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The Behavioral Foundations of Rule Compliance under Resource Scarcity: An Experimental Approach to Common-Pool Resource Governance

Thesis submitted in fulfillment of the requirements for the academic degree of Doctor of Philosophy in Social Complexity Sciences

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Dedication

To my children Sebastián and Santiago: may you grow into a world where cooperation prevails over conflict, justice over inequality, and hope over the uncertainty of a changing climate. May you always find the strength to care for others, the courage to defend what is fair, and the wisdom to nurture the fragile balance of our planet. Your future is my greatest motivation, and my deepest wish is that you inherit a world worthy of your kindness and imagination. May this small work contribute to that future.

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Contents

List of Abbreviations

CPR Common-pool resources

WUAs Water users associations

Resumen

La escasez es una característica central de muchos sistemas de recursos de uso común (CPR), pero aún se conoce poco sobre cómo sus distintas formas influyen en la disposición de las personas a cumplir reglas colectivas. Esta tesis estudia los mecanismos conductuales que sostienen el cumplimiento bajo estrés hídrico, combinando experimentos de laboratorio controlados con un experimento de campo realizado con miembros de Asociaciones de Usuarios de Agua en la zona central de Chile. Al entender la escasez como una demanda insatisfecha, la tesis distingue entre escasez exógena, que surge de restricciones externas; escasez endógena, que proviene del sobreuso ajeno; y escasez colectiva, que refleja información sobre necesidades insatisfechas a nivel del sistema.

El estudio de laboratorio identifica mecanismos distintos para cada tipo de escasez. La escasez exógena reduce el cumplimiento al estrechar el foco cognitivo, mientras que la escasez endógena activa la reciprocidad negativa. Estos procesos muestran cómo la escasez modifica percepciones de justicia, expectativas sobre otros y los procesos cognitivos que sostienen la cooperación. El experimento de campo evalúa si estos mecanismos operan en contextos reales de gobernanza del agua. Los resultados reflejan los hallazgos del laboratorio y muestran que la experiencia institucional modera algunas respuestas. Los miembros de las Asociaciones de Usuarios de Agua son más sensibles a las señales de escasez colectiva, lo que evidencia el rol de la experiencia vivida y el aprendizaje social. Además, se propone una metodología para incorporar estos mecanismos en modelos sociohidrológicos.

Estos estudios muestran que la escasez influye en el comportamiento en sistemas CPR de manera empíricamente fundamentada y relevante para la gobernanza ambiental y la sociohidrología. Los hallazgos indican que el cumplimiento no depende solo de incentivos o fiscalización, sino de respuestas psicológicas y sociales que evolucionan con el tiempo. Integrar estas dinámicas en modelos sociohidrológicos permitirá mejorar predicciones de resiliencia y apoyar el diseño de instituciones de gobernanza del agua más adaptativas frente a la incertidumbre climática.

Palabras clave: Escasez, Cumplimiento, Recursos de uso común, Experimentos conductuales, Sociohidrología

Abstract

Scarcity is a central feature of many common pool resource (CPR) systems, yet little is known about how its different forms influence individuals' willingness to follow collective rules. This thesis examines the behavioral mechanisms that sustain compliance under resource stress, combining controlled laboratory experiments with a field experiment conducted with members of Water User Associations in central Chile. By conceptualizing scarcity as unmet demand, the thesis distinguishes among exogenous scarcity arising from external constraints, endogenous scarcity resulting from others' overuse, and collective scarcity based on information about system-wide shortfalls.

The laboratory study identifies distinct mechanisms for each type of scarcity. Exogenous scarcity reduces compliance by narrowing cognitive focus, while endogenous scarcity activates negative reciprocity that increases rule violations. These processes show how scarcity alters perceptions of fairness, expectations about others' behavior, and the cognitive foundations of cooperation. The field experiment evaluates whether these mechanisms also operate in real water governance contexts. The results mirror the laboratory findings and show that institutional experience moderates some responses. Water User Association members are more sensitive to collective scarcity cues, reflecting the role of lived experience and social learning. A methodology is also proposed to incorporate these behavioral mechanisms into sociohydrological models.

These studies show that scarcity influences behavior in CPR systems in ways that are empirically grounded and highly relevant for environmental governance and sociohydrology. The findings indicate that compliance depends not only on incentives or enforcement but also on psychological and social responses that evolve over time. Integrating these dynamics into sociohydrological models will improve resilience predictions and support the design of more adaptive water governance institutions under climatic uncertainty.

Keywords: Scarcity, Compliance, Common-pool resources, Behavioral experiments, Socio-hydrology.

Chapter 1

Introduction

Climate change is intensifying the frequency and duration of droughts around the world, disrupting hydrological regimes and reducing the reliability of freshwater systems that sustain agriculture, energy production, and human consumption (Barría et al., 2025; Boisier et al., 2025; R. Garreaud et al., 2025; Julio et al., 2024; Latoja et al., 2025). As water becomes increasingly variable and uncertain, tensions between individual needs and collective sustainability deepen, especially in settings governed as common-pool resources (CPRs). These systems require coordinated rule-following to prevent overuse, yet compliance is inherently fragile. It depends not only on monitoring and sanctions but also on trust, shared expectations of reciprocity, perceptions of fairness, and the social norms that evolve within user communities (Fehr & Gächter, 2000b; Nyborg et al., 2016; Ostrom, 1990, 2009b; Tyler, 2006).

Institutional design principles can strengthen cooperation under stress, but deterrence alone is costly and often insufficient (Anderies & Janssen, 2013; Ostrom, 1990; Ostrom et al., 1994). Effective governance requires institutions capable of aligning formal rules with ecological conditions and with the social expectations that shape behavior. This challenge is particularly acute when scarcity increases, because unmet needs affect how individuals process information, evaluate risks, and assess the legitimacy of collective rules.

Chile offers a paradigmatic case for studying these dynamics. The 1981 Water Code established a decentralized, market-based system of private, tradable water rights. This framework was developed under conditions of relative abundance (Valdés-Pineda et al., 2016). After more than a decade of severe drought, many river basins now allocate more water rights than hydrological supply (R. Garreaud et al., 2025; R. D. Garreaud et al., 2020). This growing mismatch between formal property systems and ecological reality has placed sustained pressure on Water User Associations (WUAs), including Juntas de Vigilancia and Asociaciones de Canalistas, which are responsible for coordinating distribution and fostering compliance. Understanding the behavioral mechanisms that sustain or undermine rule-following in this increasingly stressed context is therefore essential for ensuring the resilience of Chile's water governance system.

Despite extensive research on CPR governance, important gaps remain. Existing work emphasizes institutional design, monitoring, graduated sanctions, fairness norms, and the role of trust in sustaining cooperation (Balliet & Van Lange, 2013; Fehr & Gächter, 2000b; Fischbacher & Gächter, 2010). Yet much less is known about how different forms of scarcity shape the psychological and social mechanisms that underpin rule compliance. Moreover, the literatures on CPR governance and the behavioral effects of scarcity have evolved largely in parallel. Research on scarcity shows that unmet needs narrow cognitive bandwidth, redirect attention toward immediate goals, and alter risk-taking and self-control (Mullainathan & Shafir, 2013; Shah et al., 2012a). CPR research, by contrast, typically represents resource shortfalls as smaller endowments, without capturing how scarcity is experienced subjectively as a loss, deprivation, or social signal. Integrating these perspectives is crucial for understanding behavior under ecological stress.

This gap motivates the core question of this dissertation:

How do different forms of scarcity influence the behavioral mechanisms that support rule compliance in common pool resource systems?

To address this question, the dissertation draws on two complementary methods. The first is a controlled laboratory experiment designed to isolate how scarcity affects compliance in a stylized CPR setting. The second is a framed field experiment implemented with irrigators in central Chile, which evaluates the same mechanisms in a real-world institutional environment. Together, these studies examine how exogenous scarcity, endogenous scarcity, and collective scarcity awareness influence compliance behavior, expectations of others, and judgments about fairness and legitimacy.

Chapter 2, Scarcity Effects on Compliance in Common Pool Resources, introduces the experimental framework. The study conceptualizes scarcity as unmet demand rather than as a reduced endowment, distinguishing three forms of deprivation that arise in CPR settings. Exogenous scarcity occurs when resource availability is limited by environmental conditions. Endogenous scarcity arises when others' overuse reduces the amount available to a focal individual. Collective scarcity refers to information indicating that unmet needs are widespread. These distinctions parallel those in the behavioral literature on loss aversion, inequity aversion, and cognitive load (Fehr & Schmidt, 1999; Kahneman & Tversky, 1979; Mullainathan & Shafir, 2013).

The laboratory experiment reveals three behavioral mechanisms. First, exogenous scarcity consistently reduces compliance. When individuals face unmet needs, their cognitive attention narrows toward immediate resource shortfalls, diminishing sensitivity to long-term collective outcomes and making rule violations appear justifiable. This effect intensifies with repeated exposure. Second, endogenous scarcity activates negative reciprocity. Individuals who experience deprivation caused by others escalate the magnitude of their violations when they choose to defect, consistent with theories of inequity aversion and retaliation. Third, collective scarcity awareness does not trigger altruistic restraint. Instead, information that others also face shortages is interpreted as a sign of intensified competition.

A central contribution of Chapter 2 is the reframing of scarcity as a psychologically meaningful loss, which aligns with how irrigators and other users experience scarcity in actual CPR systems. This framing exposes the cognitive and social pathways through which scarcity reshapes compliance, offering a behavioral foundation that informs the applied analysis that follows.

Chapter 3, Compliance Regarding Water Regulations in Situations of Water Scarcity, examines whether the mechanisms identified in the laboratory operate in real-world irrigation contexts. Through a framed field experiment with WUA members in central Chile, the study evaluates how institutional participation and lived experience moderate compliance behavior. The design mirrors the laboratory structure, adapting it to familiar elements of irrigation practice such as binding quotas, irrigation turns, and opportunities to overuse water under weak enforcement.

The results demonstrate a striking consistency with the laboratory findings. Exogenous scarcity again reduces compliance. Endogenous scarcity erodes trust and encourages retaliatory extraction. Information about high collective demand increases competitive behavior. These patterns hold for both WUA members and non-members. The magnitude of the effects, including the regression coefficients associated with each type of scarcity, is remarkably similar across experimental settings, underscoring the robustness of the behavioral mechanisms.

At the same time, the field results reveal important contextual differences. WUA members exhibit higher baseline compliance, reflecting internalized norms of reciprocity, rule legitimacy, and experience with water distribution processes. Yet they also respond more strongly to collective scarcity signals, interpreting widespread unmet needs as indicators of systemic stress. This heightened sensitivity likely reflects repeated exposure to allocation conflicts, social learning within the WUA, and an embodied understanding of drought and competition.

These studies advance a comprehensive understanding of how scarcity shapes compliance in both abstract and context-specific CPR dilemmas. They show that rule-following is influenced not only by material incentives but also by psychological and social processes that shape expectations, perceptions of fairness, and beliefs about legitimacy. Scarcity transforms behavior not only by altering payoffs but also by reshaping the cognitive and social context within which decisions are made.

The findings have direct implications for environmental policy and sociohydrological modeling. Traditional hydrological and economic approaches often assume rational, homogeneous behavior and fixed behavioral parameters (Sivapalan et al., 2012; Yu et al., 2020). These assumptions limit their capacity to anticipate behavioral responses under ecological stress. Incorporating behavioral mechanisms such as attentional narrowing, negative reciprocity, and defensive extraction would improve model predictions by capturing feedback loops between environmental stress, institutional design, and human behavior (Di Baldassarre et al., 2019; Pande & Sivapalan, 2017). Such integration is essential for identifying conditions under which compliance may falter and for designing governance interventions that remain effective as climate change intensifies water scarcity.

Addressing the challenges of water governance under increasing climatic uncertainty requires more than infrastructure or formal allocation rules. It requires a deeper understanding of the behavioral foundations that sustain or erode cooperation under resource stress. By integrating controlled experimental evidence with field-based behavioral data, this dissertation contributes a behavioral framework for explaining compliance dynamics in CPR systems and offers empirical insights that can inform more adaptive and resilient water governance institutions.

The thesis is organized as follows. Chapter 2 identifies the behavioral mechanisms linking different forms of scarcity to non-compliance in CPR settings. Chapter 3 tests these mechanisms in a real-world irrigation context and examines how institutional participation and experience shape responses to water stress. Chapter 4 synthesizes the findings and discusses their implications for environmental governance and sociohydrological modeling.

Chapter 2

Scarcity Effects on Compliance in Common-Pool Resources: Experimental Evidence

2.1 Introduction

Ensuring compliance with regulations governing the use of common-pool resources (CPRs) remains one of the most persistent challenges in environmental governance and institutional design (Agrawal, 2001; Cox et al., 2010; Eisenbarth et al., 2021; Osmundsen et al., 2017; Ostrom, 1990; Poteete et al., 2010). CPRs are characterized by difficult exclusion and subtractability, where individual use reduces the availability of the resource for others, making them especially vulnerable to overuse when individual incentives conflict with collective sustainability goals (Hardin, 1968; Ostrom, 1990). The classical "tragedy of the commons" formulation emphasizes the inevitability of overexploitation when self-interested individuals act independently (Hardin, 1968). However, extensive empirical and theoretical research shows that communities frequently develop institutional arrangements that sustain cooperation and avoid collapse (Agrawal, 2001; Dietz et al., 2003; Ostrom, 1990). These findings highlight that effective CPR governance depends not only on monitoring and sanctions but also on the interaction between formal rules, local ecological conditions, and shared social norms (Agrawal, 2001; Cox et al., 2010; Ostrom, 2009a). Although deterrence-based mechanisms can increase compliance, they are often insufficient without the support of trust, reciprocity, and norm-based motivations (Barnes et al., 2016; Ostrom, 1990, 2009b; Shimshack, 2014; Tyler, 2006).

A growing literature examines the psychological and social drivers of compliance in CPR contexts, emphasizing the roles of trust, social norms, fairness concerns, reciprocity, perceptions of legitimacy, and expectations about others' behavior (Camerer et al., 2004; Cardenas, 2011; Fehr & Gächter, 2000b; Fischbacher et al., 2001; Guala, 2012; Nyborg et al., 2016; Ostrom, 2009b; Perry et al., 2021; Tyler, 2006). However, less is known about how scarcity, especially when personally experienced or observed in others, shapes rule-following behavior. Research in behavioral economics shows that scarcity can trigger cognitive load, short-termism, and a focus on immediate needs at the expense of collective outcomes (Mani et al., 2013; Mullainathan &

Shafir, 2013; Shah et al., 2012b). This "scarcity mindset" is associated with diminished cognitive control and reduced sensitivity to long-term or prosocial motivations. Scarcity also interacts with social dynamics such as perceived unfairness, inequity, and expectations about others' non-compliance, potentially undermining conditional cooperation (Bowles, 2004; Fehr & Schmidt, 1999; Fischbacher & Gächter, 2010; Gächter et al., 2017; Poteete et al., 2010). In CPR dilemmas, scarcity can therefore operate both as a direct cognitive constraint and as a catalyst for the erosion of social norms.

Existing experimental research typically treats scarcity as a uniform reduction in resources or endowments, applied equally across participants and disconnected from their actual needs (Cardenas, 2011; Dannenberg et al., 2024; Janssen et al., 2010b; Malézieux & Spiegelman, 2025; Pfaff et al., 2015; Villamayor-Tomas, 2014). While this approach has generated valuable insights, it does not fully capture a central feature of many real-world CPR settings: individuals often have explicit needs and incur direct losses when these needs are not met (Kahneman & Tversky, 1979, 1984). Moreover, scarcity rarely manifests as a single condition, as individuals may face shortages due to external individual constraints, past overuse by others, or shared systemic stress.

In this study, we conceptualize scarcity as a shortfall between supply and individual demand that generates monetary losses relative to an expected profit. This definition aligns with economic conceptions of scarcity and provides a more ecologically valid representation of the pressures commonly experienced in CPR systems. In addition, we distinguish three forms of scarcity: an exogenous scarcity condition, arising when external allocations are insufficient to meet personal demand; an experienced endogenous scarcity condition, occurring when individuals receive less than their entitlement due to others' prior overuse; and collective scarcity awareness, when individuals learn that others also face exogenous scarcity. Each type is expected to activate distinct mechanisms: exogenous scarcity may heighten urgency to satisfy unmet needs (Mani et al., 2013; Mullainathan & Shafir, 2013; Shah et al., 2012b); endogenous scarcity may evoke perceived unfairness and elicit negative indirect reciprocity (Fehr & Schmidt, 1999; Fischbacher & Gächter, 2010); and collective scarcity awareness may lead individuals to interpret others' shortages as signals of generalized resource stress, prompting precautionary overuse rather than restraint (Bowles, 2004; Ostrom, 1990; Poteete et al., 2010).

To test these dynamics, we implemented three experimental scenarios of scarce common-pool resources varying in familiarity to participants (shared time in a university study room, shared water for irrigation, and a context-free shared resource). We introduced a weak enforcement mechanism, consisting of probabilistic inspections with non-deterrent fines, aimed at signaling a social norm rather than deterring through cost (Falk et al., 2005; Nyborg et al., 2016; Shimshack, 2014; Tankard & Paluck, 2016; Tyler, 2006). This design allows us to assess the different mechanisms behind the decision of non-compliance. The experiment consisted of an economic game in which participants attempted to satisfy their resource demand over 15 rounds to avoid monetary losses from an initial expected profit. In each round, two participants shared a fixed total allocation of the resource, using it sequentially in two shifts: one player first, then the other, under a rule entitling each to a quota equal to half of the total allocation. While the total allocation was the same at the beginning of every round, individual demands varied, and in most rounds personal demands exceeded the quota, with aggregated demands between the two players surpassing the total allocation. This excess demand served as our operationalization of exogenous scarcity, as it was externally determined and independent of participants' decisions. Before learning their shift assignments, participants decided how much of the resource they would use if placed first, thereby determining whether to comply with the quota and, if not, by how much to exceed it. Any unused portion is passed to the second-shift player. If assigned the second shift and receiving less than the quota, the shortfall represented past experienced endogenous scarcity for the subsequent round, since it resulted solely from the first-shift participant's overuse. First-shift players also faced a 20% probability of inspection, with fines for detected overuse set at half the monetary loss caused by unmet demand. The game was implemented in two versions. In Treatment 1, participants were informed only of their own demand, meaning they had no information about the other participant's needs and thus no awareness of collective scarcity. In Treatment 2, participants were also informed of the demand of the person with whom they shared the allocation, creating a condition of collective scarcity awareness.

Our results show that exogenous scarcity is the strongest driver of non-compliance, substantially increasing both the likelihood and the magnitude of rule-breaking. Repeated exposure to these shortfalls further erodes compliance over time, indicating that scarcity experiences accumulate and progressively weaken rule-following behavior. Endogenous scarcity has a more nuanced effect: on its own, it primarily shapes the amount taken among those who already choose to violate the rule, consistent with negative reciprocity and inequity aversion. However, its influence becomes statistically significant for the compliance decision itself when individuals are concurrently facing exogenous scarcity. This interaction suggests that material pressure and perceived unfairness jointly amplify the propensity to defect. By contrast, neither information about others' scarcity nor contextual framing altered compliance, and weak probabilistic enforcement had no detectable effect.

These findings suggest that scarcity is not a uniform condition but a multidimensional experience that shapes compliance in CPR dilemmas through distinct psychological and social channels. By conceptualizing scarcity as a shortfall between demand and supply that generates losses, rather than as a uniform reduction in available resources, we offer a more ecologically grounded account of the pressures individuals face in real-world resource systems. Distinguishing between exogenous and endogenous scarcity reveals that each type activates different mechanisms and that their effects are intertwined: urgent material needs strongly reduce compliance, while perceived unfairness reinforces rule-breaking, particularly when individuals are already under material pressure. These patterns persist regardless of how the resource is framed and of whether participants are informed about others' needs, suggesting that the behavioral mechanisms uncovered are robust across contexts and informational conditions. This perspective advances classical CPR frameworks that emphasize preference heterogeneity and norm-based expectations by incorporating the scarcity-mindset lens. This approach highlights how cognitive load, urgency, and the psychological salience of unmet needs reshape decision-making under resource pressure. Our findings show that non-compliance may arise not only from strategic considerations or normative expectations, but also from the cognitive and emotional constraints induced by scarcity itself, which interact with fairness motivations and shape norm formation. In doing so, the study extends behavioral experimental insights to the practical challenges of governing CPRs under rising ecological stress, inequality, and climate change (Agrawal, 2001; Ostrom, 2009a; Perry et al., 2021).

2.2 Hypotheses

We hypothesize that immediate exogenous scarcity increases the likelihood of non-compliance with regulations governing the use of a shared CPR, as well as the magnitude of overuse (measured as units extracted beyond the assigned quota) will rise. Under conditions where individual demand exceeds the available quota, participants are expected to prioritize satisfying their immediate needs, even at the cost of violating regulatory norms. This prediction follows the behavioral literature on scarcity, which demonstrates that resource shortfalls tax cognitive bandwidth and direct attention narrowly toward urgent needs, often at the expense of broader goals such as fairness, cooperation, or compliance with rules (Mani et al., 2013; Mullainathan & Shafir, 2013; Shah et al., 2012b). The scarcity mindset increases the rational allocation of cognitive resources toward solving pressing short-term problems, while simultaneously neglecting other domains that may be equally relevant in the long run (Mullainathan & Shafir, 2013). In other words, individuals under scarcity can become more efficient at addressing the most urgent aspects of their situation, but this focus leads to reduced consideration of social preferences, inequity aversion, or adherence to institutional norms that sustain collective action (Fehr & Schmidt, 1999; Ostrom, 1990) aligning with rational-choice models (Becker, 1976). In the context of CPRs, this suggests that exogenous scarcity makes non-compliance a more likely and rationally justifiable choice for individuals attempting to meet their minimum needs, even though such behavior undermines collective sustainability. This expectation is consistent with empirical evidence that indicates that scarcity reduces attention to cooperative equilibria and amplifies self-serving behavior in both laboratory and field settings. Experimental studies show that scarcity narrows cognitive focus and reduces planning, making individuals more prone to prioritize immediate needs over collective outcomes (Mani et al., 2013; Shah et al., 2012b). In public goods and CPR experiments, scarcity and resource stress accelerate the decay of cooperation, shifting behavior toward self-interest (Camerer & Fehr, 2006; Fischbacher & Gächter, 2010). Field experiments confirm these patterns, with resource users under scarcity demonstrating lower compliance and greater over-extraction in irrigation and fishery contexts (Cardenas, 2003; Cardenas et al., 2013; Dannenberg et al., 2024).

With respect to the accumulated exogenous scarcity and compliance with common-pool resource regulation, standard rational-choice models of CPR use assume that decisions are made by weighing present costs and benefits, without systematic consideration of past outcomes beyond their informational content. In practice, however, repeated exposure to scarcity conditions can shape present behavior in ways that extend beyond purely rational updating. The experience of unmet needs may heighten sensitivity to future shortfalls, prompting individuals to adjust their extraction strategies defensively even when current endowments would not require it. This dynamic aligns with evidence that past losses exert disproportionate influence on current decisions, consistent with loss aversion in Prospect Theory (Kahneman & Tversky, 1979), the break-even effect in risk-taking after losses (Thaler & Johnson, 1990), and path-dependent retaliation in social dilemmas (Selten, 1998). In this sense, accumulated scarcity introduces behavioral path dependence into compliance decisions, a mechanism that escapes the predictions of classical rational-choice approaches (Bowles, 2004; Camerer et al., 2004; Ostrom, 1990). Moreover, the cumulative experience of scarcity may exacerbate this effect by depleting psychological and motivational resources over time. Scarcity not only reduces cognitive bandwidth in the short run, but persistent exposure can also undermine patience, self-control, and willingness to uphold cooperative norms across repeated interactions (Mani et al., 2013; Mullainathan & Shafir, 2013; Shah et al., 2012b). While cooperation and compliance in CPR dilemmas are often supported by social preferences, fairness concerns, and institutional trust (Fehr & Gächter, 2000b; Fehr & Schmidt, 1999; Fischbacher & Gächter, 2010; Tyler, 2006), these mechanisms may be progressively weakened under sustained resource pressure (Ostrom, 2009b; Poteete et al., 2010). This suggests that accumulated exogenous scarcity erodes compliance over time, as individuals shift from norm-oriented behavior toward short-term strategies aimed at buffering against anticipated deprivation.

As individuals experience greater levels of endogenous scarcity, that is receiving fewer resources due to the non-compliance of others, the likelihood of their own non-compliance with CPR regulations and the magnitude of overuse are expected to increase. We hypothesize that this effect is driven both by indirect negative reciprocity, in which individuals retaliate against perceived unfairness even when interacting with new counterparts, and by the erosion of social norms triggered by awareness of others' violations. Unlike rational choice models, which assume that past experiences should not directly influence present behavior in one-shot or rotating interactions, behavioral evidence shows that perceived unfairness and observed non-compliance often spill over across rounds, shaping future compliance trajectories. Research on conditional cooperation and reciprocity demonstrates that individuals are more likely to defect or punish when they perceive others as failing to cooperate, even in anonymous or rotating settings (Fehr & Gächter, 2000b; Fischbacher & Gächter, 2010; Gächter et al., 2017). Theories of inequity aversion further suggest that disadvantageous outcomes evoke frustration and motivate actions aimed at restoring fairness, including retaliation (Fehr & Schmidt, 1999). Complementary evidence from psychology and field studies shows that visible norm violations can undermine cooperation by normalizing non-compliance, which can be perceived as a change in the social norm (Cialdini et al., 1990; Keizer et al., 2008; Nyborg et al., 2016). In CPR contexts, such dynamics manifest in declining compliance and accelerated resource depletion when participants perceive exploitation or rule-breaking by others (Cardenas, 2011; Ostrom, 2009b).

We hypothesize that awareness of others' needs in a context of scarcity will be interpreted as a signal of generalized environmental stress, activating a scarcity mindset that increases non-compliance with CPR regulations and reduces prosocial preferences, compared to conditions in which individuals receive no information about others' needs. Prior research shows that scarcity shapes behavior not only through direct material constraints but also via social cues that signal resource competition or collective deprivation (Mullainathan & Shafir, 2013; Shah et al., 2012b). The scarcity mindset narrows attention to immediate concerns and suppresses consideration of fairness, social norms, and cooperative outcomes. Experimental evidence further indicates that perceptions of widespread scarcity can reduce generosity and heighten self-protective behaviors, even in the absence of direct competition (Camerer & Fehr, 2006; Fong et al., 2006; Mani et al., 2013). Moreover, awareness of others' high demands may foster expectations of non-compliance, and studies of social norms in environmental dilemmas suggest that such beliefs can erode conditional cooperation and reinforce defensive extraction strategies (Fischbacher & Gächter, 2010; Nyborg et al., 2016).

This study implemented three contextual frames designed to reflect varying levels of real-life familiarity for participants: context-free scenario, a water use scenario, and a study room scenario. We hypothesize that the scarcity mindset will be more strongly activated in the more familiar settings. Specifically, given that participants are university students, the framing involving shared time in a study room (a context closely related to participants' lived experiences according to a survey conducted with the same students) is expected to evoke a stronger psychological response to scarcity than the water context, which in turn is expected to have a greater effect than the context-free frame. This effect is presumed to occur through the recall of personally experienced scarcity situations, which increases the salience and urgency of resource limitations, consistent with evidence that contextual cues and personal relevance amplify behavioral responses to scarcity and social dilemmas (Falk & Heckman, 2009; Kahneman & Tversky, 1984; Levitt & List, 2007; Liberman et al., 2004; Loewenstein, 1999). In addition, we expect the framing to interact with the three types of scarcity (exogenous, endogenous, and collective). That is, the behavioral effects of scarcity on compliance and prosociality may be amplified or attenuated depending on how personally meaningful the context is perceived to be. This builds on research showing that contextual cues can modulate cognitive and emotional responses to scarcity by shaping attention and perceived urgency (Mani et al., 2013; Mullainathan & Shafir, 2013; Shah et al., 2012b). More generally, evidence from behavioral economics and psychology demonstrates that framing and personal relevance strongly influence decision-making, with greater realism and salience amplifying the effect of experimental treatments (Falk & Heckman, 2009; Kahneman & Tversky, 1984; Loewenstein, 1999).

We hypothesize that the enforcement mechanism implemented in this experiment, consisting of probabilistic inspections and a low, non-deterrent fine, will serve primarily as a signal of the existence of a social norm rather than as a material deterrent. As such, enforcement is expected to reduce the likelihood of non-compliance (binary decision) in a magnitude that will not counteract the effect of the exogenous scarcity, but not the magnitude of overuse among those who do choose to violate the rule. This distinction reflects normative theories of compliance, which argue that individuals often follow rules not merely to avoid sanctions, but because enforcement communicates shared expectations and reinforces the legitimacy of the norm (Bicchieri, 2005; Tyler, 2006). Even weak enforcement can serve as a cue that "others are expected to comply", thereby increasing conformity through the perception of social consensus (Tankard & Paluck, 2016). In this sense, inspections function less as deterrence in the economic sense than as symbolic reinforcement of institutional credibility. However, when sanctions are perceived as largely symbolic or insufficiently costly, they are unlikely to affect the strategic calculus of those already inclined to defect, and thus have limited influence on the intensity of non-compliance (Becker, 1968; Guala, 2012).

Table 2.1: Summary of Hypotheses and Theoretical Mechanisms

	Hypothesis	**Mechanisms**
H1	Higher immediate exogenous scarcity will increase the likelihood and magnitude of non-compliance with common-pool resource regulations.	Scarcity reduces cognitive bandwidth, prioritizing immediate needs over norm adherence, aligning with rational-choice models.
H2	Accumulated exogenous scarcity will increase the likelihood and magnitude of non-compliance with common-pool resource regulations.	Path dependence from unmet needs, reinforced by loss aversion and the break-even effect, erodes compliance over time.
H3	Experiencing scarcity due to others' overuse increases the likelihood and magnitude of non-compliance.	Indirect negative reciprocity, as retaliation against perceived unfairness even when counterparts change, and erosion of the social norm through awareness of others' non-compliance.
H4	Knowing others are in need (T2) increases non-compliance and reduces prosocial preferences, compared to not knowing (T1).	Scarcity mindset triggered by social cues; perceptions of widespread scarcity foster self-protection, expectations of others' non-compliance, and erosion of conditional cooperation.
H5	More familiar contexts (e.g., study rooms) will activate the scarcity mindset more strongly than abstract or less familiar ones (e.g., water or context-free). Framing will interact with the different types of scarcity.	Recall of real-life scarcity increases salience and amplifies scarcity effects.
H6	Enforcement (inspection + non-deterrent fine) will reduce the likelihood of non-compliance but not its magnitude.	Enforcement acts as a social norm cue rather than a deterrent.

2.3 Methodology

2.3.1 Experimental design

To empirically test our hypotheses, we conducted a game-based experiment designed to isolate different types of scarcity and evaluate compliance with regulatory constraints under three distinct framings. The framings were designed to represent different levels of familiarity for the sample. Prior to the experiment, some students were informally interviewed on campus to identify which university resources they perceived as scarce, and study rooms were mentioned by the majority. This was later confirmed by a post-experiment survey of all participants, in which 75% reported frequently or sometimes being unable to reserve study rooms, and 80% indicated that the time assigned for study room use was insufficient. The water scenario was designed to reflect the conditions faced by farmers in Chile, who share irrigation channels and are allocated quotas for water use under the institutional arrangements of water user associations and national law. While this scenario is ecologically valid for water users, it was not familiar to the majority of university students. The context-free scenario was designed to serve as a baseline for comparison. Table 2.2 summarizes the key characteristics of each framing, including the type of resource, unit of measurement, and explanatory context. Additionally, participants were assigned to one of two treatments, which differed in the amount of information provided given a 6 possible experimental conditions (3 scenarios x 2 treatments). Figure 2.1 displays examples of the decision and results screens.

The experiment simulates decision-making in a context where participants face a demand for a scarce resource, the use of which is regulated but where they also have the opportunity to violate the established rule. The game consists of 15 rounds, during which participants were randomly paired. In each round, a fixed endowment of 24 units of the resource was available and had to be used sequentially by both players. A regulatory rule stipulated that each participant was entitled to a quota of half of the total endowment (12 units), although they could choose to use any amount, leaving the remainder to the second player. In most rounds, the aggregate demand of the pair exceeded the total endowment, and individual demands surpassed the quota, thereby introducing scarcity into the system. On the decision screen (Figure 2.1, panels a and b), participants could observe the total endowment (white rectangle with red numbers), the demands (yellow rectangles), and the quota (red dashed line and number at the midpoint).

In the Treatment 1 condition (T1), participants were informed only of their own demand for the resource (Figure 2.1, panel a). These demands varied randomly each round, ranging from 11 to 15 units during the first five rounds (low exogenous scarcity) and from 12 to 20 units during the remaining ten rounds (high exogenous scarcity). In the Treatment 2 condition (T2), participants received the same information as in T1 but were also informed of the demand of the participant with whom they shared the resource that round (Figure 2.1, panel b). Thus, participants in this condition were not only subject to their own scarcity constraints but also aware of those faced by the other person. We refer to this condition as collective scarcity awareness.

In each round, participants had to decide how many units of the resource they would use if assigned to the first shift. After both players made their decisions, the assignment of shifts was randomized, so only one of the two decisions was implemented. The participant assigned to the first shift received the number of units they had initially chosen. The second-shift participant received whatever remained from the endowment after the first-shift player's choice (Figure 2.1, panel c). When the first-shift participant extracted more than the 12-unit quota, the second-shift participant experienced endogenous scarcity.

Each participant began the game with an initial expected profit of CLP 10,000 (USD 10), which they could retain if their demand was fully met across all 15 rounds. For each unit of unsatisfied demand, participants lost CLP 100 (USD 0.10) from this fund. Compliance was monitored with a 20% probability, and any detected non-compliance resulted in a fine of CLP 50 (USD 0.05) per unit extracted over the quota, equivalent to half the monetary loss caused by unmet demand (the message they received when inspected is shown in Figure 2.1, panel d). This fine was intentionally designed to be non-deterrent. After each round, participants observed their updated total expected profit on a bar displayed at the right side of the screen (Figure 2.1).

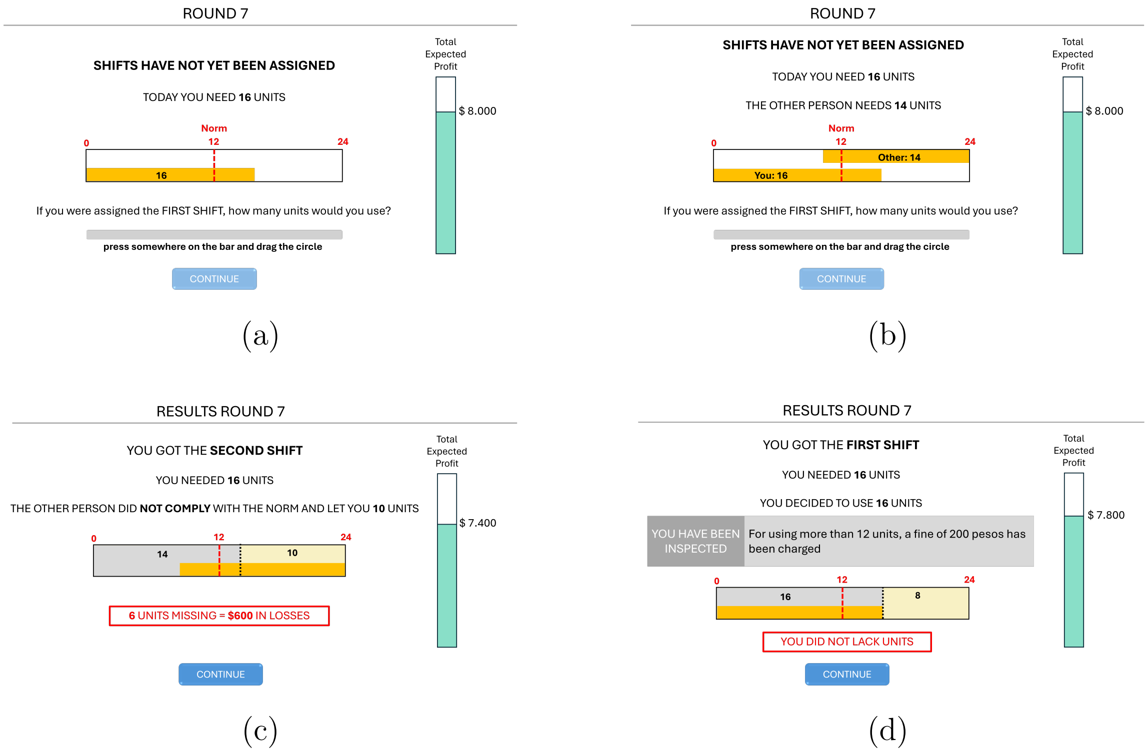

Figure 2.1: The game interface for the context-free framing. Panel (a) shows the decision page in the case with no collective scarcity awareness. The participant only has information about their demand for the resource (Treatment 1). Panel (b) shows the decision page in the case with collective scarcity awareness. The participant has information about their own and their partner's demands for the resource (Treatment 2). Panel (c) shows the result page when the participant experienced endogenous scarcity. The participant got the second shift and their partner left them less than 12 units. Panel (d) shows the result page when the participant was inspected and fined for using more than 12 units.

2.3.2 Participants

We recruited 321 undergraduate students (131 male, 190 female) between May 2024 and April 2025, from nine faculties at Universidad del Desarrollo, predominantly from Health Sciences, Economics and Business, Psicology, Engeneering, and

Table 2.2: Framing Conditions

Category	STUDY ROOM	WATER	CONTEXT-FREE
Aim	Comply with the necessary time to use the study room	Meet the irrigation needs of the crop	Meet the needs of a resource
Unit of the resource	5 minutes of use	1 hour of irrigation	1 unit
Endowment	2 hours	24 hours	24 units
Norm	1 hour	12 hours	12 units
Demand range	0:55 to 1:40	11 to 20	11 to 20
Demand stages	Low/High difficulty	Spring/Summer	Low/High necessity
Origin of the profit	Expected prize at the end of the semester for optimal compliance	Expected crop profit at the end of the season if needs are met	Expected profit if the need for the resource is met
Initial expected profit	10000 CLP	10000 CLP	10000 CLP
Losses	100 CLP per 5 minutes	100 CLP per hour	100 CLP per unit
Prob. of inspection / Fine	20% / 50 CLP per 5 min	20% / 50 CLP per hour	20% / 50 CLP per unit

Government. Participants' ages ranged from 19 to 35 years (M = 21). Participants were recruited through flyers and personal invitations in university courtyards and classrooms, and took part voluntarily. Each participant received a fixed show-up fee of 5000 CLP (USD 5) plus additional earnings based on the outcomes of the experiment, averaging 4950 CLP (USD 4.95) and ranging from 0 to 8300 CLP (USD 8.30), showing no significant differences between treatments (Treatment 1: M=4933 CLP, Treatment 2: M=4965 CLP). No significant differences in gender, parents' education, faculties, and risk aversion between treatment groups were found (reported in the Table 2.3). Participants were assigned to one of the 6 possible experimental conditions, Table 2.4 reports the number of participants in each one.

Table 2.3: Sample balance table

Variable	Level	Treat. 1 (%)	Treat. 2 (%)	p-value
N		161	160	
Sex	Men	73 (45.3)	58 (36.2)	0.123
	Woman	88 (54.7)	102 (63.7)	
Scenario	Context-free	59 (36.6)	59 (36.9)	0.997
	Study room	51 (31.7)	50 (31.2)	
	Water	51 (31.7)	51 (31.9)	
Risk.Aversion	High	100 (62.1)	111 (69.4)	0.210
	Low	61 (37.9)	49 (30.6)	
Parent.Education.Level	Primary	4 (2.5)	3 (1.9)	0.934
	Secondary	34 (21.1)	36 (22.5)	
	Higher	83 (51.6)	85 (53.1)	
	Postgraduate	40 (24.8)	36 (22.5)	
Faculty	Architecture and Art	0 (0.0)	4 (2.5)	0.132
	Communication	3 (1.9)	4 (2.5)	
	Design	0 (0.0)	2 (1.3)	
	Economics and Bussines	16 (10.3)	14 (8.8)	
	Education	2 (1.3)	4 (2.5)	
	Engineering	16 (10.3)	9 (5.7)	
	Government	9 (5.8)	10 (6.3)	
	Health Sciences	79 (50.6)	68 (42.8)	
	No Data	21 (13.5)	23 (14.5)	
	Psicology	10 (6.4)	21 (13.2)	

Table 2.4: Number of participants by treatment and scenario

Scenario	**No Collective Scarcity Awareness**	**Collective Scarcity Awareness**
Study room	51	50
Water	51	51
Context-free	59	59

2.3.3 Data collection

Sessions were conducted on campus using the equipment provided by the Mobile Experimental Laboratory of the Center for Research on Social Complexity. We conducted 22 sesions with between 8 and 30 participants. The study was approved by the Ethics Committee of Institutional Research Ethics Committee of the Universidad del Desarrollo (available on the Supplementary Material). All participants signed informed consent forms prior to participation. Sessions followed a standardized protocol (see the Supplementary Material). Instructions were given via video, and the game (programmed with oTree software, Chen et al., 2016) was played synchronously on individual laptops using an offline server. All participants in a session were assigned to the same combination of framing and treatment. The first session's combination was randomly assigned; subsequent sessions were allocated to ensure balanced amount of participants across the six experimental conditions (3 framings $\times$ 2 treatments). Each session lasted approximately one hour. Sociodemographic information (age, gender, faculty, and parents' education), risk aversion (measured using the methodology proposed by Eckel and Grossman, 2002), and initial beliefs about others' compliance in the game were collected before the game.

2.3.4 Variables

The experimental design allowed us to operationalize the following variables:

Dependent variables:

1. Non-compliance decision: This variable captures whether the participant complied with the rule of using no more than half of the total allocation (the quota). On the decision screen, the quota was indicated by a red dashed line and a number displayed at the midpoint of the rectangle showing the total allocation and demands. Participants made their decision by selecting a point on a gray slider bar on the bottom of the screen (see Figure 2.1, panels a and b). The variable takes a value of 0 if the chosen amount was equal to or below the quota, and 1 if it exceeded the quota.

$$\text{Non-compliance decision}_t = \begin{cases} 0, & \text{if decision}_t \leq \text{quota} \\ 1, & \text{if decision}_t > \text{quota} \end{cases}$$

2. Non-compliance units: This variable measures the extent of non-compliance, defined as the number of units that the participant decides to use above the quota. It corresponds to the value selected on the gray slider bar when the participant chose to exceed the quota (Figure 2.1, panels a and b).

$$\text{Non-compliance units}_t = \text{decision}_r - \text{quota}$$

Independent variables:

- Exogenous Scarcity: This variable captures the number of units demanded above the quota in each round. Although it was not directly shown to participants, it was visually indicated on the decision screen as the portion of the demand rectangle extending beyond the red quota line.

$$\text{Exogenous Scarcity}_t = \text{demand}_t - \text{quota}$$

  The variable can take negative values during the initial rounds (the low exogenous scarcity period), when individual demand fell below the quota.

- Accumulated Exogenous Scarcity: This variable represents the sum of exogenous scarcity across all previous rounds. It was neither displayed to participants during the decision screen nor in the results screen.

$$\text{Accumulated Exogenous Scarcity}_t = \sum_{r=1}^{t-1} (\text{Exogenous scarcity}_r)$$

- Last Endogenous Scarcity: This variable is operationalized in two ways. First, as a binary indicator that takes the value 1 if the participant received less than the quota in the last round in which they had the second turn, and 0 otherwise. Second, as a continuous measure corresponding to the number of units below the quota received in that round. This information was shown to participants on the results screen of that round, through a message informing them of the other player's compliance decision and the number of units they actually received (Figure 2.1, panel c).

$$\text{Last Endogenous Scarcity (Binary)}_t \begin{cases} 0, & \text{if partner comply with the quota} \\ 1, & \text{if partner did not comply with the quota} \end{cases}$$

$$\text{Last Endogenous Scarcity (Hours)}_t = \text{quota} - \text{amount received}_{t-j}$$

$$\text{where } t-j \text{ is the last round with the second shift.}$$

- Accumulated Endogenous Scarcity: This variable represents the sum of endogenous scarcity across all previous rounds when they had the second shift except the last one. It was neither displayed to participants during the decision screen nor in the results screen.

$$\text{Accumulated Endogenous Scarcity}_t = \sum_{r=1}^{t-j-1} (\text{Past Endogenous scarcity}_r)$$

- Collective Scarcity Awareness: This binary variable indicates whether participants were informed about the demand of their game partners. In the experiment, it corresponds to the assignment to the screen shown in Figure 2.1, panel a (Treatment 1) or Figure 2.1, panel b (Treatment 2). The assigned treatment condition remained fixed for each participant throughout the entire game.

$$\text{Collective Scarcity Awareness} = \begin{cases} 0, & \text{if Treatment 1} \\ 1, & \text{if Treatment 2} \end{cases}$$

- Scenario: This variable indicates the framing condition assigned in the game: context-free (default), water, or study room. The framing determined the aim of the game, the type and units of the resource, the total endowment, the norm and the range of demands, and the origin of the initial expected profit, as summarized in Table 2.2.

$$\text{Scenario} = \begin{cases} \text{Context-free} \\ \text{Water} \\ \text{Study Room} \end{cases}$$

- Inspection Previous Round: this variable indicates if the participant was inspected for non-compliance in the previous round.

$$\text{Inspection Previous Round}_t = \begin{cases} 0, & \text{if not inspected in round t-1} \\ 1, & \text{if inspected in round t-1} \end{cases}$$

Control variables:

- Beliefs: Initial beliefs about others' compliance were eliparencited before the game through the question: "If in this activity 10 people need to take out more than 12 units of the resource, how many of them will decide to take out more than assigned?" The wording was adapted to the resource used in each scenario. Participants could respond with any number between 0 and 10. For the analysis, beliefs were operationalized into two categories: responses between 0 and 5 (low) and responses between 6 and 10 (high).

$$\text{Beliefs} = \begin{cases} Low, & \text{if beliefs} \leq 5 \\ High, & \text{if beliefs} > 5 \end{cases}$$

- Risk aversion: This variable was measured before the game using a lottery-choice task with five alternatives varying in risk and expected utility, following the methodology proposed by Eckel and Grossman (Eckel & Grossman, 2002). This task was not paid in the experiment. For the analysis, responses were operationalized into two categories according to the alternative selected.

$$\text{Risk Aversion} = \begin{cases} High, & \text{if response} = 1\text{, 2 or 3} \\ Low, & \text{if response} > 4 \text{ or 5} \end{cases}$$

- Sociodemographic: We collected the following sociodemographic variables: gender, faculty, parental education level, and age (the latter showing almost no variance, as the sample consisted exclusively of undergraduate students). Among these variables, only gender had a significant effect; therefore, it is the only sociodemographic variable reported in the results.

2.3.5 Econometric analysis

We estimated four econometric models: two for each dependent variable. The baseline models included only the main independent variables considered in the hypothesis (exogenous and endogenous scarcity, collective scarcity awareness, scenario, and inspection in the previous round), while the extended models added control variables (beliefs, risk aversion, and gender). Non-compliance decisions and units were analyzed using linear regression models with cluster-robust standard errors at the participant level. Logistic regression models (logit) were also estimated for non-compliance decisions, besides panel and hierarchical models; the results are available in the Supplementary Material. Also, interaction terms were tested to assess whether the effects of the scenarios and treatments varied across scarcity conditions.

All analyses were conducted in `R` (version 4.4.1) using the packages `margins`, `plm`, `lme4`, `sandwich`, and `stargazer`. Significance was set at $\alpha = 0.05$, two-tailed. Replication materials, including the code of the experiment, data sets, and analysis scripts, are available at the Supplementary Material.

2.4 Results

Table 2.5 reports the results of linear regressions estimating the effects of the independent variables of interest across five models. Columns (1), (2), and (3) present estimates for the binary decision of whether to comply with the resource-use regulation, while columns (4) and (5) report the number of units of non-compliance (i.e., the amount over the quota), conditional on the decision to violate the rule.

The rows display the effects of nine independent variables and one interaction: (i) exogenous scarcity in the current round in units; (ii) accumulated exogenous scarcity from all previous rounds in units; (iii) and (iv) endogenous scarcity in the most recent round in which the participant had the second shift binary (experienced or not) and in units; (v) and (vi) accumulated endogenous scarcity across prior rounds (excluding the most recent one) binary and in units; (vii) collective scarcity awareness, a binary indicator for assignment to Treatment 2; (viii) framing effects (study room and water scenarios, compared to the context-free one); (ix) past inspection, a binary indicator of whether the participant was inspected in the previous round; (x) the interaction between exogenous scarcity and endogenous scarcity binary. Control variables include initial beliefs about others' compliance, risk aversion, and gender.

Table 2.5: Non-Compliance Two Parts Decision

	Dependent variable:				
	Non-compliance decision			Non-compliance units	
	(1)	(2)	(3)	(4)	(5)
Exo.	0.076***	0.085***	0.086***	0.747***	0.749***
	(0.002)	(0.004)	(0.004)	(0.020)	(0.020)
Accum. Exo.	0.004**	0.003**	0.003**	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)
Last Endo. (Binary)	0.034	0.078***	0.078***		
	(0.019)	(0.022)	(0.022)		
Last Endo. (Hours)	−0.003	−0.001	−0.001	0.051**	0.051**
	(0.004)	(0.004)	(0.004)	(0.018)	(0.018)
Accum. Endo. (Binary)	0.004	0.004	0.004		
	(0.006)	(0.006)	(0.006)		
Accum. Endo. (Hours)	−0.004*	−0.004*	−0.004*	0.021*	0.020
	(0.002)	(0.002)	(0.002)	(0.010)	(0.010)
Collective S. Awareness	0.030	0.030	0.035	−0.195	−0.166
	(0.023)	(0.023)	(0.022)	(0.126)	(0.121)
Scenario Study Room	−0.017	−0.017	−0.019	−0.192	−0.201
	(0.028)	(0.029)	(0.027)	(0.152)	(0.149)
Scenario Water	0.016	0.016	0.026	−0.144	−0.104
	(0.027)	(0.027)	(0.028)	(0.150)	(0.157)
Inspection prev. round	−0.033	−0.036	−0.034	−0.035	−0.042
	(0.018)	(0.019)	(0.018)	(0.095)	(0.094)
Beliefs (High)			0.021		0.065
			(0.014)		(0.084)
Risk Aversion (High)			−0.097***		−0.315*
			(0.024)		(0.154)
Woman			0.051*		0.003
			(0.025)		(0.146)
Exo * Last Endo (Binary)		−0.016***	−0.017***		
		(0.004)	(0.004)		
Constant	0.358***	0.338***	0.420***	0.922***	1.264***
	(0.025)	(0.025)	(0.052)	(0.129)	(0.325)
Observations	4,815	4,815	4,815	3,158	3,158
R^2	0.213	0.215	0.226	0.516	0.520
Adjusted R^2	0.211	0.213	0.223	0.515	0.519
Note:					*p<0.05; **p<0.01;***p<0.001

We find that for each unit of exogenous scarcity—measured as demand exceeding the assigned quota—the probability of non-compliance increases by 8.5% ($p<0.001$), thus accepting H1. Based on this estimate, in a round with the highest level of exogenous scarcity in the experiment (8 units), the model predicts a non-compliance probability of approximately 68%, even in the absence of other types of scarcity. Conditional on choosing to violate the rule, participants exceed the quota by an average of 75% of the excess demand ($p<0.001$). Together, these results provide strong evidence that exogenous scarcity is the most powerful predictor of rule-breaking in CPR contexts, directly supporting the hypothesis that immediate material shortfalls reduce compliance.

Supporting H2, repeated exposure to exogenous scarcity has a cumulative effect on compliance: each unit of demand exceeding the quota accumulated from prior rounds increases the probability of non-compliance by 0.4% ($p<0.001$). Although this effect is smaller than the immediate impact of exogenous scarcity, its statistical significance indicates that scarcity experiences compound over time, progressively eroding compliance. By the final round of the experiment, participants had accumulated an average of 45 units of exogenous scarcity, corresponding to an estimated 18% increase in the probability of non-compliance. Notably, accumulated scarcity does not significantly affect the magnitude of overuse among participants who choose to violate the rule, suggesting that its primary influence is on the decision to comply rather than on the extent of rule-breaking.

Supporting H3, being affected by another participant's non-compliance in the previous round increases the probability of non-compliance by 7.8% ($p<0.01$), although the number of times participants were exposed to endogenous scarcity does not significantly influence the compliance decision. By contrast, the cumulative magnitude of past endogenous scarcity reduces the probability of non-compliance by 0.4% per unit of shortfall ($p<0.05$). Among those who choose to violate the rule, the extent of overuse increases by 0.05 units ($p<0.01$) for each unit of the most recent endogenous scarcity, and by 0.02 units for each unit of accumulated endogenous scarcity, although the latter effect is only marginally significant. These findings support the hypothesis that experiences of unfair deprivation trigger retaliatory behavior, leading individuals who have already decided to defect to increase the amount they overuse—consistent with theories of negative reciprocity and inequity aversion.

Interestingly, the binary indicator of experiencing past endogenous scarcity becomes significant only when it interacts with exogenous scarcity. This interaction shows that the effect of having experienced a shortfall caused by another participant in a previous round is substantially stronger when the individual is simultaneously facing exogenous scarcity in the current round. In other words, past deprivation increases the likelihood of non-compliance primarily under conditions of current material pressure. The negative sign of the interaction term indicates that exogenous scarcity slightly attenuates the standalone effect of endogenous scarcity, suggesting that the probability of non-compliance in these situations is driven jointly by both past endogenous scarcity and current exogenous scarcity, but that the marginal effect of endogenous scarcity is smaller the bigger the exogenous scarcity in that round.

Contrary to H4, being assigned to the collective scarcity awareness condition (T2) does not significantly affect either compliance decisions or the extent of overuse compared with the other treatment. This null effect suggests that simple informational cues about others' needs are insufficient to activate perceptions of generalized scarcity or competitive pressure strong enough to shape behavior. Participants may have discounted this information as strategically irrelevant or not salient enough to influence their own payoffs.

Similarly, the evidence does not support H5. Exposure to the study room or water framings does not produce statistically significant differences in compliance or overuse compared to the context-free scenario. These results indicate that contextual familiarity alone is not sufficient to amplify scarcity effects, at least in the relatively weak framing manipulations employed here. While prior work suggests that strong, identity-relevant framing can affect cooperation, in our setting the contextual cues did not significantly influence behavior.

Our enforcement treatment provides no support for H6. Having been inspected in the previous round slightly reduces the probability of non-compliance (3%), but the effect is not statistically significant. Nor does enforcement affect the amount of overuse among non-compliant participants. Being fined in the previous round had no effect on compliance ether, so these results were not included in Table 2.5. These findings suggest that under these conditions, probabilistic inspections with non-deterrent fines lack credibility both as deterrents or as an effective norm signal.

In addition to the main hypotheses, we found that participants with higher risk aversion were significantly less likely to engage in non-compliance (coef = -0.097, $p<0.001$), and those who violated the rule overused significantly fewer units (coef = -0.315, $p<0.05$). Initial beliefs about others' compliance (measured before the game) showed no robust effects across models. Women exhibited a higher probability of non-compliance compared to men, although this result may be driven by the unbalanced composition of the sample, in which 60% of participants were women.

To test the robustness of our findings, we estimated linear models separately for each independent variable and for subsamples defined by different criteria. We also applied multiple-hypothesis testing corrections using the Benjamini–Hochberg, Holm, and Bonferroni methods, all of which confirmed that the effects remain consistent with those in the full specification. In addition, we estimated alternative models, including logistic regressions for the compliance decision, panel data specifications, and hierarchical mixed-effects models, which yielded qualitatively similar results. Full regression tables and replication code are available in the Appendix Section A and Supplementary Material.

2.5 Discussion

Our results demonstrate that exogenous scarcity is the strongest predictor of non-compliance with CPR regulations. This finding supports H1 and aligns with the concept of the scarcity mindset, which narrows cognitive bandwidth and directs attention toward pressing needs at the expense of long-term considerations or collective welfare (Mullainathan & Shafir, 2013; Shah et al., 2012b). The strong behavioral response to scarcity, both in the binary choice to break rules and in the magnitude of overuse, suggests that material shortfalls can override social preferences and normative motivations such as fairness, reciprocity, and institutional legitimacy (Fehr & Schmidt, 1999; Tyler, 2006). As in previous evidence from behavioral economics, scarcity appears to increase the rationality of choices within the domain of immediate needs, while simultaneously discouraging compliance and prosocial orientations (Cardenas, 2011; Mani et al., 2013).

Our results further support H2 by showing that repeated exposure to exogenous scarcity erodes compliance over time. The cumulative experience of scarcity appears to deplete psychological and motivational resources, gradually undermining adherence to norms and cooperation. This pattern departs from classical predictions of rational-choice, which would not expect past unmet needs to influence present compliance directly, and instead reflects the path-dependent dynamics of decision-making under sustained deprivation (Bowles, 2004; Ostrom, 1990). Such dynamics highlight how scarcity not only exerts immediate effects on cognition and choice (Mullainathan & Shafir, 2013; Shah et al., 2012b), but also reshapes behavioral trajectories over repeated interactions.

The finding that past experiences of endogenous scarcity proportionally increase the magnitude of non-compliance among those who already choose to defect supports H3, and suggests the activation of indirect negative reciprocity, whereby individuals respond to perceived unfairness by escalating their own non-cooperative behavior (Fehr & Gächter, 2000b; Gächter et al., 2017). Endogenous scarcity significantly affects the choice to defect when individuals simultaneously face exogenous scarcity, indicating that material pressure is a necessary trigger for these retaliatory mechanisms to influence the decision to violate the rule. In this sense, endogenous scarcity seems to function as a latent predisposition toward retaliation that becomes behaviorally relevant only under conditions of acute resource shortfall. Experiencing endogenous scarcity also provides participants with information about others' behavior, likely updating beliefs about future compliance and altering perceptions of the prevailing social norm. When individuals know that others are extracting more than the quota, they may infer that the norm of compliance is eroding, and, when combined with current material need, feel more justified in abandoning the rule themselves. Such norm-updating processes are consistent with evidence from public goods and CPR experiments showing that exposure to exploitation reduces trust and undermines cooperation, even when interactions are not repeated with the same individuals (Andreoni, 1995; Fischbacher & Gächter, 2010; Ostrom, 2009b). This interpretation aligns with theories of inequity aversion, which predict that disadvantageous outcomes evoke frustration and motivate retaliatory actions aimed at restoring fairness (Fehr & Schmidt, 1999). These patterns underscore the importance of understanding how different forms of scarcity interact, while endogenous scarcity alone may not be sufficient to trigger non-compliance, its effects become salient when compounded with exogenous scarcity, producing a form of scarcity-induced conditional cooperation breakdown.

An unexpected finding is that accumulated endogenous scarcity slightly reduced the probability of non-compliance. One interpretation is that sustained deprivation may generate fatigue or resignation effects, whereby individuals, instead of responding to deprivation with retaliation (by overusing the resource even more), may adapt to the constraints of the game. They might recognize that their actions cannot fully change the outcome or that repeated retaliation only increases their own losses. As a result, they settle into a pattern of compliance, not necessarily because they strongly value the rule, but because it represents a low-effort strategy that minimizes additional cognitive effort and risk (Mullainathan & Shafir, 2013; Simon, 1955). Alternatively, accumulated scarcity may have reinforced perceptions of the importance of the rule itself, consistent with theories of norm internalization and fairness heuristics (Bicchieri, 2005; Tyler, 2006). Repeated shortfalls highlight the collective risks of overuse and collapse, strengthening motivation to comply with the rule as a way of preserving fairness and stability. Rather than retaliating, participants may interpret scarcity as a reminder of the fragility of cooperation and the need for shared rules, echoing research showing that compliance is often shaped by legitimacy and fairness rather than deterrence (Fehr & Schmidt, 1999; Nyborg et al., 2016; Ostrom, 2009b). A third possible explanation is that continued compliance under scarcity may also serve as a signal of commitment to the rule, reinforcing the idea that cooperation remains appropriate despite others' violations. Such signaling dynamics are well documented in the social norms literature, where individual adherence communicates commitment and influences expectations (Cialdini et al., 1990; Tankard & Paluck, 2016). These interpretations remain speculative, but they highlight the need to distinguish between acute episodes of deprivation and long-term patterns of shortfall.

Contrary to H4, awareness of others' needs, intended to induce perceptions of collective scarcity, did not significantly affect compliance. These null results suggest that informational cues about others' demands may fail to shift behavior when they are weak, strategically irrelevant, or insufficiently connected to participants' material payoffs. While prior studies indicate that social information and scarcity-related cues can foster defensive or self-protective responses (Mullainathan & Shafir, 2013; Shah et al., 2012b) and that context-specific framing may enhance cooperation or norm salience (Fischbacher & Gächter, 2010; Nyborg et al., 2016), our manipulation may not have been sufficiently strong or personally relevant.

Similarly, we found no support for H5. Contextual framing through the study room and water use scenarios did not significantly influence compliance behavior with respect to the context-free scenario. Although contextual cues are known to modulate cooperation and norm salience when they are strongly tied to personal relevance (Falk & Heckman, 2009; Liberman et al., 2004), our treatments may have lacked the emotional or identity salience necessary to activate these mechanisms. For example, students in the study room condition may not have perceived scarcity as acute, given the availability of alternative study spaces in real life. These results suggest that under personal scarcity, frames that are both realistic and identity-relevant are more likely to shift compliance.

Finally, our enforcement treatment, consisting of probabilistic inspections and a low monetary fine, failed to reduce non-compliance, providing no support for H6. While deterrence theory predicts that higher detection and sanction probabilities should reduce violations (Becker, 1968), our results are more consistent with normative theories of compliance, which emphasize enforcement as a communicative device that signals shared expectations and institutional legitimacy (Bicchieri, 2005; Tankard & Paluck, 2016; Tyler, 2006). In our design, the weak and infrequent sanctions may have lacked credibility, reducing their effectiveness both as deterrents and as norm signals. Moreover, exposure to endogenous scarcity may have signaled that the prevailing social norm diverged from the rule imposed by enforcement. This interpretation is consistent with prior work showing that enforcement often fails under conditions of resource stress unless it is paired with legitimacy, trust, and credible monitoring systems (Guala, 2012; Ostrom, 2009a, 2009b).

This study examined how different forms of scarcity shape compliance with CPR regulations, testing six hypotheses (H1–H6). Across treatments, we found consistent evidence that exogenous scarcity (H1) and its cumulative effects over time (H2) are the most powerful drivers of non-compliance, underscoring the central role of material deprivation in eroding adherence to institutional rules. Past experiences of endogenous scarcity (H3) increased rule violations, consistent with mechanisms of negative reciprocity and inequity aversion. However, accumulated endogenous scarcity slightly reduced the probability of non-compliance, possibly reflecting resignation effects or attempts to signal adherence to the expected social norm. In contrast, collective scarcity awareness (H4) and contextual framing (H5) did not significantly affect behavior, suggesting that informational and symbolic cues are insufficient to influence decisions when individuals are personally resource-constrained or when the framings lack strong real-life relevance. Finally, weak enforcement through probabilistic inspections and low fines (H6) failed to reduce non-compliance, indicating that enforcement can function as an effective governance tool only when sanctions are credible and embedded in legitimate institutional contexts.

Our study contributes to the literature by unpacking mechanisms through which scarcity shapes compliance behavior and by advancing a more ecologically valid operationalization of scarcity in CPR dilemmas. By conceptualizing scarcity as a gap between demand and supply that generates real losses, and by distinguishing between exogenous, endogenous, and collective forms, we show that scarcity is not a unitary condition but a multidimensional experience with distinct psychological and normative implications depending on its source and informational content. This perspective contributes to understanding compliance in CPR dilemmas by demonstrating that scarcity not only impairs cognitive bandwidth in the short term but also reshapes behavioral trajectories over repeated interactions, producing a path-dependent erosion of cooperation. It also highlights how fairness concerns and reciprocity, typically supportive of collective action, may under scarcity transform into drivers of non-compliance when individuals experience deprivation caused by others. In doing so, we connect behavioral research on scarcity and cognitive bandwidth (Mullainathan & Shafir, 2013; Shah et al., 2012b) with theories of reciprocity and norm internalization (Bicchieri, 2005; Fehr & Schmidt, 1999; Tyler, 2006), demonstrating how these frameworks jointly help explain compliance dynamics in CPR settings. More broadly, our findings speak to the institutional challenges of managing common resources under conditions of increasing stress (Agrawal, 2001; Ostrom, 2009a; Perry et al., 2021).

From a policy perspective, our results caution against overreliance on weak enforcement or purely informational strategies in contexts of acute resource scarcity. Effective governance systems must instead combine mechanisms that directly mitigate material shortfalls, such as guaranteeing minimum access or buffer allocations, with institutional arrangements that strengthen trust, legitimacy, and credible monitoring. More broadly, our findings highlight that compliance in CPR settings is inseparable from the material conditions under which people operate: when individuals experience unmet needs, normative messages and low-intensity sanctions are insufficient to sustain collective action.

2.5.1 Limitations and Future Research

A key limitation of our design is that it did not allow us to measure the effect of endogenous scarcity directly, since its impact emerged only after the decision in each round and therefore influenced behavior indirectly in the following round as a past experience. A further limitation is that endogenous scarcity is itself an endogenous variable: it arises from the dynamics of the game and participants' decisions, and was therefore not directly controlled by the experimenters. We also note that the consistency of results across treatments and framings may reflect the characteristics of our student sample, for whom the contexts presented: study rooms, irrigation, or context-free resources, were likely equally unfamiliar.

Future work could experimentally manipulate endogenous scarcity to establish causal effects more precisely, or alternatively, adapt the design into a three-person sequential game, which would capture the immediate effects of endogenous scarcity within the same round (a design not implemented here due to budgetary constraints).

It would also be valuable to test stronger forms of norm signaling and context framing, as well as to examine the role of heterogeneity in participant characteristics (e.g., prior exposure to scarcity, social preferences, or cultural norms) in shaping compliance. Finally, replicating the experiment with populations of CPR users who have direct experience with resource shortages would allow us to assess the ecological validity of these findings.

Chapter 3

Compliance Regarding Water Regulations in Situations of Water Scarcity

3.1 Introduction

Human decisions shape and respond to hydrological dynamics in coupled human water systems (Montanari, 2015; Sivapalan & Blöschl, 2015; Sivapalan et al., 2012). Over the past decade, sociohydrology has advanced by integrating behavioral and institutional feedbacks into dynamic models (Di Baldassarre et al., 2019; Grames et al., 2019; Pande & Sivapalan, 2017). These efforts have improved understanding of risk adaptation, cooperation, and the emergence of vulnerability in complex systems. Yet recent reviews underscore that many sociohydrological models still rely on simplified assumptions about human behavior, often treating users as homogeneous, rational, or governed by static preferences (Alam et al., 2022; Elshafei et al., 2015; Kuil et al., 2019; Yu et al., 2020). Foundational sociohydrological frameworks (Di Baldassarre et al., 2013; Elshafei et al., 2015; Yu et al., 2020) incorporate behavioral components such as risk perception, collective memory, and social norms, but these assumptions are rarely based on empirical behavioral evidence. As calls for second-generation sociohydrological models emphasize the need to ground human decision rules in measured behavioral responses (Alam et al., 2022; Sivapalan et al., 2012), bridging this gap has become a central challenge for the discipline.

One particularly underrepresented behavioral mechanism is compliance with water use regulations. Research in the management of common pool resources (CPRs) shows that effective governance depends on users' ability to self-organize, sustain shared norms, and maintain credible monitoring systems (Ostrom, 1990; Poteete et al., 2010). Such collective arrangements can outperform centralized regulation when users build trust and design rules that reflect local realities (Baland & Platteau, 1996; Janssen et al., 2012). However, compliance is shaped by environmental, institutional, and psychological conditions (Alam et al., 2022; Pande & Sivapalan, 2017), and it becomes most crucial under scarcity, when incentives to defect intensify, perceived inequities sharpen, and system fragility increases (Anderies et al., 2013; Fischbacher & Gächter, 2010; Vollan & Ostrom, 2010). Violations often emerge as responses to perceived unfairness or declining trust rather than from opportunism alone. Sociohydrological models that ignore these behavioral dynamics risk misrepresenting system trajectories by overestimating cooperative stability and underestimating the potential for rapid collapse under stress (Anderies et al., 2004; Di Baldassarre et al., 2013). Incorporating theoretically and empirically grounded compliance mechanisms is therefore essential for modeling how human water systems respond to intensifying scarcity.

Central Chile offers a relevant empirical context for addressing this gap. Chile's Water Code created a system based on private, tradable water rights administered by autonomous Water User Associations (WUAs), which coordinate allocation, infrastructure, and rule enforcement at the local level (Donoso, 2020). This institutional structure depends on self governance, making compliance a critical component of system performance (Bauer, 2015; Scott et al., 2013). The prolonged megadrought affecting central Chile (Boisier et al., 2016; R. D. Garreaud et al., 2020; Muñoz & Garreaud, 2016) has intensified competition for water and increased exposure to coordination failures, disputes, and localized scarcity shocks (Hearne, 2017). These conditions provide a realistic setting for examining how users adjust extraction decisions under scarcity and institutional uncertainty.

Experimental methods in the behavioral sciences offer a powerful approach to isolating the mechanisms driving compliance. Controlled yet interactive environments allow researchers to systematically vary institutional conditions, resource constraints, and social signals while observing actual decisions (Cárdenas et al., 2011; Fehr & Gächter, 2000a; Fischbacher & Gächter, 2010; Ostrom, 2006). Such experiments generate quantitative behavioral data suitable for informing sociohydrological and agent-based models (Pande & Sivapalan, 2017; Yu et al., 2020). Their relevance for social–ecological modeling has been widely recognized (Janssen et al., 2010a), yet their integration into sociohydrological frameworks remains limited.

In this study, we investigate how compliance with water use regulations responds to three forms of scarcity: exogenous scarcity, endogenous scarcity, and collective scarcity awareness. Exogenous scarcity captures externally imposed shortfalls between users' needs and their assigned allocation, reflecting hydrological or policy-induced constraints that heighten immediate material pressure (Mullainathan & Shafir, 2013). Endogenous scarcity arises when users experience shortages caused by others' overuse, which can undermine trust and activate negative reciprocity (Fehr & Gächter, 2000a; Fehr & Schmidt, 1999). Collective scarcity awareness refers to information about others' high demand, which can function as a cue of system-wide stress and shape expectations about future availability (Camerer, 2003; Mani et al., 2013; Tversky & Kahneman, 1981). Distinguishing these dimensions allows us to identify the behavioral pathways through which scarcity affects cooperation and compliance.

We implemented a laboratory in the field irrigation experiment with WUA members and non-members in central Chile, enabling a comparative analysis of how institutional experience conditions behavioral responses to scarcity. The design maintains ecological validity while identifying causal effects. The resulting behavioral elasticities offer quantifiable relationships linking scarcity conditions to compliance decisions.

This study contributes to sociohydrology in three main ways. First, it provides empirical evidence on the behavioral mechanisms that shape compliance under different forms of water scarcity, addressing a persistent gap in the behavioral foundations of sociohydrological models. Second, it translates these behavioral responses into quantitative decision rules that can be directly incorporated into coupled human water models, improving their capacity to represent nonlinear feedbacks, shifts in cooperation, and vulnerability to breakdown under hydrological stress. Third, it offers a practical and replicable experimental methodology for diagnosing compliance fragility in local water user communities. By anchoring sociohydrological modeling in empirically observed decision processes, this study advances the integration of behavioral realism into the analysis and governance of water systems facing intensifying scarcity.

3.2 Behavioral mechanisms of compliance under scarcity: Theoretical framework and hypotheses

3.2.1 Norm compliance in a situation of exogenous scarcity

Exogenous scarcity occurs when individuals face limitations on resource availability that arise from environmental or institutional constraints rather than from the actions of peers. In such situations, theoretical and experimental research suggests that compliance with social norms and cooperative rules becomes more fragile as individuals adjust their behavior to meet pressing material needs.

From a psychological perspective, Mullainathan and Shafir (2013) propose the concept of scarcity-induced rationality, which suggests that acute shortages narrow cognitive focus toward immediate concerns. This shift in attention reduces the capacity to consider long-term consequences and social obligations, increasing the likelihood of short-term self-oriented decisions (Mani et al., 2013; Shah et al., 2012a). Under water allocation constraints, users facing unmet needs may disregard quotas to satisfy pressing requirements.

Complementing this view, the inequity aversion model (Fehr & Schmidt, 1999) predicts that compliance diminishes when allocations are perceived as insufficient or unfair relative to individual needs. Under conditions of scarcity, users may rationalize over extraction as a corrective response to what they interpret as inequitable institutional arrangements (Ostrom, 2000). This behavioral shift replaces cooperative motivations with compensatory strategies aimed at restoring distributive balance.

Empirical studies from common-pool resource (CPR) support these mechanisms. Prediger et al. (2014) show that individuals exposed to scarcity reduce their prosocial behavior. Cárdenas (2004) report similar patterns, especially when users perceive institutional rules as misaligned with their needs. Field and laboratory evidence further links environmental stress to declines in cooperation (Anderies et al., 2013; Fischbacher & Gächter, 2010; Gürerk et al., 2017; Janssen et al., 2010a). Collectively, this research indicates that exogenous scarcity undermines the psychological and institutional foundations of norm compliance.

3.2.2 Norms compliance in a situation of endogenous scarcity

Endogenous scarcity arises when a user experiences shortages caused by the over extraction of others within the same socio-ecological system. Unlike exogenous scarcity, which originates outside the social sphere, endogenous scarcity reflects social interactions and shapes perceptions of fairness and reciprocity. In such contexts, non-compliance often emerges from emotional and strategic responses to others' decisions rather than from material need alone.

Negative reciprocity is a central mechanism in this setting. When individuals experience deprivation due to another's violation of norms, they may retaliate by reducing their own compliance (Fehr & Gächter, 2000a; Fehr & Schmidt, 1999). This response creates a feedback loop: perceived unfairness leads to self-protective over extraction, which further erodes cooperative norms. Over time, these reciprocal defections can trigger cascades of declining trust and resource depletion (Gächter & Herrmann, 2011; Nikiforakis, 2008).

Trust deterioration reinforces this dynamic. As emphasized by Ostrom (Ostrom, 1990, 2000), cooperation in CPR systems depends on expectations that others will follow shared rules. When users observe norm violations or suspect free riding, trust erodes and individuals shift toward defensive strategies intended to avoid further disadvantage. This shift reduces compliance even among users with cooperative intentions. In public good settings, Fischbacher and Gächter (2010) show that participants decrease contributions after witnessing free riding, highlighting the role of conditional cooperation. Anderies et al. (2004) demonstrate that socially induced depletion can accelerate tragedy of the commons dynamics when users expect continued overuse. Additional experimental research confirms that perceptions of selfishness or norm violation increase the likelihood of self-protective rule-breaking (Janssen et al., 2010a; Tavoni et al., 2011; Vollan & Ostrom, 2010). These findings show how endogenous scarcity erodes compliance through social feedbacks grounded in fairness and expectations.

3.2.3 Norms compliance in a situation of collective scarcity awareness

Collective scarcity awareness refers to situations in which individuals perceive that the resource system as a whole is under stress. This perception often arises from observing others' high demand or unmet needs and signals potential basin-wide scarcity. Under these conditions, the normative frame through which decisions are made may shift substantially.

In CPR systems, norms are sensitive to environmental framing. When a user interprets another's scarcity as evidence of broader resource depletion, the motivation to uphold cooperative norms may weaken. Instead of viewing others' need as a cue for restraint, individuals may interpret it as a warning of future scarcity and increase their own extraction to secure immediate access (Camerer, 2003; Tversky & Kahneman, 1981). This process alters how social obligations are interpreted.

Scarcity mindset theory offers a psychological explanation for this pattern. When individuals perceive limited resources, attention narrows, and long horizon considerations receive less weight (Mani et al., 2013; Mullainathan & Shafir, 2013; Shah et al., 2012a). Under this cognitive shift, cooperative expectations lose relevance and defensive extraction becomes more likely even in the absence of explicit conflict.

Observing high demand by others may also serve as a forecasting signal. If users expect future scarcity based on these signals, they may increase extraction in advance as a protective strategy. Loss aversion reinforces this tendency, since individuals weigh potential losses of water more heavily than equivalent gains (Kahneman & Tversky, 1979). Empirical CPR research supports these interpretations. Cárdenas et al. (2000) show that individuals exposed to information about depletion shift behavior toward self-interest. Ruttan (2008) demonstrate that environmental stress cues can trigger defensive extraction, weakening cooperative norms. These findings suggest that collective scarcity awareness can generate behavioral responses that resemble anticipatory defection rather than altruistic support.

3.2.4 Hypothesis

The mechanisms described above motivate the following hypotheses:

H1. Exogenous scarcity increases both the likelihood and the magnitude of water over extraction.

H2. Past experiences of endogenous scarcity increase both the likelihood and the magnitude of subsequent over extraction.

H3. Awareness of collective scarcity increases the likelihood of over extraction relative to conditions without such awareness.

3.3 Methodology

We developed a game-based experiment designed to isolate the different types of scarcity and assess participants' compliance with regulatory constraints. To explore the role of real-life experience in shaping behavior, we set up an experiment with two participant groups: (i) members of water user associations (WUAs), who face these challenges directly in their daily activities, and (ii) non-users, including university students and members of local social organizations, who participated under identical experimental conditions. This design allows for a comparative analysis between experienced and non-experienced populations, shedding light on how familiarity with resource scarcity influences compliance decisions and social dynamics in water governance systems.

3.3.1 Experimental design

The experiment simulates the decision-making processes of farmers in a setting where water use is regulated, scarcity occurs when demand exceeds the quota, and participants face opportunities to violate established rules. The game consists of 15 rounds, during which participants are randomly paired in each round. The total irrigation time available per round is 24 hours, to be distributed between two individuals in consecutive turns.

Water demand is expressed in hours of irrigation. Demands vary across rounds in a random order, ranging from 11 to 15 hours during the first five rounds (the spring season) and 12 to 20 hours during the following ten rounds (the summer season). In most rounds, the combined demand of both participants exceeds the available 24-hour period, thereby introducing exogenous scarcity into the system.

During each round, participants must decide how many hours of water for irrigation to use, assuming that they will be assigned to irrigate first (the first turn), leaving the remaining time out of the 24 hours for their partner. To make this decision, they are provided with the following information:

- A regulatory rule stipulates that each participant is entitled to 12 hours of irrigation per round. On the decision screen of the game, participants see a box representing the total 24-hour period and a red dotted line marks the regulatory quota (Figure 3.1, panels A and B).

- In Treatment 1, participants are informed only about their own irrigation requirements for each round to avoid financial losses. In this condition, participants do not have information about others' needs and therefore do not experience collective scarcity awareness. The individual water demand for the round is displayed as text and illustrated by a colored rectangle within the 24-hour box (see Figure 3.1, Panel A). In Treatment 2, participants receive the same information as in Treatment 1, but are also informed of their partner's irrigation needs for that round, thereby experiencing awareness of collective scarcity (Figure 3.1, panel B).

- The game begins with a potential profit of CLP 10,000 (USD 10) for the season, which participants can retain if their water for irrigation demand is fully met throughout the 15 rounds. On the game screens, expected profit is displayed as a vertical bar that decreases as monetary losses occur across rounds.

- Any unmet hour of irrigation demand results in a loss of CLP 100 (USD 0.10) from the participant's potential profit. These losses accumulate throughout the game. Each round is independent, meaning participants cannot store water for subsequent rounds or compensate for past shortages by extracting more than they need.

- Compliance is monitored with a 20% probability each round. Any detected non-compliance results in a fine equivalent to half the monetary loss per unmet hour of irrigation demand (CLP 50 = USD 0.05). Participants see Figure 3.1, panel C, when they are monitored. This fine was intentionally designed to be non-deterrent to represent the law enforcement that people face in real life.

After deciding how many hours to use, participants' turn assignments are randomized. If a participant is assigned to the first turn, they receive the number of hours they initially decided to use to irrigate. If assigned to the second turn, they receive only the hours unclaimed by the first-turn participant. When the first-turn participant uses more than 12 hours, the second-turn participant experiences endogenous scarcity, a situation shown on their results screen as a message about the other participant's compliance and the remaining hours of water (see Figure 3.1, panel D).

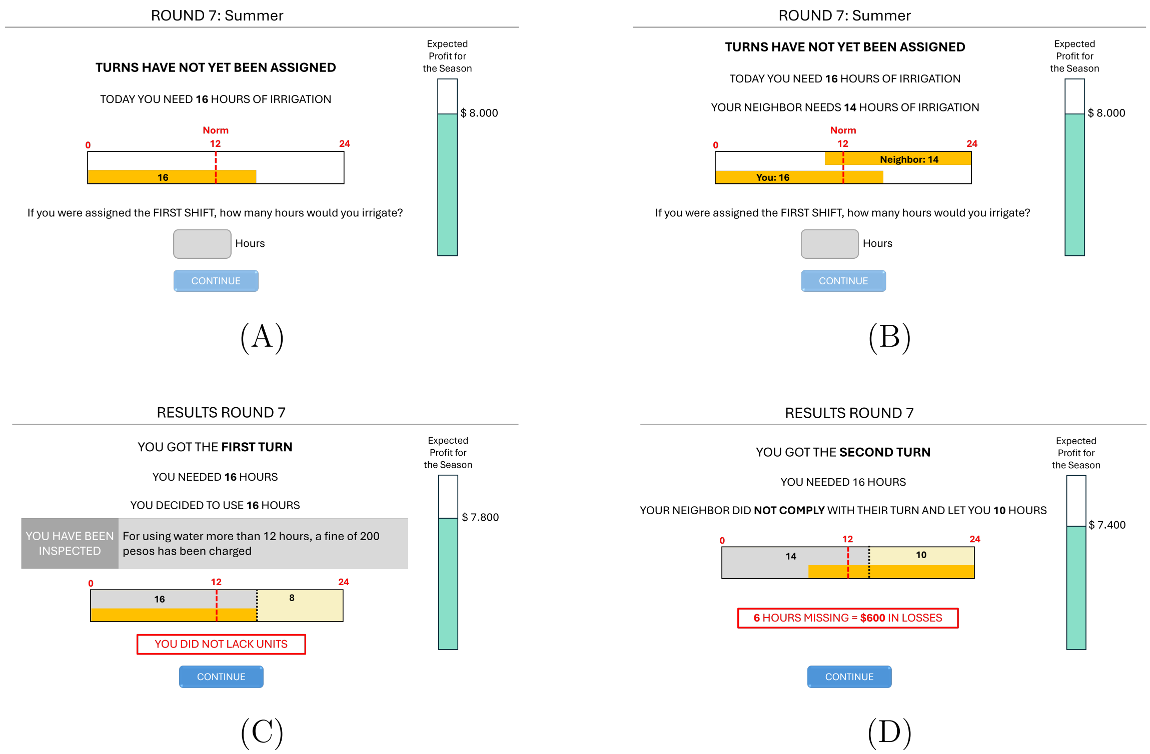

Figure 3.1: Game interface. Panel (A) shows the decision page for the case without collective scarcity awareness (Treatment 1), where the participant only has information about their own irrigation demand. Panel (B) shows the decision page for the case with collective scarcity awareness (Treatment 2), where the participant has information about both their own and their partner's irrigation demands. Panel (C) shows the result page when the participant experienced endogenous scarcity—they had the second turn, and their partner left them less than 12 hours of water. Panel (D) shows the result page when the participant was inspected and fined for using more than 12 hours of water.

3.3.2 Participants

We recruited 195 participants between June 2024 and April 2025, including 97 individuals who were either landowners or agricultural workers affiliated with Water User Associations (WUAs) in central Chile, and 98 individuals with no prior experience in canal irrigation. Participants from WUAs were recruited through direct contact with leaders of irrigation canal associations and local agricultural organizations. These leaders helped coordinate experimental sessions and extended invitations to their members. Participants without irrigation experience were recruited from community groups unrelated to water management and from the Universidad del Desarrollo in Santiago, using flyers and personal invitations.

Participants' ages ranged from 19 to 80 years (M = 45). Each participant received a fixed show-up fee to cover transportation costs (USD 10 for WUA members and USD 5 for non-WUA participants). The difference in payment reflected higher transportation costs for WUA participants due to the geographical constraints of the session locations. In addition, participants received variable earnings based on their experimental outcomes, averaging 4,987 CLP (USD 4.98) and ranging from 0 to 8,250 CLP (USD 0 to 8.30), with no significant differences between treatments (Treatment 1: M = 4,940 CLP or USD 4.94; Treatment 2: M = 5,037 CLP or USD 5.03; $p = 0.62$). No significant differences were found between treatment groups in WUA membership, gender, education level, initial beliefs, or risk aversion (see Table

3.1).

Variable	Category	Tto 1 N(%)	Tto 2 N(%)	p-value
Total		95	100	
WUA Membership	no-WUA	52 (54.7)	46 (46.0)	0.282
	WUA	43 (45.3)	54 (54.0)	
Gender	Men	38 (40.0)	50 (50.0)	0.208
	Woman	57 (60.0)	50 (50.0)	
Initial Beliefs	Low	32 (33.7)	29 (29.0)	0.506
	Mid	37 (38.9)	36 (36.0)	
	High	26 (27.4)	35 (35.0)	
Risk Aversion	High	65 (68.4)	63 (63.0)	0.518
	Low	30 (31.6)	37 (37.0)	
Education Level	No higher education	47 (49.5)	56 (56.0)	0.442
	Higher education	48 (50.5)	44 (44.0)	

Table 3.1: Number of participants in each group and results of Chi-square tests assessing whether the distributions of participants differ between Treatment 1 and Treatment 2 across categories.

3.3.3 Data collection

Sessions were conducted in different locations to facilitate attendance among participants from rural areas, using equipment provided by the Mobile Experimental Laboratory of the Center for Research on Social Complexity (CICS-UDD). In total, we conducted 15 sessions, each involving between 8 and 21 participants. All participants within a given session were assigned to the same treatment. The first session was randomly assigned to a treatment, and subsequent sessions were allocated to ensure a balanced number of participants across treatments. This procedure resulted in 95 participants in Treatment 1 (43 WUA members; 52 non-WUA participants) and 100 participants in Treatment 2 (54 WUA members; 46 non-WUA participants).

The study was approved by the Institutional Research Ethics Committee of the Universidad del Desarrollo (see Supplementary Material). All participants provided written informed consent prior to participation. Sessions followed a standardized protocol (see Supplementary Material). Instructions were delivered via video, after which participants completed a pre-game questionnaire that collected sociodemographic information (age, gender, education), risk aversion, and initial beliefs about others' compliance in the game. The experiment, programmed using oTree software (Chen et al., 2016), was played synchronously on individual laptops connected to an offline local server.

Each session lasted one to two hours. Differences in session duration were mainly due to varying levels of computer literacy among participants. Some participants required assistance during the first rounds, but most learned to operate the interface independently. Sessions conducted with WUA participants concluded with an informal coffee discussion, providing an opportunity for participants to share reflections and experiences related to the game.

3.3.4 Data analysis

Measures

The experimental design allowed us to operationalize the following variables:

Dependent variables:

1. Non-compliance decision: This variable captures whether the participant complied with the rule of using no more than half of the total water allocation (the 12-hour quota). On the decision screen, the quota is indicated by a red dashed line and the number "12" displayed at the midpoint of the rectangle representing the total allocation for both participants. Participants make their decision by entering a number between 0 and 24 in a gray box at the bottom of the screen (see Figure 3.1, Panels A and B, depending on the treatment condition). This variable takes a value of 0 if the response is equal to or below 12, and 1 if it exceeds 12.

$$\text{Non-compliance decision}_t = \begin{cases} 0, & \text{if decision}_t \leq \text{quota} \\ 1, & \text{if decision}_t > \text{quota} \end{cases}$$

2. Non-compliance hours: This variable measures the extent of non-compliance, defined as the number of hours that the participant decides to use above the quota. It corresponds to the participant's response when the participant chose to exceed the quota.

$$\text{Non-compliance hours}_t = \text{decision}_t - \text{quota}$$

Independent variables:

- Exogenous Scarcity: This variable captures the number of hours of irrigation demanded above the quota in each round. Although it was not directly shown to participants, it was visually indicated on the decision screen as the portion of the demand rectangle extending beyond the red quota line.

$$\text{Exogenous Scarcity}_t = \text{demand}_t - \text{quota}$$

The variable takes negative values during some of the initial rounds (the low exogenous scarcity period), when individual demand fell below the quota.

- Accumulated Exogenous Scarcity: The sum of exogenous scarcity across all previous rounds. This information was not displayed to participants on either the decision screen or the results screen.

$$\text{Accumulated Exogenous Scarcity}_t = \sum_{r=1}^{t-1} (\text{Exogenous scarcity}_r)$$

- Experience Last Endogenous Scarcity: This variable represents the decision of compliance of the other player the last round that the participant had the second turn in the game. This information is displayed in a message on the result screen as “Your neighbor complied/did not comply with their turn" (see

Figure 3.1, panel D).

$$\text{Experience Last Endogenous Scarcity}_t = \begin{cases} 0, & \text{if the other participant complied}_{t-j} \\ 1, & \text{if the other participant did not comply}_{t-j} \end{cases}$$

where $t - j$ is the last second-turn round.

- Last Endogenous Scarcity: Number of hours below the quota received in the last round that the participant had the second turn in the game. This information is not directly shown to participants; on the results screen, they are informed about the number of irrigation hours received from the other player in that round, and they can infer a shortfall when the reported amount is less than 12 hours (see Figure 3.1, panel D).

$$\text{Last Endogenous Scarcity}_t = \text{quota} - \text{amount received}_{t-j}$$

where $t - j$ is the last second-turn round.

- Accumulated Endogenous Scarcity: The sum of endogenous scarcity across all previous rounds. This information was not displayed to participants on either the decision screen or the results screen.

$$\text{Accumulated Endogenous Scarcity}_t = \sum_{r=1}^{t-j-1} (\text{Last Endogenous scarcity}_r)$$

- Collective Scarcity Awareness: This binary variable indicates whether participants were informed about the demand of their game partners. In the experiment, it corresponds to the assignment to the screen shown in Panel A (Treatment 1) or panel B (Treatment 2) in Figure 3.1. The assigned treatment condition remained fixed throughout the entire game.

$$\text{Collective Scarcity Awareness} = \begin{cases} 0, & \text{if Treatment 1} \\ 1, & \text{if Treatment 2} \end{cases}$$

- Inspection Previous Round: Binary variable indicating if the participant was monitored for non-compliance in the previous round.

$$\text{Inspection Previous Round}_t = \begin{cases} 0, & \text{if not inspected in round t-1} \\ 1, & \text{if inspected in round t-1} \end{cases}$$

Control variables:

- Initial Beliefs: Initial beliefs about others' non-compliance were elicited before the game through the question: "If in this activity 10 people need to use more than 12 hours of irrigation, how many of them will decide to use more than the quota?" Participants could respond with any number between 0 and 10. For the analysis, beliefs were operationalized into three categories depending on the number they responded.

$$\text{Beliefs} = \begin{cases} Low, & \text{if beliefs} \leq 3 \\ Mid, & \text{if } 4 \leq \text{beliefs} \leq 6 \\ High, & \text{if beliefs} > 7 \end{cases}$$

- Risk aversion: This variable was measured before the game using a lottery-choice task with five alternatives varying in risk and expected utility, following the methodology proposed by (Eckel & Grossman, 2002). This task was not paid in the experiment. For the analysis, responses were operationalized into two categories according to the alternative selected.

$$\text{Risk Aversion} = \begin{cases} High, & \text{if response} = 1\text{, 2 or 3} \\ Low, & \text{if response} > 4 \text{ or } 5 \end{cases}$$

- Sociodemographic: We collected the following sociodemographic variables: gender (man or woman), educational level (participants were asked "What is your highest completed level of education?" and this was operationalized as a binary variable indicating whether or not they had higher education), and membership in a Water User Association (WUA) (yes or no).

Econometric analysis

We estimated four econometric models: two for each dependent variable. The baseline models included only the main independent variables considered in the hypothesis (exogenous scarcity, endogenous scarcity, and collective scarcity awareness), operationalized as explained in the Independent Variables section, plus being inspected and interaction between them; while the extended models added control variables (beliefs, risk aversion, WUA membership, gender, and education level). Non-compliance decisions and hours were analyzed using linear regression models with cluster-robust standard errors at the participant level. Logistic regression models (logit) were also estimated for non-compliance decisions, besides panel and hierarchical models; the results are available in the Supplementary Material in Appendix B. Also, interaction terms were tested to assess whether the effect of the treatments varied across scarcity conditions.

All analyses were conducted in `R` (version 4.4.1) using the packages `margins`, `plm`, `lme4`, `sandwich`, and `stargazer`. Significance was set at $\alpha = 0.05$, two-tailed. Replication materials, including the code of the experiment, data sets, and analysis scripts, are available at the Supplementary Material.

3.4 Results

3.4.1 Behavioral responses to scarcity

Regression estimates reveal that individual exogenous scarcity, defined as the shortfall between a participant's water demand and the quota they are entitled to, is the strongest and most consistent driver of non-compliance. For each additional hour of unmet demand, the probability of non-compliance increases by 7 percentage points ($p < 0.001$). The accumulated experience of exogenous scarcity, measured as the total number of hours demanded above the quota in all previous rounds, further increases non-compliance by 0.3 percentage points per accumulated hour ($p < 0.01$). Conditional on choosing to violate the quota, the magnitude of the over-extraction is also strongly sensitive to scarcity: participants extract, on average, 0.72 hours above the quota for each additional hour of exogenous shortfall ($p < 0.001$). These results indicate that when scarcity arises from external constraints beyond individual control, participants tend to prioritize their immediate needs over collective norms and cooperative compliance, and that repeated exposure to scarcity intensifies this tendency over time.

Endogenous scarcity, defined as receiving less water than the quota due to another user's over-extraction, also shapes compliance decisions. Recently experiencing such deprivation increases the probability of non-compliance by 10 percentage points ($p < 0.01$), regardless of the magnitude of the other user's violation. However, its influence is moderated by current exogenous scarcity: the effect of endogenous scarcity declines by 0.026 percentage points for each additional hour of unmet personal demand ($p < 0.05$). This interaction indicates that as material needs intensify, the motivational force of immediate exogenous scarcity becomes more salient than the retaliatory tendencies associated with past unfair treatment. In practical terms, endogenous scarcity may activate negative reciprocity, but its behavioral relevance decreases under strong resource pressure, which positions exogenous scarcity as the primary driver of non-compliance. Among participants who choose to violate the rule, the quantity they extract above their quota is proportional to the deprivation they experienced: for each hour of endogenous shortfall in the previous round, they extract an additional 0.056 hours ($p < 0.01$). By contrast, accumulated endogenous scarcity has no significant effect on either the decision to defect or the degree of over-extraction, suggesting that fairness-based responses are driven by recent interactions rather than long-term deprivation.

Information about others' water needs, operationalized as collective scarcity awareness, increases the probability of non-compliance by 8.5 percentage points ($p < 0.05$). Although this effect is similar for members and non-members of Water User Associations (WUAs), the magnitude of over-extraction differs: among violators, WUA members extract an average of 0.72 additional hours above the quota when they experience collective scarcity awareness, while non-members show no such effect. These results indicate that, when individuals learn that scarcity is systemic, they tend to anticipate intensified competition and respond defensively by reducing compliance.

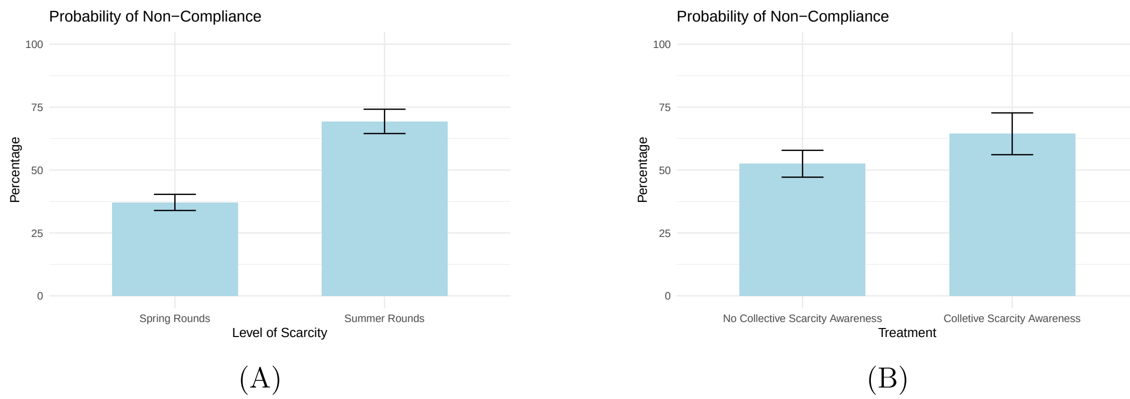

Figure 3.2: The effects of exogenous scarcity on the probability of non-compliance (Panel A), comparing the spring season (first 5 rounds, with low exogenous scarcity) and the summer season (next 10 rounds, with high exogenous scarcity), and the effects of collective scarcity awareness on the probability of non-compliance (Panel B).

Inspection has a modest deterrent effect: being inspected in a given round reduces the probability of non-compliance in the subsequent round by approximately 5 percentage points ($p < 0.05$), regardless of whether a fine was applied. However, this reduction is insufficient to counteract the much larger behavioral effects of scarcity. Neither exogenous nor endogenous scarcity, nor collective scarcity awareness, are offset by the presence of weak monitoring. Thus, inspections increase compliance temporarily but do not fundamentally alter behavioral trajectories under resource pressure.

Control variables such as risk aversion, education, and gender show no significant effects. Initial beliefs about others' compliance also do not predict behavior, likely because participants rapidly update their expectations based on observed extraction decisions within the game. WUA membership, however, significantly reduces the baseline probability of non-compliance by 14 percentage points ($p < 0.01$), consistent with the idea that institutional affiliation strengthens familiarity with collective rules and cooperative norms.

3.4.2 Implications for socio-hydrological modeling

The estimated coefficients define a set of empirically grounded behavioral elasticities that can be incorporated into sociohydrological models as decision rules for water extraction. When the demands of individual users, their assigned quotas, and the actual water allocations are known, the probability of non-compliance can be expressed as a function of three central drivers: exogenous scarcity, endogenous scarcity, and collective scarcity awareness. These behavioral relationships can be formalized as:

$$\begin{aligned} P(\text{non-compliance}) = \alpha &+ 0.084\, S_{exo} + 0.003\, S_{exo}^{acc} \\ &+ 0.10\, I_{endo} - 0.026\, (S_{exo} \cdot I_{endo}) \\ &+ 0.085\, I_{collective} - 0.05\, I_{inspection}. \end{aligned} \tag{3.1}$$

where α denotes the baseline probability of compliance. In our sample, $\alpha = 0.37$ for non-members of Water User Associations (WUAs) and $\alpha = 0.22$ for WUA

Table 3.2: Non-Compliance Two Parts Decision

	Dependent variable:	
	Non-compl. decision	Non-compl. hours
	$P(non - compliance)$	$E(overuse)$
	(1)	(2)
Exogenous Scarcity (S_{exo})	0.084***	0.728***
Exogenous Scarcity Accu. (S_{exo}^{accu})	0.003*	0.011
Experience Last Endo. Scarcity (binary) (I_{endo})	0.103**	
Last Endogenous Scarcity (S_{endo})	0.004	0.056*
Endogenous Scarcity Accu. (S_{endo}^{accu})	−0.0004	−0.002
Collective Scarcity Awareness (binary) ($I_{collective}$)	0.085*	−0.221
Inspection Previous Round (binary) ($I_{inspection}$)	−0.051*	−0.053
Initial Beliefs	0.018	0.074
WUA Membership (M_{WUA})	−0.142**	−0.390
Risk Aversion (High)	−0.053	0.213
Education Level (Higher Education)	−0.038	0.139
Gender (Woman)	0.066*	0.275
Exo Scarcity*Exp. Last Endo Scarcity	−0.026***	
Collective Scarcity Awareness on WUA	0.068	0.726*
Constant	0.369***	−0.093
Observations	2,925	1,714
R^2	0.219	0.516
Adjusted R^2	0.215	0.513
Note:		*p<0.05; **p<0.01; ***p<0.001

members. The term S_{exo} represents the current exogenous shortfall experienced at the given time step, S_{exo}^{acc} denotes the accumulated experience of exogenous scarcity across all previous time steps, I_{endo} indicates if endogenous was experienced recently, and S_{endo} corresponds to the most recent endogenous shortfall generated by another user's over-extraction. The indicator $I_{collective}$ captures the availability of information regarding others' water needs, $I_{inspection}$ reflects whether monitoring occurred in the previous time step, and M_{WUA} identifies WUA membership.

The magnitude of over-extraction among non-compliant individuals can be described as:

$$E(\text{overuse}) = 0.72S_{exo} + 0.056S_{endo} + 0.72(I_{collective} \cdot M_{WUA}). \qquad (3.2)$$

These decision rules can be incorporated into agent-based or system-dynamics sociohydrological models to represent how water users adjust their extraction behavior in response to hydrological variability and to the actions of other users. Exogenous scarcity introduces a positive feedback loop where increasing hydrological stress raises extraction pressure, which can accelerate resource depletion. Endogenous scarcity activates social feedbacks rooted in reciprocity and fairness that may intensify extraction when users perceive unfair treatment. Collective scarcity awareness captures the influence of information flows within irrigation communities, reflecting competitive responses under perceived basin-wide stress. Membership in Water User Associations and the presence of inspections operate as institutional and governance parameters that influence, although do not fully counteract, scarcity-driven behavior.

These behavioral relationships provide a mechanistic basis for modeling the co-evolution of water availability, extraction decisions, and institutional dynamics in sociohydrological systems exposed to persistent resource pressure.

3.5 Discussion

The laboratory-in-the-field experiment provides evidence on how different types of scarcity influence compliance with water-use regulations. The results show that individuals adjust their extraction decisions in response to hydrological constraints and social interactions, reflecting behavioral mechanisms relevant for irrigation governance. The findings indicate that compliance is not a fixed personal trait. Instead, it shifts with changing material pressure and social cues, revealing a context-dependent structure with direct implications for behavioral modeling and sociohydrological analysis.

A central result is that greater scarcity leads to lower compliance with collective norms. This pattern is consistent with previous evidence from common-pool resource experiments and behavioral economics (Gächter & Herrmann, 2011; Janssen & Anderies, 2011; Ostrom et al., 1994). The observed behavior resembles real-world irrigation contexts, where users under stress may prioritize short-term access and income stability over the long-term sustainability of collective arrangements (Anderies & Janssen, 2013; Vollan & Ostrom, 2010).

Supporting H1, exogenous scarcity emerged as the strongest and most consistent predictor of non-compliance. When resource access directly constrains potential income, individuals appear to experience a scarcity mindset. This cognitive shift narrows attention toward immediate needs and reduces sensitivity to social considerations such as reciprocity, norm adherence, or long-term consequences (Mani et al., 2013; Mullainathan & Shafir, 2013). The powerful effect of exogenous scarcity helps explain why users facing hydrological stress often deviate from institutional rules even when they value cooperation. Material shortfalls reduce cognitive bandwidth and elevate the salience of personal losses, resulting in extraction patterns that favor short-term security over collective welfare.

Endogenous scarcity also shaped compliance, providing support for H2. Experiencing deprivation due to another participant's overuse in the most recent decision step increased the probability of non-compliance and intensified the magnitude of over-extraction among those who chose to defect. This response is consistent with theories of negative reciprocity and inequity aversion (Falk & Fischbacher, 2006; Fehr & Schmidt, 1999). However, the influence of endogenous scarcity weakened as exogenous scarcity increased. This interaction suggests that retaliatory impulses lose relevance once material need becomes severe. When hydrological pressure is acute, individuals focus primarily on meeting their own requirements, and fairness-based motivations diminish. The accumulated experience of endogenous scarcity showed no significant effect, indicating that reactions to unfair treatment are immediate rather than cumulative under these conditions.

Collective scarcity awareness also influenced extraction, supporting H3. Individuals who were informed about their partner's high demand were more likely to violate the rule. Instead of interpreting this information as an opportunity for restraint or empathy, participants appear to have seen it as a sign of system-wide stress. Under this perception, users anticipate greater competition for water and act defensively in the present. This result aligns with research showing that information about others' needs can be interpreted as a threat when scarcity is salient (Mullainathan & Shafir, 2013; Shah et al., 2012b). The effect was particularly pronounced among Water User Association members, suggesting that real-world irrigation experience shapes how individuals interpret social signals. For these participants, information about others' demands may activate memories of coordination failures or distributional disputes, reinforcing self-protective strategies.

Inspections produced only a modest effect, slightly reducing non-compliance in the next decision step. The influence was small relative to scarcity-related mechanisms. Weak monitoring may increase compliance through norm salience or perceived oversight, but it does not offset the motivational force of unmet needs or fairness concerns.

These results align with normative theories of compliance emphasizing legitimacy and credible institutional signals rather than deterrence alone.

A central insight from the comparison between WUA members and non-members is that both groups display similar foundational mechanisms. Exogenous scarcity consistently increases the likelihood and intensity of over-extraction, and endogenous scarcity triggers retaliatory behavior under the right conditions. This consistency strengthens their relevance for sociohydrological modeling by demonstrating that scarcity responses do not require sector-specific knowledge or prior exposure to irrigation systems.

At the same time, WUA members exhibit distinctive behavioral responses shaped by institutional experience and social learning. Their baseline non-compliance probability is fourteen percentage points lower, and they respond more strongly to collective scarcity awareness, with a fifteen percent probability of non-compliance compared to eight percent among non-members. Their over-extraction under collective awareness is also significantly higher. These differences indicate that WUA members interpret social information through mental models shaped by their history of coordination challenges, distributional conflicts, and past experiences of scarcity. This interpretation aligns with context-dependent cognition (Harrison & List, 2004; Henrich & Boyd, 2001), social identity theory (Ellemers et al., 2002; Tajfel et al., 2001), and research on scarcity framing (Mullainathan & Shafir, 2013; Tversky & Kahneman, 1981). For WUA members, others' high demand is rarely a neutral signal. It often carries institutional meaning related to risk, competition, or unfairness, which heightens defensive extraction.

These findings reveal two complementary processes. The behavioral effects of scarcity are fundamental and generalizable across populations, reflecting universal cognitive and motivational responses to resource pressure. Simultaneously, institutional histories shape how individuals interpret social information, producing group-specific reactions under collective scarcity awareness. Incorporating both dimensions can improve the realism of sociohydrological models and help identify conditions under which cooperation is vulnerable to breakdown.

From a sociohydrology perspective, the behavioral patterns identified in this study represent core feedback mechanisms that can be explicitly modeled in coupled human and water systems. Exogenous scarcity functions as a direct hydrological pressure that raises extraction incentives when supply falls short of individual needs. Endogenous scarcity introduces a social feedback grounded in fairness perceptions that affects trust, expectations, and rule compliance. Collective scarcity awareness captures the role of information flows by revealing how signals about others' demand influence anticipations of basin-wide stress and prompt defensive behavior. WUA membership reflects how institutional identity and social memory shape the interpretation of these signals. Incorporating these behavioral responses into sociohydrological or agent-based models can generate realistic nonlinearities, threshold dynamics, and path dependence, enhancing the capacity of models to represent how compliance, cooperation, and resource availability co-evolve under scarcity (Elshafei et al., 2015; Yu et al., 2020).

A further contribution of this study is methodological. The experimental design provides a simple and replicable approach for quantifying how water users adjust their behavior when facing hydrological stress, social cues, and institutional signals. These measured sensitivities can be translated into behavioral equations or decision rules for agent-based or system-dynamics models, offering empirically grounded parameters that improve the representation of human decision processes in sociohydrology. By enabling the systematic identification of how scarcity shapes compliance, this approach also offers diagnostic insights that can inform governance interventions and support community-based water management.

Finally, the findings show that information disclosure can produce unintended effects under hydrological stress. Communication strategies that emphasize scarcity may inadvertently trigger defensive extraction, especially among users with prior experience of coordination failures. Effective interventions must therefore consider both the material conditions and the social meaning conveyed by informational and regulatory signals. This insight strengthens the link between behavioral evidence and water policy and underscores the importance of integrating cognitive and institutional dynamics into sociohydrological research.

3.6 Conclusions

This study provides a quantitative analysis of compliance with water-use regulations under different forms of scarcity. The results demonstrate that compliance is a context-dependent behavior shaped by hydrological pressure and social interactions. Exogenous scarcity narrows attention to immediate needs and reduces compliance. Endogenous scarcity activates reciprocity-based reactions to unfair treatment. Collective scarcity awareness induces defensive extraction when individuals interpret others' high demand as a sign of systemic stress. These mechanisms explain how short-term rule violations emerge from scarcity-induced decision processes rather than opportunism alone.

Two contributions stand out for water governance. First, socially induced scarcity has pronounced effects on compliance. Deprivation caused by others' overuse and information about peers' high demand both reduce willingness to follow rules, revealing that perceived unfairness and strategic expectations play a central role in shaping decisions. Second, persistent exogenous scarcity combined with weak monitoring substantially erodes compliance. Low-probability inspections and small fines do not counteract the motivational force of unmet needs. These results challenge deterrence-based regulatory approaches and underscore the importance of institutions that address both material constraints and the normative foundations of cooperation.

The behavioral parameters estimated here can be incorporated into sociohydrological models as empirically grounded decision rules. The effects of exogenous scarcity, endogenous scarcity, collective scarcity awareness, and institutional membership provide a basis for representing how water users adjust extraction behavior under changing hydrological and social conditions. Embedding these rules in agent-based or system-dynamics models enhances the realism of simulations by linking hydrological variability with behavioral feedbacks that influence cooperation, over-extraction, and institutional resilience.

The methodological approach of this study also offers a practical diagnostic tool for identifying compliance sensitivities in local water-user communities. Applying similar experimental designs can help identify groups vulnerable to cooperation breakdowns, reveal how fairness concerns shape rule adherence, and inform strategies that strengthen institutional resilience under stress.

The findings highlight that effective water governance under scarcity requires addressing both material needs and cognitive responses to scarcity. Communication strategies that emphasize collective water stress may unintentionally trigger defensive extraction unless they are paired with credible signals of fairness and shared responsibility. Institutions that reduce the severity of scarcity, reinforce trust, and ensure predictable enforcement are more likely to sustain cooperation as hydrological pressures intensify. By integrating behavioral evidence with system-level modeling, this study advances the incorporation of human decision-making processes into sociohydrological frameworks and strengthens our ability to design water governance institutions that remain stable under increasing environmental and social stress.

Chapter 4

Conclusions

This dissertation has examined how scarcity shapes rule compliance in common pool resource systems by combining controlled laboratory experiments with behavioral evidence from irrigation communities in central Chile. Across both studies, a clear pattern emerges. Scarcity is not only a physical reduction in resource availability but also a behavioral condition that influences how individuals allocate attention, interpret fairness, evaluate others' actions, and judge the legitimacy of collective rules. By distinguishing among exogenous, endogenous, and collective forms of scarcity, the research identifies mechanisms that are central to understanding compliance under rising environmental stress.

A defining contribution of this thesis is that it adds the insights of the scarcity literature to CPR theory and governance research, an integration that has remained underdeveloped. CPR research has traditionally focused on institutional design, monitoring, incentives, and collective action, while the behavioral science of scarcity has emphasized cognitive load, attentional narrowing, and how unmet needs reshape decision-making. This dissertation provides an empirical and conceptual link between these two bodies of research. It shows that scarcity influences rule compliance not only by altering material payoffs but also by changing how resource users think, feel, and interpret the social environment. This integration allows CPR theory to account for behavioral states that emerge under ecological stress and that substantially shape cooperative outcomes.

A central strength of the dissertation is the consistency of findings across two very different contexts. Chapter 2 relies on an abstract laboratory environment that presents participants with three distinct scarcity scenarios, using a student sample with no practical experience in irrigation management or water allocation. Chapter 3 examines farmers and Water User Association members whose daily activities involve irrigation decisions and recurring exposure to drought. Despite these contrasts in population, context, and institutional experience, the core mechanisms associated with exogenous and endogenous scarcity appear with remarkable stability, and the estimated coefficients reflect this in their sign, magnitude, and statistical significance. Two results demonstrate this convergence especially clearly. First, exogenous scarcity reduces compliance in both studies, with individuals under unmet needs prioritizing their immediate shortfall over collective rules. The similarity in coefficients suggests that the cognitive pressures induced by exogenous scarcity have broad generality rather than being artifacts of laboratory conditions. Second, endogenous scarcity increases the magnitude of non-compliance among those who choose to defect, again with highly similar effect sizes across samples. This confirms that perceptions of inequity and negative reciprocity are fundamental drivers of norm erosion, operating in both abstract experimental environments and real-world irrigation settings.

The field experiment in Chapter 3 enriches this understanding by showing how institutional embeddedness and lived experience mediate these mechanisms. Water User Association members interpret scarcity signals in a manner that reflects their historical exposure to negotiations, conflicts, and shared understandings of drought. Their responses to collective scarcity diverge from those of individuals with less institutional experience, indicating that formal and informal governance leave behavioral imprints that shape how resource users respond to stress. This perspective positions CPR governance as a dynamic system where rules, experiences, social learning, and environmental signals interact continuously.

These findings advance CPR theory by introducing a more detailed understanding of the behavioral foundations of compliance. Exogenous scarcity redirects cognitive attention toward immediate needs and makes cooperative restraint difficult to sustain. Endogenous scarcity produces perceptions of unfairness that foster retaliatory extraction and erode norms of conditional cooperation. Signals of collective scarcity often intensify expectations of competition rather than promote restraint. These mechanisms reveal compliance as a fragile equilibrium shaped by cognitive states, emotions, expectations, and interpretations of legitimacy. They also highlight the temporal dimension of scarcity, because repeated experiences of unmet needs accumulate and shape behavior over time.

The dissertation offers implications for water governance in contexts facing increasing hydrological uncertainty. The strong influence of exogenous scarcity indicates that traditional enforcement tools lose effectiveness precisely when compliance becomes most important. When individuals experience unmet needs, non-compliance is often perceived as justified regardless of sanctions. Deterrence-based approaches are therefore likely to face challenges during extreme drought. Perceptions of inequity are equally significant. When scarcity is interpreted as the result of others' overuse, retaliatory behavior can spread rapidly and weaken social norms. Institutions that guarantee transparent allocation, timely conflict resolution, and credible monitoring are essential for maintaining fairness and trust. Communication about scarcity requires careful design, because messages about widespread unmet demand can heighten expectations of competition unless accompanied by assurances of coordinated behavior and equitable burden sharing.

Beyond CPR theory and behavioral economics, the dissertation contributes to sociohydrology by providing empirically validated behavioral mechanisms that can strengthen human–water feedback models. Sociohydrological models often assume rational optimization or stable preferences that do not adapt to stress. The findings presented here show that behavior under scarcity is dynamic and shaped by cognitive, emotional, and social processes. Compliance responds non-linearly to unmet needs, is influenced by past experiences of deprivation, and reflects judgments about fairness, reciprocity, and legitimacy. Integrating these mechanisms into sociohydrological models would improve their ability to capture threshold effects, norm breakdowns, and the co-evolution of institutions and hydrological stress.

This research, therefore, contributes an important conceptual bridge between experimental behavioral science, scarcity research, CPR governance, and sociohydrological modeling. It supports the development of governance arrangements that recognize the behavioral foundations of compliance and that remain adaptive and robust in a changing climate.

Several limitations motivate future work. Because endogenous scarcity is produced by participants' decisions rather than through direct manipulation, identifying its causal effects remains challenging. Experimental designs that vary the timing and intensity of deprivation could deepen understanding of retaliatory dynamics. The focus on dyadic interactions limits the social complexity captured, while real CPR systems involve larger groups, spatial asymmetries, leadership structures, and diverse communication channels. Extending the experimental framework to multi-player settings, asymmetric entitlements, repeated interactions, or networked environments would enrich understanding of CPR dynamics. Although the field experiment provides ecological validity, it remains a stylized representation of irrigation practice. Future research could embed behavioral tasks directly in Water User Association processes, link decisions to actual extraction data, or combine experiments with ethnographic and network-based approaches to study how norms develop. Finally, compliance is influenced not only by scarcity but also by institutional trust, cultural norms, leadership patterns, and historical trajectories. Incorporating these dimensions would broaden and deepen the theoretical contributions developed here.

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Appendix A

Supplementary material for Chapter 2

Table A.1: Non-Compliance Two Parts Decision - OLS robust SE cluster player

	Non-compliance decision			Non-compliance units	
	(1)	(2)	(3)	(4)	(5)
Exogenous Scarcity	0.076*** (0.002)	0.085*** (0.004)	0.086*** (0.004)	0.747*** (0.020)	0.749*** (0.020)
Accum. Exogenous Scarcity	0.004** (0.001)	0.003** (0.001)	0.003** (0.001)	0.001 (0.004)	0.001 (0.004)
Last Endogenous Scarcity (Binary)	0.034 (0.019)	0.078*** (0.022)	0.078*** (0.022)		
Last Endogenous Scarcity (Hours)	−0.003 (0.004)	−0.001 (0.004)	−0.001 (0.004)	0.051** (0.018)	0.051** (0.018)
Accum. Endogenous Scarcity (Binary)	0.004 (0.006)	0.004 (0.006)	0.004 (0.006)		
Accum. Endogenous Scarcity (Hours)	−0.004* (0.002)	−0.004* (0.002)	−0.004* (0.002)	0.021* (0.010)	0.020 (0.010)
Collective Scarcity Awareness	0.030 (0.023)	0.030 (0.023)	0.035 (0.022)	−0.195 (0.126)	−0.166 (0.121)
Scenario Study Room	−0.017 (0.028)	−0.017 (0.029)	−0.019 (0.027)	−0.192 (0.152)	−0.201 (0.149)
Scenario Water	0.016 (0.027)	0.016 (0.027)	0.026 (0.028)	−0.144 (0.150)	−0.104 (0.157)
Inspection previous round	−0.033 (0.018)	−0.036 (0.019)	−0.034 (0.018)	−0.035 (0.095)	−0.042 (0.094)
Beliefs (High)			0.021 (0.014)		0.065 (0.084)
Risk Aversion (High)			−0.097*** (0.024)		−0.315* (0.154)
Woman			0.051* (0.025)		0.003 (0.146)
Exo Scarcity*Exp. Last Endo Scarcity (Binary)		−0.016*** (0.004)	−0.017*** (0.004)		
Constant	0.358*** (0.025)	0.338*** (0.025)	0.420*** (0.052)	0.922*** (0.129)	1.264*** (0.325)
Observations	4,815	4,815	4,815	3,158	3,158
R^2	0.213	0.215	0.226	0.516	0.520
Adjusted R^2	0.211	0.213	0.223	0.515	0.519

Note: *p<0.05; **p<0.01; ***p<0.001

Table A.2: Non-Compliance Two Parts Decision - Interactions - OLS robust SE cluster player

	NCbinary	NChours
	(1)	(2)
Exogenous Scarcity	0.080*** (0.003)	0.809*** (0.029)
Accum. Exogenous Scarcity	0.005*** (0.001)	−0.005 (0.006)
Last Endogenous Scarcity (binary)	−0.005 (0.027)	−0.006 (0.160)
Last Endogenous Scarcity (hours)	−0.002 (0.004)	0.042 (0.022)
Accum. Endogenous Scarcity	−0.004* (0.002)	0.022* (0.010)
Collective Scarcity Awareness	0.030 (0.039)	0.109 (0.183)
Scenario Study Room	0.014 (0.047)	0.153 (0.253)
Scenario Water	−0.017 (0.045)	0.279 (0.255)
Inspection previous round	−0.034 (0.018)	−0.044 (0.092)
Exo. Scarcity: Scenario Studyroom	−0.010 (0.006)	−0.096* (0.044)
Exo. Scarcity: Scenario Water	−0.001 (0.005)	−0.104* (0.047)
Exo. Accu. Scarcity: Scenario Studyroom	−0.002 (0.001)	0.012 (0.008)
Exo. Accu. Scarcity: Scenario Water	−0.00002 (0.001)	0.006 (0.007)
Endo. Scarcity: Scenario Studyroom	0.098* (0.038)	0.103 (0.231)
Endo. Scarcity: Scenario Water	0.032 (0.038)	0.184 (0.217)
Coll. Scarcity Awareness: Scenario Studyroom	−0.034 (0.057)	−0.492 (0.300)
Coll. Scarcity Awareness: Scenario Water	0.036 (0.055)	−0.474 (0.295)
Constant	0.358*** (0.031)	0.650*** (0.182)
Observations	4,815	3,158
R^2	0.216	0.521
Adjusted R^2	0.213	0.518
Note:		*p<0.05; **p<0.01; ***p<0.001

Table A.3: Non-compliance binary - Independent variables - OLS robust SE cluster player

	NCbinary							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exogenous Scarcity	0.081*** (0.002)							
Accum. Exo. Scarcity		0.007*** (0.0005)						
Last Endo. Scarcity (Binary)			0.131*** (0.016)					
Last Endo. Scarcity (Hours)				0.023*** (0.003)				
Accum. Endo. Scarcity (Hours)					0.010*** (0.001)			
Collective Scarcity Awar.						0.027 (0.023)		
Scenario Study Room							−0.022 (0.028)	
Scenario Water							0.004 (0.028)	
Inspection previous round								0.020 (0.019)
Constant	0.410*** (0.012)	0.538*** (0.013)	0.585*** (0.014)	0.609*** (0.013)	0.601*** (0.013)	0.643*** (0.018)	0.662*** (0.019)	0.653*** (0.012)
Observations	4,815	4,815	4,815	4,815	4,815	4,815	4,815	4,815
R^2	0.203	0.047	0.019	0.016	0.022	0.001	0.001	0.0002
Adjusted R^2	0.202	0.047	0.019	0.016	0.022	0.001	0.0001	0.00003
Note:								*p<0.05; **p<0.01; ***p<0.001

Table A.4: Non-compliance hours - Independent variables - OLS robust SE cluster player

	NChours							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exogenous Scarcity	0.773*** (0.017)							
Accum. Exogenous Scarcity		0.042*** (0.003)						
Last Endogenous Scarcity (Binary)			0.963*** (0.100)					
Last Endogenous Scarcity (Hours)				0.191*** (0.019)				
Accum. Endogenous Scarcity (Hours)					0.085*** (0.007)			
Collective Scarcity Awareness						−0.196 (0.116)		
Scenario Study Room							−0.397** (0.141)	
Scenario Water							−0.326* (0.135)	
Inspection previous round								0.254* (0.122)
Constant	0.865*** (0.090)	3.107*** (0.066)	3.315*** (0.075)	3.449*** (0.066)	3.357*** (0.064)	3.982*** (0.087)	4.109*** (0.083)	3.842*** (0.062)
Observations	3,158	3,158	3,158	3,158	3,158	3,158	3,158	3,158
R^2	0.505	0.054	0.035	0.042	0.055	0.001	0.005	0.001
Adjusted R^2	0.505	0.054	0.034	0.042	0.054	0.001	0.004	0.001
Note:								*p<0.05; **p<0.01; ***p<0.001

Table A.5: Multiple Hypothesis Testing - Non-compliance decision

	beta	SE	p_Satt	padj_BH	padj_holm	padj_bonferroni
(Intercept)	0.358	0.025	0	0	0	0
Exogenous Scarcity	0.076	0.002	0	0	0	0
Accum. Exogenous Scarcity	0.004	0.001	0.002	0.006	0.014	0.017
Last Endogenous Scarcity (Binary)	0.034	0.019	0.070	0.144	0.489	0.768
Last Endogenous Scarcity (Hours)	-0.003	0.004	0.449	0.567	1	1
Accum. Endogenous Scarcity	0.004	0.006	0.522	0.567	1	1
Collective Scarcity Awareness	-0.004	0.002	0.028	0.078	0.226	0.310
Scenario Study Room	0.030	0.023	0.193	0.303	0.964	1
Scenario Water	-0.017	0.028	0.558	0.567	1	1
Inspection previous round	0.016	0.027	0.567	0.567	1	1
Exo*Last Endogenous Scarcity (Binary)	-0.033	0.018	0.079	0.144	0.489	0.866

Table A.6: Multiple Hypothesis Testing - Non-compliance in hours

	beta	SE	p_Satt	padj_BH	padj_holm	padj_bonferroni
(Intercept)	0.922	0.129	0	0	0	0
Exogenous Scarcity	0.747	0.020	0	0	0	0
Accum. Exogenous Scarcity	0.001	0.004	0.871	0.871	1	1
Last Endogenous Scarcity (Hours)	0.051	0.018	0.006	0.017	0.040	0.051
Accum. Endogenous Scarcity	0.021	0.010	0.049	0.110	0.293	0.440
Collective Scarcity Awareness	-0.195	0.126	0.122	0.219	0.608	1
Scenario Study Room	-0.192	0.152	0.210	0.315	0.839	1
Scenario Water	-0.144	0.150	0.336	0.432	1	1
Inspection previous round	-0.035	0.095	0.711	0.800	1	1

Table A.7: Non-Compliance Two Parts Decision - Scenario Study Room - OLS robust SE cluster player

	NCbinary		NChours	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.070*** (0.005)	0.070*** (0.005)	0.712*** (0.034)	0.717*** (0.034)
Accum. Exogenous Scarcity	0.002 (0.002)	0.002 (0.002)	0.006 (0.007)	0.005 (0.006)
Last Endogenous Scarcity (Binary)	0.083* (0.032)	0.071* (0.032)		
Last Endogenous Scarcity (Hours)	−0.001 (0.006)	0.001 (0.006)	0.060 (0.031)	0.059 (0.030)
Accum. Endogenous Scarcity (Binary)	0.002 (0.011)	−0.001 (0.011)		
Accum. Endogenous Scarcity (Hours)	−0.003 (0.004)	−0.002 (0.004)	0.024 (0.019)	0.025 (0.017)
Collective Scarcity Awareness	−0.004 (0.043)	0.008 (0.040)	−0.383 (0.237)	−0.222 (0.230)
Inspection previous round	−0.040 (0.039)	−0.037 (0.037)	−0.007 (0.198)	−0.055 (0.185)
Beliefs (High)		0.022 (0.032)		−0.103 (0.193)
Risk Aversion (High)		−0.152*** (0.043)		−0.686* (0.281)
Woman		0.045 (0.046)		−0.379 (0.253)
Exo Scarcity*Exp. Last Endo Scarcity (Binary)	0.376*** (0.036)	0.548*** (0.109)	0.822*** (0.178)	2.314** (0.708)
Observations	1,515	1,515	969	969
R^2	0.176	0.201	0.483	0.508
Adjusted R^2	0.172	0.196	0.480	0.503
Note:				*p<0.05; **p<0.01; ***p<0.001

Table A.8: Non-Compliance Two Parts Decision - Scenario Water - OLS robust SE cluster player

	NCbinary		NChours	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.078*** (0.004)	0.078*** (0.004)	0.705*** (0.037)	0.706*** (0.038)
Accum. Exogenous Scarcity	0.003 (0.002)	0.003 (0.002)	−0.004 (0.008)	−0.004 (0.008)
Last Endogenous Scarcity (Binary)	0.017 (0.036)	0.018 (0.036)		
Last Endogenous Scarcity (Hours)	−0.003 (0.006)	−0.004 (0.006)	0.042 (0.032)	0.040 (0.033)
Accum. Endogenous Scarcity (Binary)	0.015 (0.009)	0.016 (0.009)		
Accum. Endogenous Scarcity (Hours)	−0.005 (0.004)	−0.006 (0.003)	0.040 (0.021)	0.042 (0.021)
Collective Scarcity Awareness	0.065 (0.039)	0.068 (0.040)	−0.370 (0.234)	−0.329 (0.228)
Inspection previous round	−0.040 (0.029)	−0.040 (0.029)	0.047 (0.158)	0.038 (0.159)
Beliefs (High)		0.007 (0.026)		0.154 (0.137)
Risk Aversion (High)		−0.027 (0.044)		0.203 (0.277)
Woman		0.054 (0.043)		−0.019 (0.280)
Exo Scarcity*Exp. Last Endo Scarcity (Binary)	0.347*** (0.033)	0.347*** (0.078)	0.992*** (0.194)	0.378 (0.380)
Observations	1,530	1,530	1,018	1,018
R^2	0.228	0.232	0.480	0.484
Adjusted R^2	0.224	0.226	0.477	0.479
Note:				*p<0.05; **p<0.01; ***p<0.001

Table A.9: Non-Compliance Two Parts Decision - Scenario Context-free - OLS robust SE cluster player

	NCbinary		NChours	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.080*** (0.003)	0.080*** (0.003)	0.810*** (0.030)	0.812*** (0.030)
Accum. Exogenous Scarcity	0.006** (0.002)	0.005** (0.002)	−0.001 (0.006)	−0.001 (0.006)
Last Endogenous Scarcity (Binary)	−0.001 (0.029)	−0.002 (0.028)		
Last Endogenous Scarcity (Hours)	−0.002 (0.006)	−0.002 (0.006)	0.056 (0.032)	0.057 (0.033)
Accum. Endogenous Scarcity (Binary)	−0.003 (0.010)	−0.004 (0.011)		
Accum. Endogenous Scarcity (Hours)	−0.006 (0.003)	−0.005 (0.003)	0.006 (0.015)	0.008 (0.015)
Collective Scarcity Awareness	0.030 (0.039)	0.032 (0.037)	0.113 (0.184)	0.110 (0.178)
Inspection previous round	−0.025 (0.029)	−0.026 (0.029)	−0.151 (0.131)	−0.165 (0.130)
Beliefs (High)		0.021 (0.022)		0.020 (0.122)
Risk Aversion (High)		−0.105* (0.042)		−0.484 (0.263)
Woman		0.053 (0.043)		0.250 (0.239)
Exo Scarcity*Exp. Last Endo Scarcity (Binary)	0.356*** (0.031)	0.452*** (0.073)	0.641*** (0.174)	1.221* (0.486)
Observations	1,770	1,770	1,171	1,171
R^2	0.243	0.254	0.581	0.589
Adjusted R^2	0.239	0.250	0.579	0.586

Note: *p<0.05; **p<0.01; ***p<0.001

Table A.10: Robustness Analysis - Non-compliance Binary - OLS robust SE cluster player

	NCbinary									
	All	Tto1	Tto2	Neutral	Water	StudyR	Woman	Men	RiskAv-L	RiskAv-H
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Exo. Scarcity	0.076***	0.074***	0.078***	0.080***	0.078***	0.070***	0.078***	0.074***	0.077***	0.075***
Exo. Scarcity Accu	0.004**	0.005**	0.002	0.006**	0.003**	0.002**	0.002	0.005*	0.004**	0.002
Endo. Scarcity (bin)	0.034	0.006	0.061*	−0.001	0.017	0.083	0.059*	−0.006	0.039	0.010
Endo. Scarcity	−0.003	−0.003	−0.002	−0.002	−0.003	−0.001	−0.005	0.001	−0.004	0.002
Endo. Scarcity Accu	0.004	−0.006	0.015*	−0.003	0.015	0.002	0.013*	−0.010	0.004	0.002
Collective Scarcity	−0.004*	−0.004	−0.006*	−0.006	−0.005	−0.003	−0.006*	−0.002	−0.005	−0.003
Scenario Study Room	0.030			0.030	0.065	−0.004	0.018	0.059	0.022	0.072*
Scenario Water	−0.017	−0.007	−0.032				−0.019	−0.016	−0.039	0.033
Inspection prev. round	0.016	−0.006	0.035				0.027	0.002	0.045	−0.041
Exo* Endo (bin)	−0.033	−0.001	−0.063*	−0.025	−0.040	−0.040	−0.055*	−0.003	−0.071**	0.043
Constant	0.358***	0.382***	0.364***	0.356***	0.347***	0.376***	0.366***	0.346***	0.327***	0.407***
Observations	4,815	2,415	2,400	1,770	1,530	1,515	2,850	1,965	3,165	1,650
R^2	0.213	0.192	0.242	0.243	0.228	0.176	0.229	0.199	0.219	0.226
Adjusted R^2	0.211	0.189	0.239	0.239	0.224	0.172	0.226	0.195	0.216	0.221

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table A.11: Robustness Analysis - Non-compliance Hours - OLS robust SE cluster player

	NChours									
	All	Tto1	Tto2	Neutral	Water	StudyR	Woman	Men	RiskAv-L	RiskAv-H
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Exo. Scarcity	0.747***	0.772***	0.725***	0.810***	0.705***	0.712***	0.752***	0.741***	0.742***	0.765***
Exo. Scarcity Accu	0.001	−0.001	0.002	−0.001	−0.004	0.006	−0.0004	0.001	0.001	−0.001
Endo. Scarcity	0.051**	0.038	0.065*	0.056	0.042	0.060	0.035	0.075*	0.037*	0.083*
Endo. Scarcity Accu	0.021*	0.032	0.012	0.006	0.040	0.024	0.030*	0.010	0.023	0.020
Collective Scarcity	−0.195			0.113	−0.370	−0.383	−0.131	−0.218	−0.202	−0.076
Scenario Study Room	−0.192	0.069	−0.430*				−0.434*	0.191	−0.346*	0.050
Scenario Water	−0.144	0.100	−0.366				−0.153	−0.117	0.063	−0.514*
Inspection previous round	−0.035	−0.167	0.071	−0.151	0.047	−0.007	−0.130	0.061	−0.114	0.057
Constant	0.922***	0.685***	0.938***	0.641***	0.992***	0.822***	0.921***	0.885***	0.830***	0.971***
Observations	3,158	1,552	1,606	1,171	1,018	969	1,901	1,257	1,987	1,171
R^2	0.516	0.534	0.503	0.581	0.480	0.483	0.548	0.483	0.555	0.485
Adjusted R^2	0.515	0.532	0.501	0.579	0.477	0.480	0.546	0.479	0.553	0.482

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table A.12: Non-Compliance Binary Decision - Logit Models

	NCbinary	
	(1)	(2)
Exo. Scarcity	0.483*** (0.040)	0.497*** (0.041)
Accum. Exo. Scarcity	0.019*** (0.005)	0.020*** (0.005)
Past Endo. Scarcity	0.309** (0.115)	0.322** (0.117)
Past Endo. Scarcity	−0.014 (0.022)	−0.014 (0.022)
Accum. Past Endo. Scarcity	−0.021 (0.012)	−0.022 (0.012)
Collective Scarcity	0.166 (0.131)	0.196 (0.127)
Scenario Study Room	−0.107 (0.163)	−0.115 (0.158)
Scenario Water	0.064 (0.157)	0.125 (0.166)
Inspection previous round	−0.216* (0.105)	−0.227* (0.104)
Beliefs		0.118 (0.084)
Risk Av High		−0.566*** (0.144)
Woman		0.291* (0.145)
Exo:Endo_pastB	−0.060 (0.044)	−0.071 (0.045)
Constant	−0.840*** (0.134)	−0.365 (0.298)
Observations	4,815	4,815
Log Likelihood	−2,513.849	−2,480.239
Akaike Inf. Crit.	5,049.697	4,988.477
Note:		*p<0.05; **p<0.01; ***p<0.001

Table A.13: Non-Compliance Binary Decision - Marginal Effects Logit Models

	NCbinary	
	(1)	(2)
Exo. Scarcity	0.079*** (0.003)	0.030 (0.020)
Accum. Exo. Scarcity	0.003*** (0.001)	0.079*** (0.003)
Last Endo. Scarcity (Binary)	−0.002 (0.004)	−0.004 (0.002)
Last Endo. Scarcity (Hours)	−0.004 (0.002)	0.021 (0.028)
Accum. Past Endo. Scarcity	0.029 (0.023)	−0.098*** (0.025)
Collective Scarcity	−0.019 (0.029)	−0.020 (0.028)
Scenario Study Room	0.011 (0.027)	0.003*** (0.001)
Scenario Water	−0.038* (0.019)	−0.040* (0.018)
Inspection previous round		0.020 (0.014)
Beliefs		0.034 (0.022)
Risk Av High		
Woman		
Observations	4,815	4,815
Log Likelihood	−2,513.849	−2,480.239
Akaike Inf. Crit.	5,049.697	4,988.477
Note:		*p<0.05; **p<0.01; ***p<0.001

Table A.14: Non-Compliance Two Parts Decision - Hierarchical Model

	Non-compliance decision		Non-compliance units	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.087*** (0.004)	0.087*** (0.004)	0.776*** (0.018)	0.776*** (0.018)
Accum. Exogenous Scarcity	0.003*** (0.001)	0.003*** (0.001)	0.004 (0.004)	0.004 (0.004)
Last Endogenous Scarcity (Binary)	0.089*** (0.022)	0.089*** (0.021)		
Last Endogenous Scarcity (Hours)	0.001 (0.003)	0.001 (0.003)	0.061** (0.019)	0.060** (0.019)
Accum. Endogenous Scarcity	−0.003 (0.002)	−0.003 (0.002)	0.010 (0.009)	0.010 (0.009)
Collective Scarcity Awareness	0.030 (0.023)	0.036 (0.022)	−0.173 (0.121)	−0.140 (0.117)
Scenario Study Room	−0.016 (0.029)	−0.017 (0.028)	−0.220 (0.143)	−0.225 (0.141)
Scenario Water	0.016 (0.028)	0.027 (0.029)	−0.210 (0.146)	−0.169 (0.154)
Inspection previous round	−0.035* (0.017)	−0.035* (0.016)	−0.012 (0.079)	−0.015 (0.079)
Beliefs (High)		0.021 (0.014)		0.076 (0.080)
Risk Aversion (High)		−0.098*** (0.024)		−0.336* (0.146)
Woman		0.051* (0.025)		0.022 (0.138)
Exo:Endo_pastB	−0.019*** (0.004)	−0.019*** (0.004)		
Constant	0.331*** (0.026)	0.414*** (0.052)	0.706*** (0.115)	1.059*** (0.311)
Observations	4,815	4,815	3,158	3,158
Log Likelihood	−2,460.114	−2,459.569	−6,031.373	−6,031.282
Akaike Inf. Crit.	4,946.228	4,951.138	12,084.750	12,090.560
Bayesian Inf. Crit.	5,030.461	5,054.810	12,151.380	12,175.370

Note: *p<0.05; **p<0.01; ***p<0.001

Table A.15: Non-Compliance Two Parts Decision - Panel Models Fixed Effecs Player

	NCbinary	NChours
	(1)	(2)
Exogenous Scarcity	0.087*** (0.004)	0.784*** (0.018)
Accum. Exogenous Scarcity	0.003*** (0.001)	0.005 (0.004)
Last Endogenous Scarcity (Binary)	0.088*** (0.022)	
Last Endogenous Scarcity (Hours)	0.001 (0.003)	0.063** (0.020)
Accum. Endogenous Scarcity	−0.003 (0.002)	0.008 (0.010)
Exo:Endo_pastB	−0.019*** (0.004)	
Observations	4,815	3,158
R^2	0.263	0.631
Adjusted R^2	0.210	0.589

Note: *p<0.05; **p<0.01; ***p<0.001

Appendix B

Supplementary material for Chapter 3

Table B.1: Non-Compliance Two Parts Decision - OLS robust SE cluster player

	Non-compliance decision		Non-compliance hours	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.084*** (0.005)	0.071*** (0.003)	0.725*** (0.026)	0.728*** (0.026)
Exogenous Scarcity Accu.	0.002 (0.001)	0.003** (0.001)	0.010 (0.007)	0.011 (0.007)
Experience Last Endo. Scarcity (binary)	0.115*** (0.034)			
Last Endogenous Scarcity	0.004 (0.005)	0.006 (0.004)	0.065** (0.024)	0.056* (0.024)
Endogenous Scarcity Accu.	0.001 (0.003)	−0.001 (0.003)	−0.001 (0.017)	−0.002 (0.018)
Collective Scarcity Awareness (binary)	0.107*** (0.032)	0.085* (0.040)	0.062 (0.172)	−0.221 (0.192)
Inspection Previous Round (binary)	−0.057* (0.024)	−0.047* (0.023)	−0.103 (0.137)	−0.053 (0.132)
Initial Beliefs	−0.026*** (0.006)			
WUA Membership (WUA)		0.017 (0.019)		0.074 (0.101)
Risk Aversion (High)		−0.145** (0.052)		−0.390 (0.232)
Education Level (Higher Education)		−0.055 (0.033)		0.213 (0.177)
Gender (Woman)		−0.039 (0.032)		0.139 (0.179)
Exo Scarcity*Exp. Last Endo Scarcity		0.065 (0.033)		0.275 (0.165)
Collective Scarcity Awareness on WUA		0.071 (0.062)		0.726* (0.329)
Constant	0.231*** (0.025)	0.407*** (0.087)	0.657*** (0.127)	−0.093 (0.446)
Observations	2,925	2,925	1,714	1,714
R^2	0.196	0.215	0.501	0.516
Adjusted R^2	0.194	0.211	0.499	0.513

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table B.2: Non-Compliance Two Parts Decision - Samples - OLS robust SE cluster player

	Non-compliance decision			Non-compliance hours		
	Total	WUA	NON-WUA	Total	WUA	NON-WUA
	(1)	(2)	(3)	(4)	(5)	(6)
Exogenous Scarcity	0.084*** (0.005)	0.078*** (0.006)	0.090*** (0.007)	0.725*** (0.026)	0.716*** (0.041)	0.737*** (0.033)
Exogenous Scarcity Accu.	0.002 (0.001)	0.003 (0.002)	0.003 (0.002)	0.010 (0.007)	0.013 (0.012)	0.009 (0.008)
Last Endogenous Scarcity	0.115*** (0.034)	0.094 (0.051)	0.113* (0.046)			
Endogenous Scarcity Accu.	0.004 (0.005)	0.011 (0.007)	−0.002 (0.007)	0.065** (0.024)	0.069 (0.042)	0.054* (0.025)
Experience Last Endo. Scarcity (binary)	0.001 (0.003)	−0.001 (0.004)	−0.0004 (0.004)	−0.001 (0.017)	−0.007 (0.033)	−0.003 (0.018)
Collective Scarcity Awareness (binary)	0.107*** (0.032)	0.162*** (0.047)	0.079* (0.039)	0.062 (0.172)	0.536 (0.289)	−0.303 (0.189)
Inspection Previous Round (binary)	−0.057* (0.024)	−0.065 (0.034)	−0.043 (0.033)	−0.103 (0.137)	−0.121 (0.244)	−0.038 (0.151)
WUA Membership (WUA)	−0.026*** (0.006)	−0.031*** (0.009)	−0.023* (0.009)			
Exo Scarcity*Exp. Last Endo Scarcity	0.231*** (0.025)	0.160*** (0.036)	0.287*** (0.031)	0.657*** (0.127)	0.386 (0.201)	0.794*** (0.163)
Observations	2,925	1,455	1,470	1,714	769	945
R^2	0.196	0.184	0.224	0.501	0.447	0.572
Adjusted R^2	0.194	0.179	0.220	0.499	0.442	0.570

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Table B.3: Non-Compliance Two Parts Decision - Samples - OLS robust SE cluster player

	Non-compliance decision			Non-compliance hours		
	Total	WUA	NON-WUA	Total	WUA	NON-WUA
	(1)	(2)	(3)	(4)	(5)	(6)
Exogenous Scarcity	0.071*** (0.003)	0.078*** (0.006)	0.090*** (0.007)	0.728*** (0.026)	0.730*** (0.043)	0.737*** (0.033)
Exogenous Scarcity Accu.	0.003** (0.001)	0.003 (0.002)	0.003 (0.002)	0.011 (0.007)	0.014 (0.011)	0.009 (0.009)
Last Endogenous Scarcity	0.006 (0.004)	0.009 (0.007)	−0.001 (0.007)	0.056* (0.024)	0.058 (0.041)	0.048* (0.023)
Endogenous Scarcity Accu.	−0.001 (0.003)	−0.0004 (0.004)	−0.0005 (0.004)	−0.002 (0.018)	−0.006 (0.032)	−0.002 (0.019)
Experience Last Endo. Scarcity (binary)		0.095 (0.051)	0.113* (0.045)			
Collective Scarcity Awareness (binary)	0.085* (0.040)	0.151** (0.047)	0.080 (0.040)	−0.221 (0.192)	0.547 (0.291)	−0.262 (0.185)
Inspection Previous Round (binary)	−0.047* (0.023)	−0.064 (0.034)	−0.040 (0.032)	−0.053 (0.132)	−0.054 (0.238)	−0.017 (0.154)
Initial Beliefs	0.017 (0.019)	0.021 (0.031)	0.016 (0.026)	0.074 (0.101)	−0.128 (0.193)	0.204* (0.090)
WUA Membership (WUA)	−0.145** (0.052)			−0.390 (0.232)		
Risk Aversion (High)	−0.055 (0.033)	−0.059 (0.051)	−0.039 (0.046)	0.213 (0.177)	0.742** (0.274)	−0.162 (0.244)
Education Level (Higher Education)	−0.039 (0.032)	−0.041 (0.048)	−0.033 (0.044)	0.139 (0.179)	0.177 (0.297)	0.100 (0.205)
Gender (Woman)	0.065 (0.033)	0.095* (0.047)	0.030 (0.049)	0.275 (0.165)	0.514 (0.278)	0.124 (0.199)
Exo Scarcity*Exp. Last Endo Scarcity	0.071 (0.062)			0.726* (0.329)		
Collective Scarcity Awareness on WUA		−0.029** (0.009)	−0.023* (0.009)			
Constant	0.407*** (0.087)	0.240 (0.142)	0.349** (0.110)	−0.093 (0.446)	−1.169 (0.878)	0.454 (0.439)
Observations	2,925	1,455	1,470	1,714	769	945
R^2	0.215	0.197	0.227	0.516	0.478	0.580
Adjusted R^2	0.211	0.191	0.221	0.513	0.471	0.575

Note: *p<0.05; **p<0.01; ***p<0.001

Table B.4: Non-Compliance Two Parts Decision - Other Variables - OLS robust SE cluster player

	Non-compliance decision		Non-compliance hours	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.084*** (0.005)	0.084*** (0.005)	0.672*** (0.036)	0.677*** (0.036)
Exogenous Scarcity Accu.	0.002 (0.001)	0.003* (0.001)	0.007 (0.007)	0.005 (0.007)
Experience Last Endo. Scarcity (binary)	0.116*** (0.034)	0.108** (0.034)	−0.096 (0.198)	−0.032 (0.198)
Last Endogenous Scarcity	0.004 (0.005)	0.003 (0.005)	0.039 (0.035)	0.030 (0.035)
Endogenous Scarcity Accu.	0.001 (0.003)	−0.0003 (0.003)	−0.001 (0.017)	0.004 (0.017)
Partner Exogenous Scarcity	−0.001 (0.004)	−0.002 (0.004)	0.058** (0.017)	0.059*** (0.017)
Collective Scarcity Awareness (binary)	0.107*** (0.032)	0.122*** (0.031)	0.051 (0.169)	0.065 (0.162)
Inspection Previous Round (binary)	−0.067* (0.028)	−0.057* (0.028)	−0.193 (0.170)	−0.178 (0.164)
Fine Previous Round	0.034 (0.048)	0.018 (0.049)	0.241 (0.211)	0.272 (0.214)
Initial Beliefs		−0.112*** (0.032)		0.078 (0.186)
WUA Membership (WUA)		0.017 (0.020)		0.105 (0.099)
Risk Aversion (High)		−0.050 (0.033)		0.189 (0.181)
Education Level (Higher Education)		0.067* (0.033)		0.331 (0.176)
Gender (Woman)	−0.027*** (0.006)	−0.026*** (0.006)	0.073 (0.044)	0.067 (0.044)
Exo Scarcity*Exp. Last Endo Scarcity	0.248*** (0.054)	0.316*** (0.087)	−0.036 (0.259)	−0.823 (0.472)
Observations	2,925	2,925	1,714	1,714
R^2	0.196	0.217	0.507	0.516
Adjusted R^2	0.193	0.213	0.504	0.512

Note: *p<0.05; **p<0.01; ***p<0.001

Table B.5: Non-compliance binary - Independent variables - OLS robust SE cluster player

	NCbinary							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exogenous Scarcity	0.077*** (0.003)							
Accum. Exo. Scarcity		0.008*** (0.001)						
Last Endo. Scarcity (Binary)			0.163*** (0.022)					
Last Endo. Scarcity (Hours)				0.031*** (0.004)				
Accum. Endo. Scarcity (Hours)					0.015*** (0.002)			
Collective Scarcity Awar.						0.119*** (0.032)		
Inspection previous round							0.002 (0.026)	
WUA								−0.114*** (0.032)
Constant	0.354*** (0.014)	0.464*** (0.018)	0.508*** (0.019)	0.532*** (0.018)	0.514*** (0.018)	0.525*** (0.027)	0.586*** (0.017)	0.643*** (0.021)
Observations	2,925	2,925	2,925	2,925	2,925	2,925	2,925	2,925
R^2	0.166	0.046	0.027	0.024	0.037	0.015	0.00000	0.013
Adjusted R^2	0.166	0.046	0.027	0.024	0.037	0.014	−0.0003	0.013
Note:								*p<0.05; **p<0.01; ***p<0.001

Table B.6: Non-compliance hours - Independent variables - OLS robust SE cluster player

	NChours							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exogenous Scarcity	0.746*** (0.025)							
Accum. Exogenous Scarcity		0.041*** (0.004)						
Last Endogenous Scarcity (Binary)			0.834*** (0.139)					
Last Endogenous Scarcity (Hours)				0.163*** (0.028)				
Accum. Endogenous Scarcity (Hours)					0.077*** (0.011)			
Collective Scarcity Awareness						0.086 (0.164)		
Inspection previous round							0.288 (0.175)	
WUA1								0.065 (0.118)
Constant	0.903*** (0.104)	3.050*** (0.093)	3.350*** (0.095)	3.466*** (0.090)	3.374*** (0.106)	3.761*** (0.111)	3.765*** (0.091)	3.780*** (0.079)
Observations	1,714	1,714	1,714	1,714	1,714	1,714	1,714	1,714
R^2	0.491	0.052	0.029	0.032	0.042	0.0003	0.002	0.0002
Adjusted R^2	0.491	0.051	0.028	0.031	0.041	−0.0003	0.001	−0.0004
Note:								*p<0.05; **p<0.01; ***p<0.001

Table B.7: Multiple Hypothesis Testing - Non-compliance decision

	beta	SE	p_Satt	padj_BH	padj_holm	padj_bonferroni
(Intercept)	0.258	0.024	0	0	0	0
Exogenous Scarcity	0.071	0.003	0	0	0	0
Accum. Exogenous Scarcity	0.003	0.002	0.094	0.170	0.472	0.850
Last Endogenous Scarcity (Binary)	0.040	0.029	0.171	0.256	0.683	1
Last Endogenous Scarcity (Hours)	0.002	0.005	0.646	0.731	1	1
Accum. Endogenous Scarcity	-0.002	0.009	0.872	0.872	1	1
Collective Scarcity Awareness	0.001	0.003	0.650	0.731	1	1
Inspection previous round	0.107	0.032	0.001	0.003	0.007	0.009
Exo∗Last Endogenous Scarcity (Binary)	-0.053	0.023	0.025	0.057	0.151	0.227

Table B.8: Multiple Hypothesis Testing - Non-compliance in hours

	beta	SE	p_Satt	padj_BH	padj_holm	padj_bonferroni
(Intercept)	0.657	0.127	0.00000	0.00000	0.00000	0.00001
Exogenous Scarcity	0.725	0.026	0	0	0	0
Accum. Exogenous Scarcity	0.010	0.007	0.166	0.290	0.663	1
Last Endogenous Scarcity (Hours)	0.065	0.024	0.007	0.016	0.035	0.049
Accum. Endogenous Scarcity	-0.001	0.017	0.937	0.937	1	1
Collective Scarcity Awareness	0.062	0.172	0.717	0.837	1	1
Inspection previous round	-0.103	0.137	0.453	0.634	1	1

Table B.9: Robustness Analysis - Non-Compliance Decision - OLS robust SE cluster player

	NCbinary							
	CTRL	TTO	WUA	NOWUA	WOM	MEN	RAvL	RAvH
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exo. Scarcity	0.077***	0.092***	0.078***	0.090***	0.083***	0.085***	0.078***	0.096***
Exo. Scarcity Accu	0.001	0.003	0.003	0.003	0.003	0.001	0.002	0.002
Endo. Scarcity (Bin)	0.066	0.159***	0.094	0.113*	0.133**	0.104*	0.108*	0.132*
Endo. Scarcity (Hour)	0.012	−0.001	0.011	−0.002	−0.001	0.009	0.007	0.0001
Endo. Scarcity Accu	0.005	−0.002	−0.001	−0.0004	−0.001	0.005	0.001	0.0004
Collective Scarcity			0.162***	0.079*	0.112**	0.120*	0.132**	0.052
Inspection Prev. Round	−0.067*	−0.048	−0.065	−0.043	−0.099**	−0.002	−0.064*	−0.034
Exo*Endo(Bin)	−0.023*	−0.031***	−0.031***	−0.023*	−0.022*	−0.032***	−0.027**	−0.027**
Constant	0.256***	0.311***	0.160***	0.287***	0.266***	0.175***	0.221***	0.253***
Observations	1,425	1,500	1,455	1,470	1,605	1,320	1,920	1,005
R^2	0.159	0.216	0.184	0.224	0.204	0.198	0.178	0.241
Adjusted R^2	0.154	0.212	0.179	0.220	0.200	0.193	0.175	0.235

Note: *p<0.05; **p<0.01; ***p<0.001

Table B.10: Robustness Analysis - Non-Compliance Hours - OLS robust SE cluster player

	NChours							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exo. Scarcity	0.600***	0.682***	0.597***	0.690***	0.675***	0.606***	0.616***	0.693***
Exo. Scarcity Accu	0.005	0.020	0.018	0.015	0.016	0.007	0.010	0.014
Endo. Scarcity (Hours)	0.098**	0.081*	0.081*	0.075*	0.118**	0.059*	0.094*	0.080*
Endo. Scarcity Accu	0.040	−0.006	0.003	0.004	−0.012	0.048	0.025	0.003
Collective Scarcity			1.126**	0.041	0.511	0.652*	0.720**	0.097
Inspection Prev. Round	−0.178	−0.193	−0.285	−0.035	−0.451*	0.178	−0.235	−0.045
Constant	−0.535***	−0.275*	−1.132***	−0.318	−0.440*	−1.027***	−0.720***	−0.525
Observations	1,425	1,500	1,455	1,470	1,605	1,320	1,920	1,005
R^2	0.313	0.392	0.321	0.426	0.368	0.364	0.338	0.413
Adjusted R^2	0.310	0.390	0.318	0.424	0.365	0.362	0.336	0.409

Note: *p<0.05; **p<0.01; ***p<0.001

Table B.11: Non-Compliance Binary Decision - Logit Models

	NCbinary	
	(1)	(2)
Exogenous Scarcity	0.418*** (0.037)	0.430*** (0.039)
Exogenous Scarcity Accu.	0.009 (0.006)	0.012 (0.007)
Experience Last Endo. Scarcity (binary)	0.474** (0.161)	0.450** (0.164)
Last Endogenous Scarcity	0.020 (0.027)	0.018 (0.027)
Endogenous Scarcity Accu.	0.010 (0.016)	0.001 (0.017)
Collective Scarcity Awareness (binary)	0.547*** (0.161)	0.623*** (0.159)
Inspection Previous Round (binary)	−0.291* (0.123)	−0.278* (0.124)
Initial Beliefs		0.101 (0.103)
WUA Membership (WUA)		−0.558** (0.174)
Risk Aversion (High)		−0.289 (0.177)
Education Level (Higher Education)		−0.204 (0.169)
Gender (Woman)		0.362* (0.175)
Exo Scarcity*Exp. Last Endo Scarcity	−0.122** (0.044)	−0.123** (0.044)
Constant	−1.291*** (0.126)	−0.698 (0.451)
Observations	2,925	2,925
Log Likelihood	−1,670.455	−1,629.865
Akaike Inf. Crit.	3,358.910	3,287.730
Note:		*p<0.05; **p<0.01; ***p<0.001

Table B.12: Non-Compliance Binary Decision - Marginal Effects Logit Models

	NCbinary	
	(1)	(2)
Exogenous Scarcity	0.070*** (0.004)	0.070*** (0.004)
Exogenous Scarcity Accu.	0.002 (0.001)	0.002 (0.001)
Experience Last Endo. Scarcity (binary)	0.034 (0.030)	0.027 (0.029)
Last Endogenous Scarcity	0.004 (0.005)	0.003 (0.005)
Endogenous Scarcity Accu.	0.002 (0.003)	0.0003 (0.003)
Collective Scarcity Awareness (binary)	0.107*** (0.032)	0.119*** (0.030)
Inspection Previous Round (binary)	−0.057* (0.024)	−0.053* (0.024)
Initial Beliefs		0.019 (0.019)
WUA Membership (WUA)		−0.106** (0.033)
Risk Aversion (High)		−0.055 (0.033)
Education Level (Higher Education)		−0.039 (0.032)
Gender (Woman)		0.069* (0.033)
Exo Scarcity*Exp. Last Endo Scarcity		
Constant	0.070*** (0.004)	0.070*** (0.004)
Observations	2,925	2,925
Log Likelihood	−1,670.455	−1,629.865
Akaike Inf. Crit.	3,358.910	3,287.730
Note:		*p<0.05; **p<0.01; ***p<0.001

Table B.13: Non-Compliance Two Parts Decision - Hierarchical Models

	Non-compliance decision		Non-compliance hours	
	(1)	(2)	(3)	(4)
Exogenous Scarcity	0.085*** (0.005)	0.085*** (0.005)	0.756*** (0.025)	0.756*** (0.025)
Exogenous Scarcity Accu.	0.003** (0.001)	0.003** (0.001)	0.004 (0.006)	0.005 (0.006)
Experience Last Endo. Scarcity (binary)	0.115*** (0.033)	0.112*** (0.033)		
Last Endogenous Scarcity	0.002 (0.005)	0.002 (0.005)	0.051** (0.019)	0.049* (0.019)
Endogenous Scarcity Accu.	−0.002 (0.002)	−0.002 (0.002)	0.014 (0.012)	0.013 (0.013)
Collective Scarcity Awareness (binary)	0.112*** (0.032)	0.125*** (0.031)	0.113 (0.173)	−0.131 (0.193)
Inspection Previous Round (binary)	−0.050* (0.021)	−0.049* (0.021)	−0.055 (0.119)	−0.048 (0.119)
Initial Beliefs		0.016 (0.020)		0.074 (0.097)
WUA Membership (WUA)		−0.114*** (0.032)		−0.449 (0.236)
Risk Aversion (High)		−0.052 (0.033)		0.175 (0.176)
Education Level (Higher Education)				0.076 (0.180)
Gender (Woman)		0.068* (0.033)		0.375* (0.172)
Exo Scarcity*Exp. Last Endo Scarcity	−0.027*** (0.006)	−0.026*** (0.006)		
Collective Scarcity Awareness on WUA				0.635 (0.337)
Constant	0.225*** (0.025)	0.293*** (0.070)	0.413** (0.129)	−0.182 (0.466)
Observations	2,925	2,925	1,714	1,714
Log Likelihood	−1,621.840	−1,621.822	−3,158.416	−3,157.110
Akaike Inf. Crit.	3,265.680	3,273.644	6,334.832	6,344.219
Bayesian Inf. Crit.	3,331.472	3,363.359	6,383.852	6,425.918
Note:				*p<0.05; **p<0.01; ***p<0.001

Table B.14: Non-Compliance Two-parts Decision - Panel Models Fixed Effecs Player

	NCbinary	NChours
	(1)	(2)
Exo. Scarcity	0.085***	0.765***
Accum. Exo. Scarcity	0.004***	0.003
Endo. Scarcity (binary)	0.114***	
Endo. Scarcity (hours)	0.001	0.048**
Accum. Endo. Scarcity	−0.003	0.019
Inspection	−0.048*	−0.052
Exo:Endo_pastB	−0.027***	
Observations	2,925	1,714
R^2	0.232	0.651
Adjusted R^2	0.175	0.607
Note:	*p<0.05; **p<0.01; ***p<0.001	