutes of water [SHOW IT VERY CAREFULLY, MAKE SURE EVERYONE IS UNDERSTANDING]. For simplicity sake we are using minutes instead of volumetric units of water use measures. [ASK FURTHER QUESTIONS ABOUT THE

TABLE on blue sheet] We will announce your collective investment. But we will not say anything about your individual investments.

25. If you remember, we said each round each player makes two decisions. The investment decision was your first decision in the round. Your second decision is about your water extraction. That is your water use.

26. As in real life farming, here your earnings are dependent on your water use. Lets' go back to your folder. There you will see a **pink paper**, which has the title "Second decision". Again, there you see both a table and a graph. As it was on the blue paper, here as well both (table and graph) carry the same information. Let's go with the table as we did before [SHOW WHICH on the paper]. The first column of the table shows you how many minutes of water you used and the second column shows how many coupons you earn from your used water minutes. For example, one player uses 18 minutes of water, how many coupons do you earn? You earn 19 coupons. [ASK QUESTIONS TO MAKE SURE THEY – EACH UNDERSTOOD the table]. This was briefly about your second decision.

27. Now we return to the yellow paper [SHOW IT], the paper where you wrote the letter of the alphabet. You might ask: why we need to give such a position to you? Well, you all are farmers in irrigated areas, who have a lot of experience in water use. That is, you know very well that there are always people who get access to water before others because of their position. In other words, there is always someone who is an upstream water user and someone who is a downstream water user. [DRAW THE FOLLOWING AND EXPLAIN]



28. So in our case, as you might have understood that player A is an upstream water user. Only after A finishes using water, can player Б withdraw water to his field. Then comes B, then Г and Д. Remember, do not tell anyone your position, I mean the other players.

29. Now that I have somewhat introduced the main conditions of our experiment, I will provide you with an example for better understanding. For example, I am one of five players. In the envelope I received the

“A” position. That is, I am the upstream water user. And [indicate another assistant] she/he received “Б” . But we both don’t know each other’s letters. I just know my own. That is it. The round starts. The experimenter asked us to make our first decision of the first round. I need to decide where to invest my 10 coupons. [REMIND about initial endowment of each round, about 10 coupons]. I need to decide how many of the 10 coupons to invest in the public fund which then goes to the maintenance of the irrigation system we use. I will write down my decision on the yellow paper in the third column [SHOW IT]. Then all the yellow papers are collected. Here on this table [SHOW the table] everyone’s investment is summed up and the group investment is written on the board. The point is that everyone knows the aggregate investment, but nobody will know what (for example) my particular-individual investment was. On the board we will write the group investment. And looking back to the blue paper we will see how much water that investment creates for our collective use.

30. Then the time for the second decision comes. NOW please pay attention! After the first decision, the experimenters collected the yellow paper (do you remember?), so in order for us to make our second decisions we need the yellow papers back. Those papers are returned back, BUT only one player receives his paper with such a sticker [SHOW the sticker] with water minutes available to him. For example, let’s say the group investment was 42 coupons, please look to your blue paper, how many water minutes does it give? 95 right? So player A (upstream one) receives his paper with a sticker attached, where 95 is written. This means that first it is only this player’s turn to withdraw water and the rest of the participants will just sit without doing anything. We have these wooden barriers in between you because of this reason, to make sure that you cannot see each other writing or not writing. So, coming back to this sticker. We said 95 minutes was the group’s water level, player A‘s paper is attached with this “95” sticker. Then we will distribute the papers to the owners. So player A (who received his paper with the sticker) makes his first decision. Then we collect everyone’s yellow paper. We take records for ourselves. We update the sticker. For example if Player A used 15 minutes of water (95-15=80). We take a new sticker and write 80 minutes on it and attach it to player Б’s yellow paper. (Why Б?, because it is the second person who can get access to the water – [show the graph]). Б makes a decision then the yellow papers are collected, an updated sticker

is attached to player B’s paper (Cyrillic), and so on so forth, and this procedure continues until the last player Д makes his water use decision. Then the next round starts.

31. To train ourselves, we can start with a “practice” round. You can see a row where it is written “Practice round”. So we can play this round, and see if everyone has understood things correctly or not.

32. If you have any questions, you can also ask now. If not, we will start the round.

[PLEASE BEFORE STARTING SHOW HOW TO CALCULATE THEIR EARNINGS]

Communication treatment (explained after round 11)

33. Now we would like to introduce something else to the experiment.

34. Before starting every round, that is, before making your first decision, we will invite you talk to each other. We will give you three minutes before each round to communicate. We will not intervene in your conversations. It is totally up to you how you lead the communication. After three minutes of communication, the same steps will follow. That is, you make your simultaneous first decision. Then the papers are collected. Then you will make your second decisions sequentially in alphabetical order.

Penalty treatment (explained after round 11)

[Either communication or Penalty treatment is played, but not both]

35. Now we would like to introduce something else. We will introduce a regulation.

36. The regulation is about the amount of water you use/extract. We say: whatever amount of water you have after your investment decision, we will divide the total water minutes by five (Total Water Minutes/5) and the result will be the norm (of equal sharing). [On the board we will write down new line “RULE____minutes per person”] After the second decision is made, an inspector is sent to investigate your second (water use) decision. Our inspector will inspect you only when [SHOW THE DICE] “six” is rolled. One of our assistants [TEL THE NAMEs] will roll the dice in front of you. And if the dice shows 6 you will be checked. If you violate the norm-rule (which was written on the board), our assistant will tell us how much you extracted,

36.1**. [Low-penalty-treatment**] and we will subtract the extra coupons you made from the violation of the rule. We will take them back. If the dice does not roll 6, you will not be inspected.

36.1. [**High-penalty-treatment**] we will subtract the extra coupons you made from the norm violation, and in addition you will be forced to pay a fine in the form of 6 coupons.

Player's decision sheet (yellow paper)

Player's position (alphabetical letter from your envelope) ___________

Player's decisions and respective earnings					
	X	**Y**		**Z**	**X-Y+Z**
Round	**Number of tokens we give each round**	**1st DECISION: Your contribution for irrigation infrastructure maintenance**	**2nd DECISION: Your water use** (how many minutes you use water)	**Your earning from water use** (see how much water you used then look to the "water use" table)	**Your total earning (in coupons)**
Practice	10				
1	10				
…	…	…	…	…	…

Player ID____________________

Water amount resulting from collective investment – table

First decision (blue sheet of paper)

Group investment (in coupons)	**Water available (in minutes)**
0-10	0
11-15	5
16-20	20
21-25	40
26-30	60
31-35	75
36-40	85
41-45	95
46-50	100

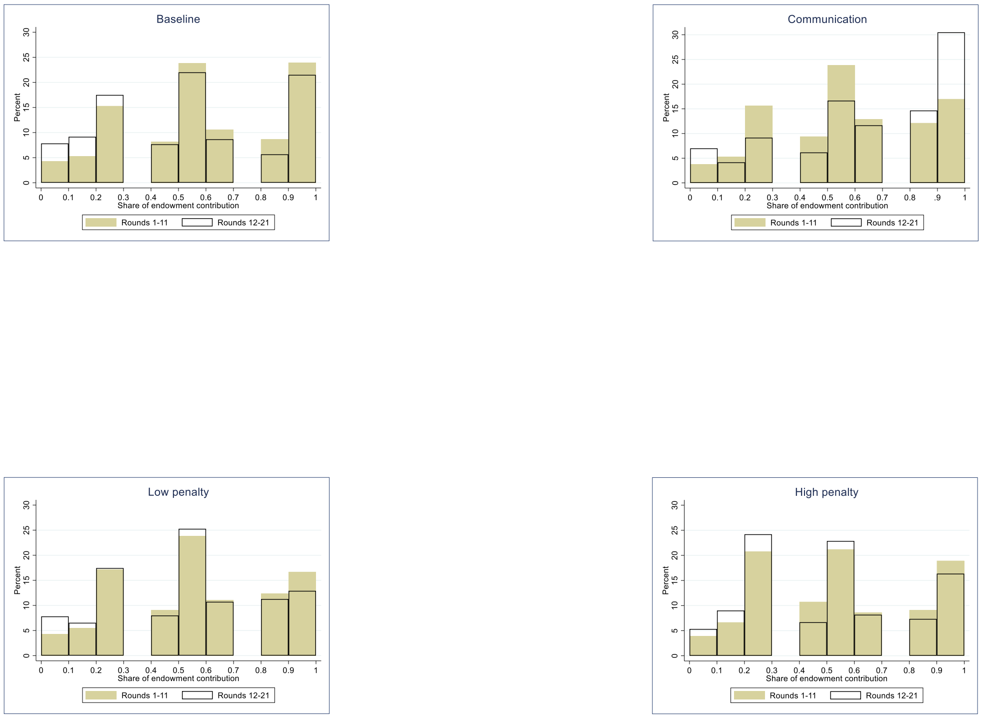
Amount of earnings (coupons) from irrigation decisions – table

Second decision (pink sheet of paper)

Your water extraction in minutes	**Coupons earned**
0-5	0
6-7	2
8-10	5
11-12	10
13-15	15
16-17	18
18-20	19
21 -22	20
23-25	20
26-28	18

Appendix 3: Distribution of contribution decisions across baseline and treatment games

Figure 0-1: Distribution of contribution decisions across baseline and treatment games



Source: Irrigation game experiments in Kazakhstan and Uzbekistan

APPENDIX – II

To

INVESTMENT TRAPS IN COLLECTIVE WATER GOVERNANCE: THEORY AND EXPERIMENTAL EVIDENCE FROM CENTRAL ASIA

Sensitivity analysis of bandwidth and degree selection

Based on the eyeball method, we chose degree=3 and bandwidth=3.23 for the baseline irrigation game (Figure A1). To analyse the communication games we chose degree =1 and bandwidth = 2.07 specifications of polynomial smoothening (Figure A2). Furthermore we chose degree=1 and bandwidth=1.18 to model data obtained from low-penalty treatment sessions of the irrigation game (Figure A3). For high-penalty irrigation game sessions' data we chose degree=2 and bandwidth=1.65 specifications (Figure A4).

Steps of the eyeball method of sensitivity analyses

Stata's lpoly uses the rule-of-thumb (ROT) method to estimate the bandwidth used for the smoothing. First we get the ROT value for bandwidth. This way of choosing the bandwidth, however, is usually criticized (Cleveland & Loader, 1996; StataCorp 2017), hence we conducted a sensitivity analysis to select the best fit by altering the bandwidth value from ROT value and then visually assessing its suitability. Initially we decreased the bandwidth from the default value, then we increased that value.

The default value for the polynomial degree is zero in Stata. Keeping the ROT bandwidth we generated three different functions with degrees one, two and three. In case the smoothing lines depicted better the observations with increased degrees we decreased the bandwidth from its ROT value. In this way we come up with our chosen bandwidth and polynomial degree. The figures below illustrate this procedure for both bandwidth and degree selection.

Figure A 1

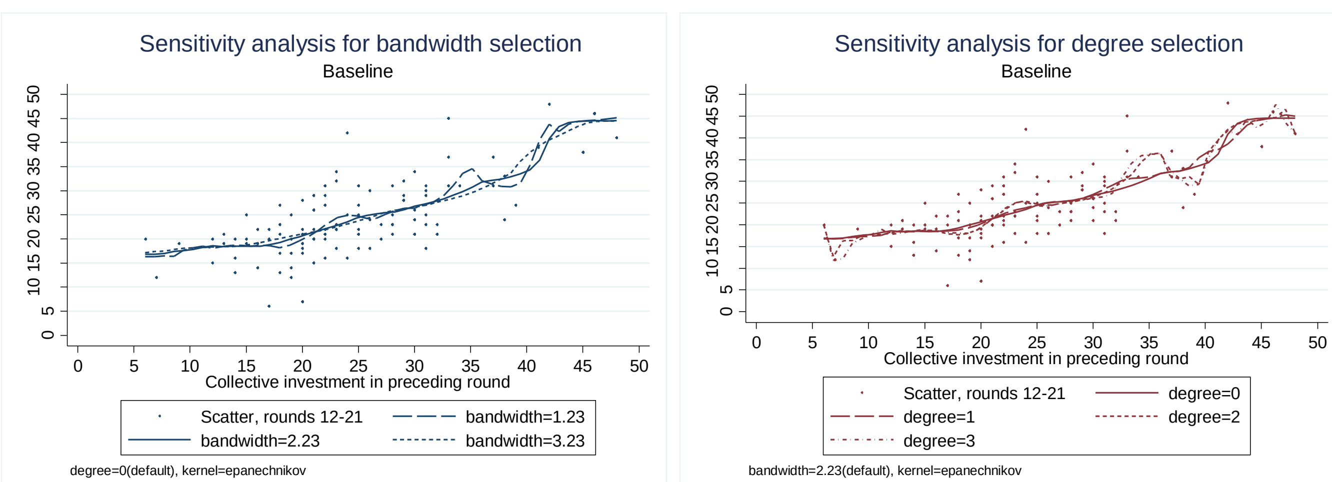
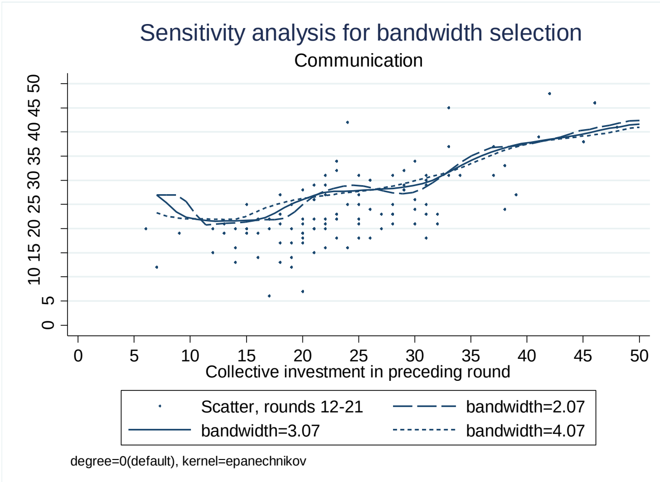


Figure A 2



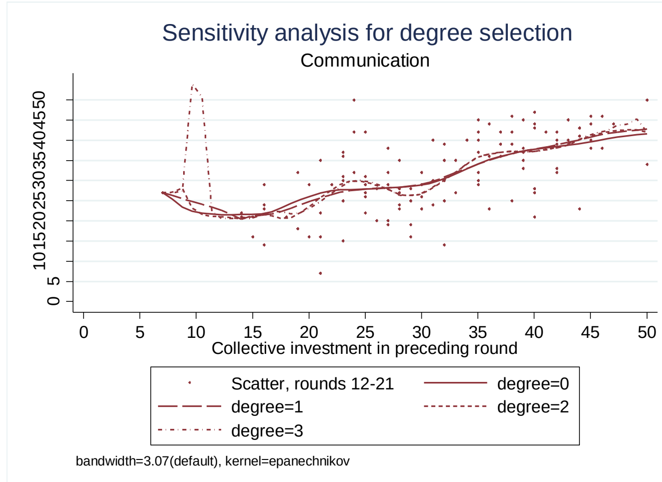
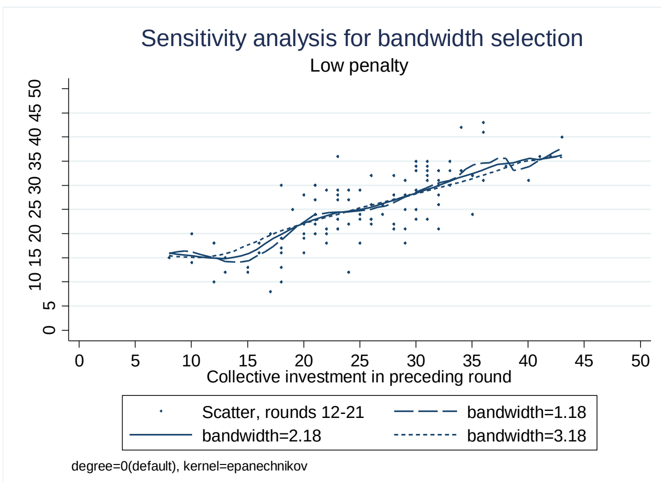


Figure A 3



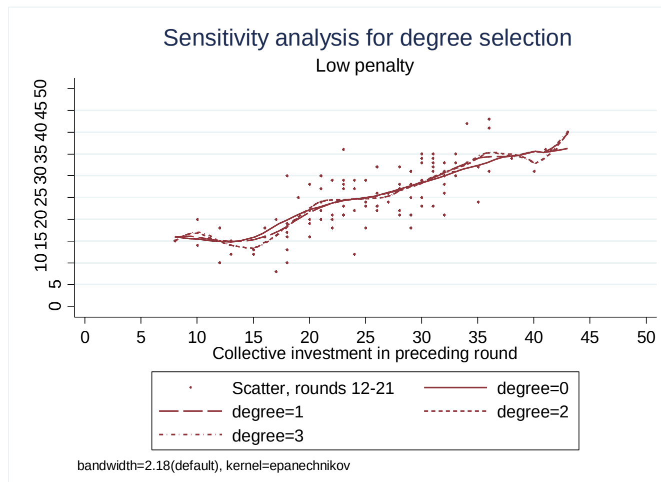
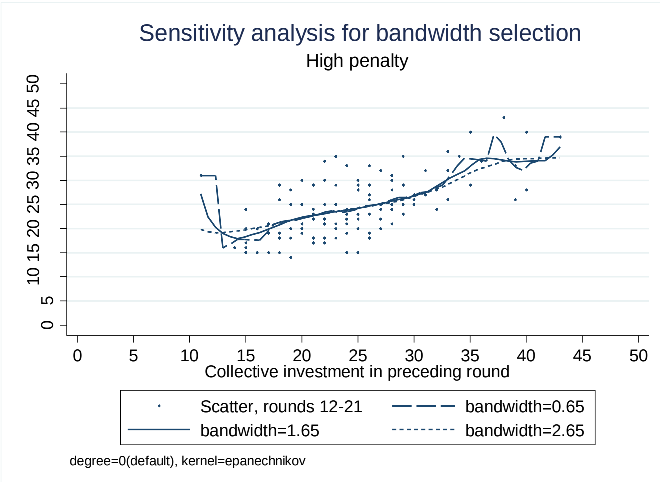
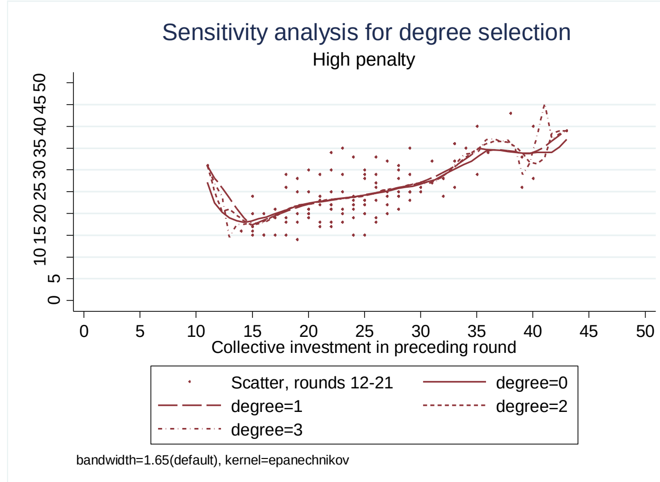


Figure A 4


Sensitivity analysis for bandwidth selection
High penalty
0 5 10 15 20 25 30 35 40 45 50
0 5 10 15 20 25 30 35 40 45 50
Collective investment in preceding round
Scatter, rounds 12-21
bandwidth=0.65
bandwidth=1.65
bandwidth=2.65
degree=0(default), kernel=epanechnikov


Sensitivity analysis for degree selection
High penalty
0 5 10 15 20 25 30 35 40 45 50
0 5 10 15 20 25 30 35 40 45 50
Collective investment in preceding round
Scatter, rounds 12-21
degree=0
degree=1
degree=2
degree=3
bandwidth=1.65(default), kernel=epanechnikov

Eidesstattliche Erklärung / Declaration under Oath

Ich erkläre an Eides statt, dass ich die Arbeit selbstständig und ohne fremde Hilfe verfasst, keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt und die den benutzten Werken wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht habe.

I declare under penalty of perjury that this thesis is my own work entirely and has been written without any help from other people. I used only the sources mentioned and included all the citations correctly both in word or content.

______________________ ____

Datum / Date Unterschrift des Antragstellers / Signature of the applicant

Ich erkläre, die wissenschaftliche Arbeit an keiner anderen wissenschaftlichen Einrichtung zur Erlangung eines akademischen Grades eingereicht zu haben.

I declare that the thesis has not been used previously at this or any other university in order to achieve an academic degree.

Datum / Date

Unterschrift des Antragstellers / Signature of the applicant

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June, 2011-January, 2012	Intern, Central Asian and South Caucasus Association of Agricultural Research Institute (CACAARI), Tashkent, Uzbekistan

Academic background

Since March, 2015	Ph.D. Programme in Agricultural Science, Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Martin Luther University of Halle-Wittenberg, Germany Doctoral thesis: “Collective action, institutions and the evolution of Central Asian irrigation water governance” Supervisors: Prof. Dr. Martin Petrick and Dr. Nodir Djanibekov Field work: social science field experiments and quantitative farm survey in Kazakhstan and Uzbekistan (October –December 2016)
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October, 2007 – October, 2011	Bachelor of Science in Economics, Westminster International University in Tashkent, Uzbekistan Bachelor thesis: “Economic analysis of international labor migration remittances, evidences from CIS countries”

Peer reviewed articles (published)

Amirova, I., Petrick, M., and N. Djanibekov (2019). Long- and short-term determinants of water user cooperation: experimental evidence from Central Asia. World Development 113, pp. 10-25. DOI: 10.1016/j.worlddev.2018.08.014

Further publications

Otoo, M.; Gebrezgabher, S.; Danso, G.; Amewu, S. & *Amirova, I.* (2018). Market adoption and diffusion of fecal sludge-based fertilizer in developing countries: Cross-country analyses. Resource Recovery & Reuse Series, Colombo.

Posters

Amirova, I., Petrick, M., & Djanibekov, N. (2019). Long- and short-term determinants of water user cooperation: experimental evidence from Central Asia. Almaty, Kazakhstan, 16.04.2018 - 18.04.2018.

Amirova, I., Petrick, M., & Djanibekov, N. (2017). Does endogenous cooperation work in a post-Socialist setting? Experimental evidence from irrigation management in Central Asia. Parma, Italy, 29.08.2017 - 01.09.2017.

Presentations

Amirova, I. (2018). Social-science experiments in the field. Innovative academic research and teaching on water governance and agricultural development in Central Asia, Tashkent, Uzbekistan.

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