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Water overvaluation in incentivized bargaining games

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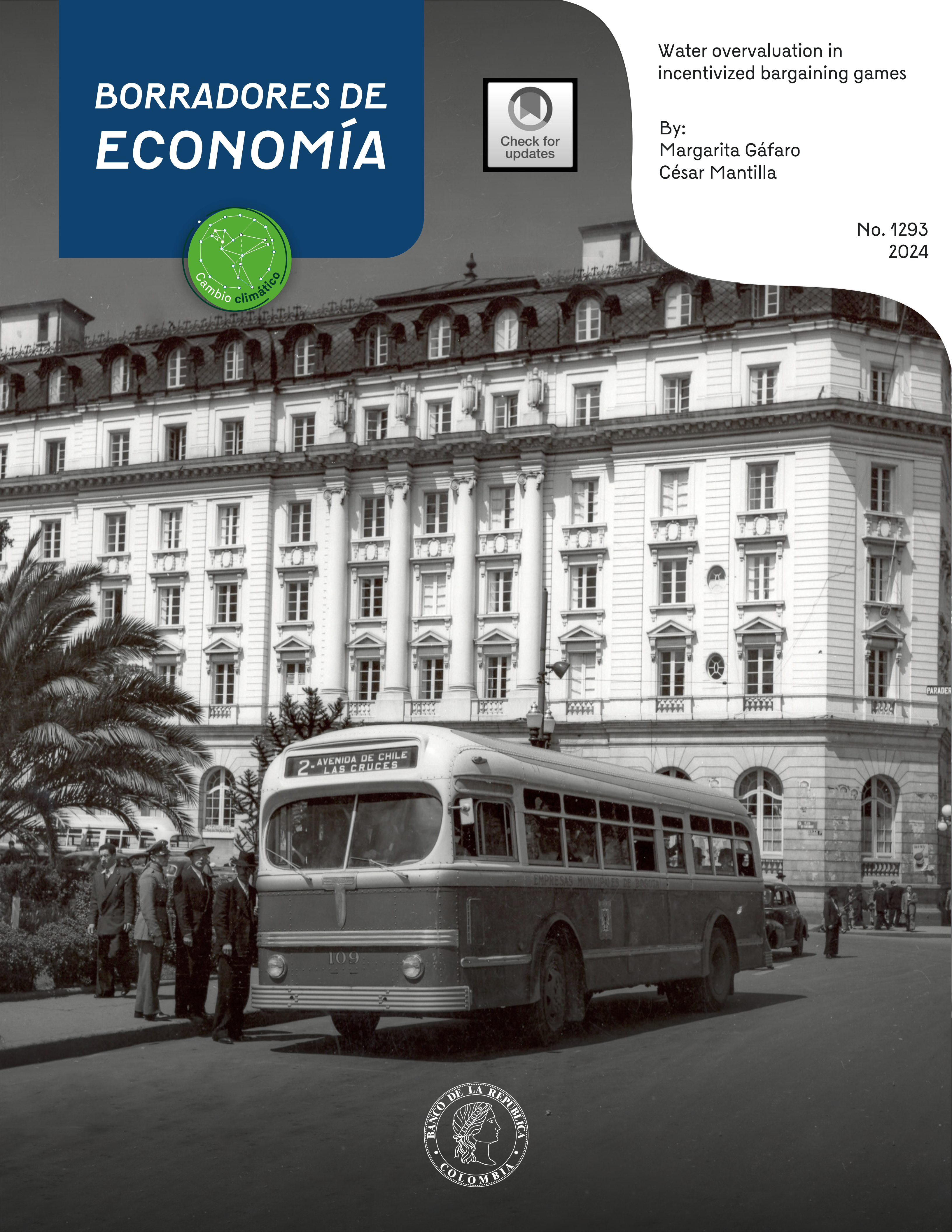
No. 1293
2024



BANCO DE LA REPUBLICA
COLOMBIA

Water overvaluation in incentivized bargaining games*

Margarita Gáfaro† and César Mantilla‡

Abstract

The design of mechanisms for sustainable irrigation water management requires a deep understanding of the value of water to local communities. We present results from a lab-in-the-field incentivized game that sheds light on irrigation water overvaluation patterns among small farmers in Colombia. In this game, two players divide a jointly endowed agricultural land plot, with some pieces having direct access to irrigation water. Although the induced cost of irrigation water in our game was one token, farmers paid between 2.1 and 3.5 times this amount. We generalize this result by presenting a general bargaining game that can be used to identify overvaluation in settings contexts where relevant use conflicts arise.

Keywords: lab-in-the-field experiment; cooperative bargaining; irrigation water; non-cooperative bargaining; Nash bargaining;
JEL classification: C78, C90, Q51

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*We thank the comments from Juan Camilo Cárdenas, Fredrik Carlsson, Juan Esteban Carranza, Nicolai Kuminoff, Jorge Maldonado, and from seminar participants in RIDGE-Environmental Economics, BEBES, Universidad Javeriana, and Banco de la República. We gratefully acknowledge research assistance by Paola Poveda, Leonel Criado, Steffanny Romero, Cristhian Contreras, Natalia Moreno, Yenny Mora, and Mateo Aristizabal, as well as the fieldwork coordination by Julián Pico and fieldwork assistance by Felipe Coy, Natalia Delgado, Brayan Díaz, Lukas Muñoz and Jacqueline Santos. Financial Support from the program *"Inclusión productiva y social: programas y políticas para la promoción de una economía formal, código 60185, que conforma la Alianza EFI, bajo el Contrato de Recuperación Contingente No. FP44842-220-2018."* is gratefully acknowledged.

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Sobrevaloración del agua en juegos de negociación incentivados

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Resumen

El diseño de mecanismos para la gestión sostenible del agua de riego requiere una comprensión profunda del valor del agua para las comunidades locales. En este trabajo presentamos los resultados de un juego incentivado de laboratorio en el campo que muestra patrones de sobrevaloración del agua de riego entre pequeños agricultores Colombia. En este juego dos participantes se dividen un terreno agrícola, heredado conjuntamente, en el que algunas parcelas tienen acceso directo al agua de riego. Aunque el costo inducido del agua en nuestro juego es de una ficha, los jugadores pagaron entre 2,1 y 3,5 veces esta cantidad. Proponemos un modelo de negociación que explica este resultado y que puede utilizarse para identificar sobrevaloración en entornos con conflictos de uso relevantes.

Palabras clave: experimento de laboratorio en campo; negociación cooperativa; agua de riego; negociación no cooperativa; negociación de Nash.
JEL classification: C78, C90, Q51

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* Agradecemos los comentarios de Juan Camilo Cárdenas, Fredrik Carlsson, Juan Esteban Carranza, Nicolai Kuminoff, Jorge Maldonado, y los asistentes al los seminarios RIDGE-Environmental Economics, BEBES, Universidad Javeriana y Banco de la República. También agradecemos el trabajo de Paola Poveda, Leonel Criado, Steffanny Romero, Cristhian Contreras, Natalia Moreno, Yenny Mora y Mateo Aristizabal, como asistentes de investigación, y de Julián Pico como coordinador de trabajo de campo y de Felipe Coy, Natalia Delgado, Brayan Díaz, Lukas Muñoz and Jacqueline Santos como asistentes de campo. Este proyecto recibió el apoyo financiero del programa *"Inclusión productiva y social: programas y políticas para la promoción de una economía formal, código 60185, que conforma la Alianza EFI, bajo el Contrato de Recuperación Contingente No. FP44842-220-2018."* Correos electrónicos: mgafargo@banrep.gov.co, mantillacesar@javeriana.edu.co.

1 Introduction

Population growth and variability in weather patterns put pressure on global water availability. This can have significant implications for welfare in developing countries where large shares of the population rely on agriculture as the primary source of income. Therefore, designing mechanisms that promote efficient and sustainable water use is important for these countries' policy agendas. Crafting these mechanisms requires a deep understanding of the value of water to local communities and the potential strategies for efficient and sustainable water management. Valuation estimates, especially those that capture deviations from its use value, can enhance the development of effective water management policies.

Water valuation in rural areas of developing countries faces several challenges. First, poorly defined property rights, high transaction costs, and ineffective contract enforcement hinder the development of formal markets for water (Foster and Sekhri, 2008; Abramson et al., 2011). Second, direct estimates of demand can underestimate the willingness to pay–WTP–for water due to credit and liquidity constraints (Devoto et al., 2012; Weldesilassie et al., 2009), the prevalence of distortionary subsidies (Perfetti et al., 2019; Whittington and Pagiola, 2012), coordination problems in communal irrigation facilities (Nauges and Whittington, 2010), and protest responses due to perceptions of low quality provision (Jorgensen et al., 1999; Meyerhoff and Liebe, 2006). Third, access to irrigation water can have a high degree of rivalry and significant heterogeneity between users (Jack, 2009; Moreno-Sanchez et al., 2012; Sekhri, 2014).

In this paper, we present the results of a lab-in-the-field-incentivized game that provide evidence of overvaluation of irrigation water among small farmers in Colombia.[1] We argue that game-based valuation exercises, such as the one proposed in this paper, may be informative for water management in developing countries for two reasons. First, when markets for environmental goods and services are thin or absent, they are an alternative source of information on the value of water to local communities (Chakravorty and Swanson, 2002). Second, they facilitate the connection between bargaining models and the behavior of water users, which is essential for understanding how to mitigate conflicts in water management (Carraro et al., 2007). Moreover, while many water management studies using cooperative (or Nash) bargaining methods rely on simulations with aggregated stakeholders (Kahil et al., 2016; Nehra and Caplan, 2022), there is still a lack of knowledge regarding the microeconomic bargaining behavior of individual water users.

In our incentivized bargaining game, participants must divide an agricultural land plot

[1] We refer to our lab-in-the-field intervention as an incentivized game–and not as an experiment– because we only use one treatment arm from an experiment with two treatments. (Gáfaro and Mantilla, 2020) report the between-treatment analysis from the same experiment.

with irrigated and non-irrigated land tiles. The irrigation attribute has an induced value of 1 token, representing water conveyance costs. However, players' choices in this game reveal an overvaluation of irrigation as a game attribute. In particular, the sample of Colombian farmers playing the game paid between 3 and 4 tokens for the irrigation attribute. This overvaluation may occur because participants associate game attributes to context-specific values or elements from their identity (Cárdenas and Ostrom, 2004).

This behavioral pattern can provide information about players' preferences for irrigation water that is relevant to policy design. Overvaluation can significantly affect the efficiency and sustainability of water allocation. On the one hand, it can lead to inefficient market allocations, as individuals with higher disposable incomes can afford to pay prices above the actual productive values. On the other hand, it can help internalize the positive externalities of upstream watershed conservation. In addition, overvaluing irrigation water beyond its productive use can distort investment decisions with regard to irrigation infrastructure, threatening the sustainability of community-based irrigation projects. This is particularly important in areas where credit-constrained farmers rely entirely on their current farm income to pay for water services.

Our participants, farmers in the Northeast of Colombia, come from a context with a lack of formal water markets, credit and liquidity constraints, and poorly-defined property rights that can increase the notion of rivalry over the irrigation opportunities, even in a game (Moreno-Sanchez et al., 2012). Indeed, we find that the overvaluation is driven by municipalities with water scarcity. This result favors the external validity of this valuation pattern: farmers' perceived constraints on irrigation water are reflected in how they reach agreements with larger transfers per irrigated tile in a framed bargaining situation.

Our result contributes to understanding water management in developing contexts in two avenues. First, it complements the results from water valuation where standard methods often yield low WTP for environmental services (Whittington and Pagiola, 2012; Whittington, 2010). Our bargaining game helps detect overvaluation patterns in contexts subject to social desirability bias, lack of trust (e.g., subject to the fear of being charged a higher price for the environmental good), and higher notions of rivalry. Second, whereas negotiations can improve water management (Carraro et al., 2007), there is little evidence at the individual level on how these bargaining processes may occur. The overvaluation of irrigated water calls for augmented bargaining models describing the sources that increase conflict among water users. These may add behavioral constraints (e.g., sequential bargaining) that take into account how agents deal with resource scarcity, and directly capture preferences over water beyond its productive value.

In addition to our empirical contribution, we characterize a bargaining game helpful for designing more compact negotiation scenarios. This game serves as an instrument for detecting the overvaluation of an environmental attribute of interest if: *(i)* two players are jointly endowed with a good that is divisible into smaller units, *(ii)* at least one of these units has an attribute with an associated cost of F per unit, and *(iii)* both bargaining parties can use monetary transfers, from an individually endowed stock of tokens, in exchange for accruing a larger share of the jointly endowed good.

We use the framing of the attribute with a cost F to detect the potential overvaluation. To convey the intuition, imagine a simple scenario where two parties must agree on splitting three units, and only one unit has this costly attribute. There are two allocations [2:1] (i.e., with one player having two units and the other player one unit) that only differ in who has the unit with the extra cost F. The difference in the acceptable transfer to implement these allocations must be exactly F units. Suppose the transfers differ by an amount larger (resp. lower) than F. In that case, we have evidence of the attribute's overvaluation (resp. undervaluation).[2] We show that the valuations above or below the induced value could be detected, regardless of whether the bargaining process is assumed as a cooperative or a non-cooperative scenario.

Our study also speaks to the experimental economics literature applied to environmental questions. We can distinguish two relevant families of methodological applications. First, the refinement of valuation methods using incentivized decision-making protocols. They delve into the understanding of the preference elicitation mechanisms and the role of framing, communication, and context in such elicitation procedures (Cummings and Taylor, 1999; Bulte et al., 2005; Plott and Zeiler, 2005; Shogren, 2005; Harrison, 2006). Second, the collective action problem of provision and use of water have been explored in lab-in-the-field experiments, revealing the interplay between fair shares of allocated water and cooperation (Janssen et al., 2012, 2015). In a study closely related to our setting, Pfaff and co-authors (2019) adapt the simple yet powerful ultimatum game to illustrate the conflict between upstream and downstream water users. They show that contract enforcement, as opposed to promises and non-enforceable arrangements, enhances efficiency and equity.

More structured bargaining games than the *ultimatum* are seldom employed outside the lab (Henrich et al., 2004; Gurven et al., 2008). Our game, and its potential adaptations, offers several advantages for future valuation exercises with incentivized games. First, it introduces an endogenous surplus, an important feature to connect bargaining games with welfare analyses (Baranski, 2019). Second, the valuations are inferred based on accepted

[2]For brevity, we will only refer to the overvaluation phenomenon throughout the rest of the manuscript. The general intuition also applies to undervaluation, though it may be harder to detect given statistical power limitations.

allocations of a jointly endowed good, avoiding the gap between willingness-to-pay and willingness-to-accept (Knetsch, 1989; Kahneman et al., 1990). Third, bargaining parties can be asymmetric, expanding the range of framing options and raising the adaptability to explore other environmental conflicts (e.g., upstream and downstream users).

The rest of the paper is organized as follows. Section 2 introduces our application of the bargaining game for water valuation. We explain the game and provide the intuition for detecting overvaluation. This is followed by an "augmented" model of sequential Nash bargaining that formalizes the conditions to detect overvaluation. Section 3 describes our sampling and how the game was conducted. In Section 4, we show that the value of irrigated plots relative to non-irrigated plots exceeds the irrigation costs in our game. In Section 5, we discuss some implications of our results and summarize a general bargaining model that can be extended in future research. Section 6 concludes.

2 Water valuation in a land division game

Subsections 2.1 to 2.3 describe the bargaining game we use for water valuation. In this game, initially proposed by Gáfaro and Mantilla (2020), players agree on an allocation of land and water from a joint endowment. Subsection 2.4 summarizes the main results on land allocation presented by Gáfaro and Mantilla (2020), which show that egalitarian land allocations are predominant. Subsection 2.5 provides some intuition on how we will exploit this empirical finding to detect water overvaluation. Finally, Subsection 2.6 generalizes this result by deriving an expression for the equilibrium token transfer in a sequential Nash bargaining.

2.1 General setup of the bargaining game

Two players, H and L, are jointly endowed with a farm plot that can be divided into nine triangular tiles of the same size, as shown in Figure 1. Each player also receives an endowment of 10 tokens that they can offer to the counterpart in exchange for keeping more land tiles. At the end of the game, each land tile grants a die roll simulating a realization of a stochastic plot yield. Player H has higher land productivity than Player L, with an expected yield of 4 units compared to L's 3 units.[3] The expected differences in yields are

[3]In (Gáfaro and Mantilla, 2020), we present two treatment arms with alternative parameterizations of the possible land yields for players H and L. In the *low spread* condition, Player H's dice faces are marked as $\{3, 3, 4, 4, 5, 5\}$ and Player L's dice faces are marked as $\{2, 2, 3, 3, 4, 4\}$. In the *high spread* condition, the dices are marked as $\{2, 2, 4, 4, 6, 6\}$ and $\{1, 1, 3, 3, 5, 5\}$ for Players H and L, respectively. In this paper, we pool the data of both treatments because the dice spread does not affect land allocations.

common information. However, the realized dice roll is private information for each player, minimizing the role of ex-post risk-sharing agreements unobserved by the researcher.

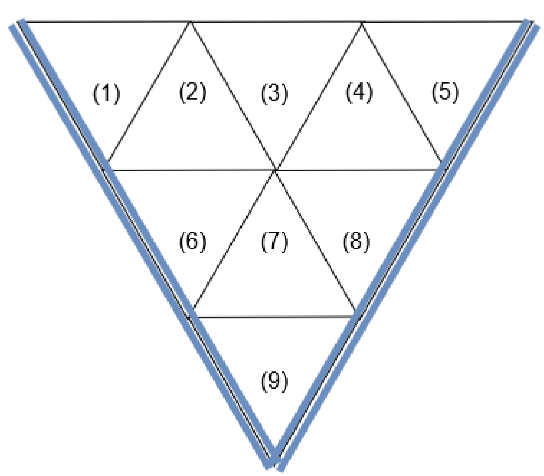
Players bargain over an allocation of land tiles $[\ell_H : \ell_L]$ and a token transfer T in a negotiation with two phases: an initial explicit bargaining phase with face-to-face communication for 5 minutes, followed by a structured bargaining phase. In the latter, Player H makes a written offer to Player L. If she rejects this offer, she can make a take-it or leave-it counter-offer. If Player H rejects the counter-offer, we implement a disagreement outcome, leaving each player with her endowed tokens and four land tiles (i.e., the ninth tile is lost). At the end of the game, each player's agricultural profits and tokens from the transfer are converted into monetary earnings.

2.2 Land Configuration and Costs

Some land tiles have the attribute of irrigation water. Figure 1 depicts two thick double lines on the left and right sides of the plot. These lines represent a water stream. The land plots that share at least one side with the stream have access to water. These are numbered (1), (5), (6), (8), and (9). In these *irrigated* land tiles, the cost of agricultural production is zero. By contrast, in the non-irrigated tiles, numbered (2), (3), (4), and (7), agricultural production has a cost of 1 token (i.e., the "irrigation costs"). We denote the number of irrigated tiles of Player i by ℓ_i^w. Hence, the total irrigation costs for Player i are $c^{I_i} = \ell_i - \ell_i^w$ tokens.

Besides irrigation costs, the game includes border costs that were added to reinforce the

Figure 1: Plot configuration in the bargaining game.



inefficiencies of non-contiguous land divisions. These border costs minimize the number of different configurations for every allocation $[\ell_H : \ell_L]$ and are defined as follows: any tile from Player i adjacent to a tile from her counterpart is defined as a "border tile" and generates a cost of 1 to its owner. Total border costs for Player i are given by the number of border tiles c^{B_i} that she holds.

2.3 Payoffs

Monetary payoffs for Player i, which we denote by m_i, depend on the realization of total agricultural output in her ℓ_i tiles ($Y_i^{\ell_i}$), the endowment of 10 tokens, the transfer (T), and the irrigation and border costs (ℓ_i^w and c^{B_i}).

$$m_H(Y_i^{\ell_H}, T) = 10 - T + Y_i^{\ell_H} - c^{I_H} - c^{B_H} \tag{1}$$

$$m_L(Y_i^{\ell_L}, T) = 10 + T + Y_i^{\ell_L} - c^{I_L} - c^{B_L}. \tag{2}$$

By convention, the transfer T goes from Player H to L, though we allow for negative transfers (i.e., from L to H). This explains the different signs of T in Equations 1 and 2. Note that the transfer T and the irrigation costs are additive in the payoff functions. Therefore, if two land allocations have the same number of tiles ℓ_i but differ in their irrigation costs ℓ_i^w, then the transfer T can be modified to offset the additional irrigation costs.

The face-to-face communication in our protocol calls for a model that captures the joint gains from reaching an agreement. The Nash bargaining cooperative solution serves this purpose by putting together both player's utility differences from reaching and not reaching an agreement, $v_i(m_i) - d_i$. Recall from Equations 1 and 2 that m_i depends on the accrued tiles ℓ_i and the transfer T resulting from an agreement. The utility under the disagreement outcome, d_i, comes from the conditions described in Section 2.1: each participant keeps 4 tiles ($\ell_i = 4$) and there is no transfer ($T = 0$), so we write it as $d_i(m_i(4, 0))$.[4] In the cooperative

[4]Player i's expected utility from an agreement with a land allocation $[\ell_H : \ell_L]$ and a transfer T is

$$v_i(\ell_i, T) = \sum_s Pr(Y_i^{\ell_i} = s) \cdot u_i\left(m_i(s, T)\right),$$

where $Pr(Y_i^{\ell_i} = s)$ is the probability that the sum of all rolled dice of Player i takes the value of s, and u is a utility function that represents players' preferences. Similarly, the expected utility from the disagreement, setting $T = 0$ and deducting four tokens–from the endowment of 10–for the irrigation and border costs, is given by

$$d_i = \sum_s Pr(Y_i^4 = s) \cdot u_i\left(s + 6\right).$$

bargaining model, Players H and L jointly maximize the gains from an agreement, so the terms $(v_H(.) - d_H)^{2-p}$ and $(v_L(.) - d_L)^p$ are multiplied. Assuming symmetric bargaining power ($p = 1$), this joint maximization is represented by:

$$\max \quad (v_H(m_H(\ell_H, T)) - d_H(m_H(4, 0))) \cdot (v_L(m_L(\ell_L, T)) - d_L(m_L(4, 0))) \tag{3}$$

Note that both players know the value of d_i and the larger productivity of player H over L. Hence, the solution to the maximization problem in Equation 3 should involve a transfer from H to L (i.e., $T > 0$) in exchange for keeping more than half of the land tiles. In Gáfaro and Mantilla (2020) we show that, for our game parameterization, the optimal solution involves $T = 10$ (i.e., transferring the whole H's endowment to L) and keeping 8 or 9 tiles, depending on the players' risk aversion (embedded in $v_i()$). Besides, the more efficient agreement yielding an (expected) egalitarian payoff is an allocation [7:2] with a transfer $T = 10$.

2.4 A contrast of theoretical and observed outcomes: Efficient *vs.* egalitarian land allocations

We referred above to the cooperative solution yielding a large monetary transfer from the most to the least productive player, in exchange for accruing most (or all) land tiles. While the prediction is similar, though less extreme, for the non-cooperative solution, the observed outcomes defy these efficient predictions. We now summarize our key findings regarding the land allocations, fully reported in Gáfaro and Mantilla (2020), to define more precisely our benchmark for detecting water overvaluation:

1. From the $N = 64$ rural bargaining pairs, 75% reached an agreement in which one player kept 5 tiles. The average tiles accrued by Player H was 4.9.

2. There were no disagreement outcomes when participants could choose any land allocation. We ran another treatment condition (N=64) where land could not be divided and the disagreement outcome was the same (4 tiles per player, $T = 0$). In this condition, we observed only one disagreement.

3. Most face-to-face agreements were respected during the structured bargaining phase: 74% were implemented as H's to L's offer, and another 20% were implemented as L's to H's counter-offer.

According to these results, the informal agreements from face-to-face interactions are properly reflected in the observed offers and counter-offers. More importantly, the observed agreements reveal concerns beyond mere efficiency, and even beyond payoff-equalizing outcomes. Instead, participants appear to value land-equalizing outcomes. In Gáfaro and Mantilla (2020), we provide two explanations for these results: an overvaluation of the land tiles, and a model of sequential bargaining in which participants first agree on a land allocation and then find an acceptable transfer for this land division. In Subsection 2.6, extend this framework to incorporate the possibility of water overvaluation.

2.5 Detecting overvaluation using egalitarian land allocations

The egalitarian land allocations [5:4] and [4:5] are not only the most prevalent outcomes but they also turn out to be the more helpful in conveying the intuition behind the detection of water overvaluation. The reason is threefold and we will explain it using the [5:4] allocation, but a similar logic applies to [4:5].

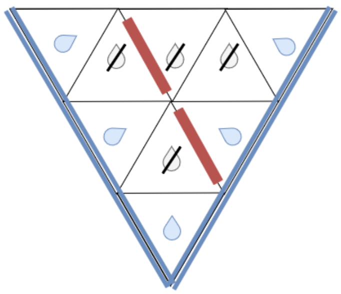
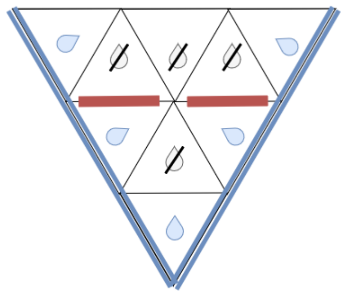
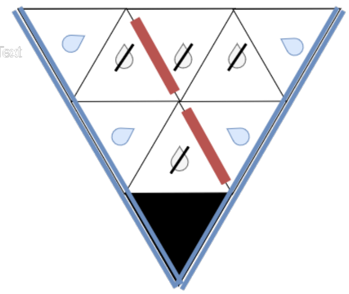
First, the [5:4] allocation has only two possible configurations for the five irrigated land plots: for the player accruing 5 tiles, either 2 or 3 are irrigated. To see why, recall that contiguous tile division to minimize border costs.[5] These two possible land configurations are depicted in panels (a) and (b) in Table 1. This restriction, in addition to the symmetry of the triangle sides representing the water stream, limits the potential land divisions for [5:4] that differ in irrigation costs.

The second reason is that the [5:4] allocation allows us to interpret the transfer T as the compensation for the marginal land tile (i.e., the ninth one). The disagreement outcome is helpful to illustrate this: compared to a [4:4] allocation with $T = 0$ and two irrigated tiles per player (see panel (c) in Table 1), accruing one more tile (to reach the [5:4]) would cost a transfer T to player H. Comparing the payoffs in panels (a) and (c) shows that both players benefit if Player L requests a transfer of up to four tokens—the expected productivity of the tile for Player H—in exchange for allowing her to keep the ninth tile. The sequential bargaining model supports this intuition by determining the acceptable transfer T to avoid disagreement, given the focal [5:4] outcome.

Third, conditional on reaching an egalitarian allocation, it is very unlikely that one of the land configurations from panels (a) and (b) in Table 1 reflected a better understanding of the game than the other. Certain elements of bounded rationality may be useful for participants who find the game rules complex (e.g., the sequential bargaining model discussed above or an equal-division heuristic Messick (1993)). We argue that these elements may explain why participants settle on an egalitarian allocation, but they fall short in predicting whether 2 or 3 irrigated tiles are retained in a [5:4] allocation. This is more likely the result of idiosyncratic

[5] When participants suggested any other allocation with non-contiguous divisions, we reminded them that it would require more border tiles and, therefore, would yield lower profits. In practice, this rarely happened.

Table 1: Configurations of irrigated and non-irrigated tiles in the egalitarian land allocation (panels a and b). Land configuration under the disagreement outcome (panel c).

(a) Majority of irrigated tiles	(b) Majority of non-irrigated tiles	(c) Disagreement outcome
		
$c^{I_H} = 2$, $c^{I_L} = 2$ $c^{B_H} = 2$, $c^{B_L} = 2$	$c^{I_H} = 3$, $c^{I_L} = 1$ $c^{B_H} = 2$, $c^{B_L} = 2$	$c^{I_H} = 2$, $c^{I_L} = 2$ $c^{B_H} = 2$, $c^{B_L} = 2$
$[5:4]$ $m_H = Y_H^{[5]} + (6 - T)$ $m_L = Y_L^{[4]} + (6 + T)$	$[5:4]$ $m_H = Y_H^{[5]} + (5 - T)$ $m_L = Y_L^{[4]} + (7 + T)$	$[4:4]$ $m_H = Y_H^{[4]} + 6$ $m_L = Y_L^{[4]} + 6$

decisions in the bargaining process and cannot be attributed to a poor understanding of the game rules.

Let us analyze in detail the payoffs of the two unique possible tile configurations for [5:4]. Below the depicted land divisions in each panel, Table 1 lists the associated border and irrigation costs, and the expected payoffs for Players H and L.[6] The expected payoffs are a function of the stochastic production $Y_i^{[\ell_i]}$ and the non-random component that results from deducting the irrigation and border costs from the endowment, plus (or minus) the transfer (see the parenthesis).

In Panel (a), Player H accrues three irrigated tiles and two non-irrigated tiles. Since this leaves Player L with two non-irrigated plots, each player assumes an irrigation cost of $\ell_H^w = \ell_L^w = 2$. We will call this configuration the *Majority irrigated*, reflecting that the player with the most tiles also has the majority of irrigated tiles. In Panel (b), Player H accrues two irrigated tiles, yielding a higher irrigation cost for her, with $c^{I_H} = 3$ and $\ell_L^w = 1$. We will call this configuration the *Majority non-irrigated*.

Note that Player H can make her expected payoff, m_H, identical between the configurations shown in panels (a) and (b): the transfer T must be one unit higher in the *Majority irrigated* with respect to the *Majority non-irrigated* configuration.[7] This additional unit in

[6]In Panel (c), recall that $T = 0$, while border and irrigation costs are equally divided.

[7]This payoff equivalence is independent of the players' relative risk-aversion levels because the stochastic

T offsets the reduction in the total border cost paid by Player H when she accrues 3 instead of 2 irrigated tiles. This difference, of exactly one unit, matches the induced irrigation cost in our game, $c^I = 1$ per non-irrigated tile.

Given a [5:4] allocation, we interpret as evidence of overvaluation if the difference in the average transfer T between the *Majority irrigated* and the *Majority non-irrigated* is greater than $c^I = 1$. This computation is straightforward due to the two unique configurations of the [5:4] allocation, meaning that we always compare the transfer when keeping 3 *vs.* 2 irrigated tiles, with everything else equal.

For brevity, we do not describe the [4:5] scenario. The reasoning is identical, except that the transfer will go in the opposite direction and the expected outcome is slightly less efficient regarding the agricultural yield. More generally, a similar logic applies to land allocations in which a player accrues at least 3 and at most 6 tiles, as they offer exactly two configurations of the irrigated tiles. For more extreme land allocations there is a single configuration. However, and given our limited number of observations, we will also conduct a regression analysis with all the bargaining outcomes to estimate the average transfer increase per irrigated and non-irrigated tile.

2.6 Sequential Nash bargaining to model water overvaluation

Gáfaro and Mantilla (2020) show that a sequential bargaining model can explain the evidence on Section 2.4. In this sequential bargaining players first agree on a tile allocation and then on a token transfer to sustain this allocation. We now extend this framework to explicitly model water overvaluation. We derive a formal expression for the token transfer that can be broken down into two components: one that depends on total tiles held by Player H and the other that depends on her number of irrigated tiles. and therefore can provide a measure of players' water valuation.

In the sequential bargaining game, players first choose an allocation $[\ell^*_H{:}\ell^*_L]$ of total tiles. Players then proceed to a second stage in which they bargain over the allocation of irrigated tiles ℓ^I_H (holding the distribution of total tiles constant) and a token transfer T. Let y_H and y_L be the expected tile yields for players H and L. Given an allocation $[\ell^*_H{:}\ell^*_L]$, the irrigation costs can be expressed as the difference between the total and irrigated tiles accrued by player i. Thus, expected payoffs from Equations 1 and 2 can be rewritten as

$$m_H = 10 - T + y_H \ell^*_H - (\ell^*_H - \ell^I_H) - c^{B_H} \tag{4}$$

$$m_L = 10 + T + y_L \ell^*_L - (\ell^*_L - \ell^I_L) - c^{B_L} \tag{5}$$

component in the payoff, $Y_i^{[\ell_i]}$, is unaffected by irrigation costs and transfers.

The difference in each parenthesis highlights that water valuation stems from the cost of irrigation and depends on non-irrigated tiles. In Appendix A.1, we derive Equations 4 and 5 and present the Nash bargaining solution (ℓ^{I^n}, T^n) to this problem. This appendix shows that there are multiple interior solutions, which satisfy the following condition:

$$T^n = \frac{1}{2}\left[\ell_H^*\left((2-p)(y_H-1)+p(y_L-1)\right)-D\right]+\ell_H^{I^n}, \tag{6}$$

where $p \in (0,2)$ represents the relative bargaining ability of Player H, and D is a constant term that captures border costs, outside options, and the token endowment.[8]

Equation 6 shows a direct correspondence between the equilibrium transfer and Player H's irrigated tiles (*i.e.*, $\partial T^n/\partial \ell^{I^n_H} = 1$). This happens because, conditional on the total number of tiles allocated to each player, every additional irrigated tile accrued by Player H implies an additional non-irrigated tile, and therefore an additional cost of one unit, for Player L. In equilibrium, the transfer should adjust to compensate for this additional cost. In the Appendix, we show that the latter is also true for a non-cooperative solution in which Player L makes a take-it or leave-it offer to Player H.

The framework we presented above implies that the token transfer depends only on the parameters of the game. However, if players bring into the negotiation idiosyncratic preferences over the irrigated tiles (e.g., they value water access for reasons beyond the game's payoffs), the token transfer also adjusts according to these preferences. To illustrate this, we include in the payoff functions 4 and 5 an additional term $\gamma_i \ell_i^I$. Here, the parameter γ_i captures Player i's intrinsic preferences over water. This leads to

$$m_H = 10 - T + y_H\ell_H^* - (\ell_H^* - (1+\gamma_H)\ell_H^I) - c^{B_H}$$
$$m_L = 10 + T + y_L\ell_L^* - (\ell_L^* - (1+\gamma_L)\ell_L^I) - c^{B_L}.$$

The cost of irrigation (in the parentheses) is now increased by player's intrinsic preferences over water γ_i. As before, players bargain over a token transfer and an allocation of irrigated tiles. In the Nash bargaining solution $(T^{n,o}, \ell^{I^{n,o}})$, the token transfer satisfies

$$T^{n,o} = \frac{1}{2}\left[\ell_H^*\left((2-p)(y_H-1)+p(y_L-1)\right)-D+\ell_H^{I^{n,o}}\left((2-p)(1+\gamma_H)+p(1+\gamma_L)\right)\right]. \tag{7}$$

The transfer adjustment for the marginal irrigated tile (i.e., $\partial T^{n,o}/\partial \ell_H^I$) now takes into

[8] $D = (2-p)(C_H - d_H) - p(C_L - d_L)$, $C_H = 10 - c^{B_H}$ and $C_L = 6 + 9y_L - c^{B_L}$

account irrigation costs and a weighted average of player's preferences over water.[9] The weighting factor is bargaining power, $p \in [0, 2]$. This implies that the greater the bargaining power of Player i, the larger the influence of γ_i in the transfer adjustment above the induced irrigation costs. To see the interplay between bargaining power and overvaluation in the transfer adjustment, note that when bargaining power is equally distributed ($p = 1$), then both players preferences equally influence the token transfer $\partial T^{n,o}/\partial \ell_H^I = 1 + (\gamma_L + \gamma_H)/2$. Despite this relationship, overvaluation from at least one player is necessary for a transfer adjustment above the irrigation cost (i.e. whenever $\gamma_H = \gamma_L = 0$, $\partial T^{n,o}/\partial \ell_H^I = 1$).

Summing up, our augmented sequential bargaining model theoretically distinguishes the required transfer adjustments to compensate for the induced value and idiosyncratic preferences over water. Besides, there is an interplay between idiosyncratic preferences and bargaining power that will be addressed in our discussion of the empirical results.

3 Game set up

3.1 Sampling

We applied this game in eight rural municipalities in the Northeast of Colombia between September and November 2018. The selected municipalities differ in their access to markets (i.e., distance to the nearest city), the share of the rural population, and agro-climatic conditions. There is also significant variation in the type of agriculture across the selected municipalities. The largest share of planted areas in six of these municipalities corresponds to crops typically produced in small farms: coffee, cocoa, potato, tomato, and sugar cane. In the other two municipalities, African palm, a crop with significant economies of scale, has the largest share of planted area (see Table A.1 in the Appendix).

Water supply conditions also vary across the selected municipalities. Table A.1 presents the mean of yearly rainfall by municipality and two water supply measures provided by the National Institute of Meteorology and Environmental Studies (IDEAM). Our empirical analysis uses this variable to classify the municipalities in the sample across the median of availability during dry years and explore whether the relative abundance of water explains players' valuation of irrigated tiles.

The research team conducting the sessions consisted of a research coordinator and a field assistant. The same research coordinator conducted the sessions in all the municipalities. Nonetheless, several field assistants ensured that at least one member was acquainted with

[9] D is defined as before, but now $C_L = 6 + 9y_L - c^{B_L} + 5\gamma_L$. In the Appendix, we derive an analogous expression for the transfer in the non-cooperative bargaining solution.

the area before the visit. A local person was hired in each municipality to aid the recruitment. The game was applied over the weekends, when the rural population congregates in local market areas.

The initial rural sample accounted for 256 participants, 32 per municipality. However, half of the participants from our initial study intervened in a game variation without land division. They were excluded from the analysis in this paper because if the land is not divided, we do not have multiple configurations of the irrigated tiles. This restriction left us with 128 participants (64 bargaining pairs) for the analysis we present below. Forty-nine percent of the participants were males. Participants were, on average, 38 years old, 48% identified as farmers, and 85% reported that their household owns land.

3.2 Implementation of the bargaining game

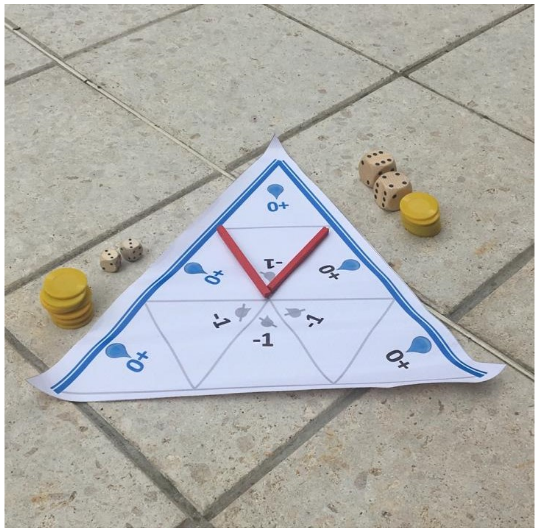
We obtained clearance from the Ethics Committee at Universidad del Rosario, including permission to voice record the bargaining stage. We limited the number of participants per session to four, and always an even number. Each session began with the field coordinator briefly introducing the activity. The game was played only once, and the implementation proceeded as follows:

(i) **Explanation of the jointly endowed plot.** The field team delivered to each pair of participants a printed version of Figure 1. In the protocol, this is called the "map" of the jointly inherited land plot and explained that their objective was to find an agreement in which they can use their tokens to find an acceptable allocation of the land tiles. The map was placed so that each participant was next to one of the blue sides (i.e., the water stream) to ensure that they had a symmetric view of the land plot. Irrigated tiles were marked with a blue drop of water and a "+0" indicating the null irrigation cost. Non-irrigated tiles were marked with a grey crossed drop of water and a "-1" corresponding to the irrigation cost (see Figure 2).

(ii) **Random assignment of pairs and roles as Players H and L.** Participants rolled a plastic die, numbered from 1 to 6, twice. First, to divide the four participants per session into two pairs. In the second roll, the participant in each pair with the highest number was assigned to the role of Player H. To remark on the asymmetry in their productivity, Player H received a "big" wooden die (27cm^3), and Player L received a "small" wooden die (1cm^3). Each die was marked with the potential outcomes. The participants were reminded that, at the end of the game, they would receive as many dice as accrued tiles, identical to the one in their hands.

(iii) **Explanation of irrigation costs.** The field coordinator pointed to the water

Figure 2: "Map", tokens and dice delivered to each bargaining pair of participants.



stream and the irrigated land plots on the map. Then, she explained the cost of conveying water for production in non-irrigated plots.

(iv) **Explanation of border tiles.** The field team delivered to each bargaining pair a set of red wooden logs to mark the boundaries in case the land plot was divided. The coordinator explained that each log would increase the production costs of each participant by one token.

(v) **Final instructions for the bargaining game.** The coordinator provided a predefined example and announced that participants would have five minutes to reach a verbal agreement. Once time ran out, or if participants announced earlier that they had reached an agreement, they proceeded with the structured bargaining phase.

(vi) **Informed consent.** Once participants confirmed they understood the instructions, they provided written consent to participate in the game and let us voice-record the unstructured bargaining stage.

(vii) **Bargaining phase.**

(viii) **Payoff calculation.** Each participant was taken in private. She put inside a box as many dice as tiles she accrued according to the bargaining outcome. The participant was instructed to vigorously shake the box to "roll the dice" and make sure that her yield, and therefore her earnings, could only be observed by the experimenter. The earnings were paid after completing a post-game survey.

The randomness and privacy of the payoffs helped reduce the concern that, even if participants were randomly assigned to their pairs and roles, they probably knew each other and could redistribute their earnings after leaving the experimental sessions. Besides, the observed outcomes reinforce the idea that *ex post* transfer did not drive players choices in the game, as three-quarters of the participants reached the most egalitarian, but also more inefficient, allocations. Hence, there is little room for redistribution after the sessions.

The entire protocol is available in English and Spanish in the supplementary material. Each session lasted at most 60 minutes, and participants received on average $22,300 (± 5,750) Colombian pesos (COP).[10] Although the session length appears large, the unstructured and structured bargaining took about 10 minutes, and roughly the last 20 minutes were devoted to the post-game survey and the payment. In the remaining 30 minutes, we explained the instructions to ensure that participants understood the game rules. We argue that using maps, tokens, dice, and wooden logs makes the rules more tractable, even if it takes more time to explain, with an overall effect of reducing the associated complexity.

4 Empirical Results

This section explores how the token transfer adjusts to the allocation of non-irrigate tiles. As discussed in the previous section, this adjustment provides information about players' valuation of in-plot irrigation water. First, we present a non-parametric analysis for the egalitarian land allocations, following the intuition described in Section 2.5. This is followed by the econometric analysis with the whole sample of land allocations. The data and scripts are available in a repository from the Open Science Framework.[11]

4.1 Non-parametric results

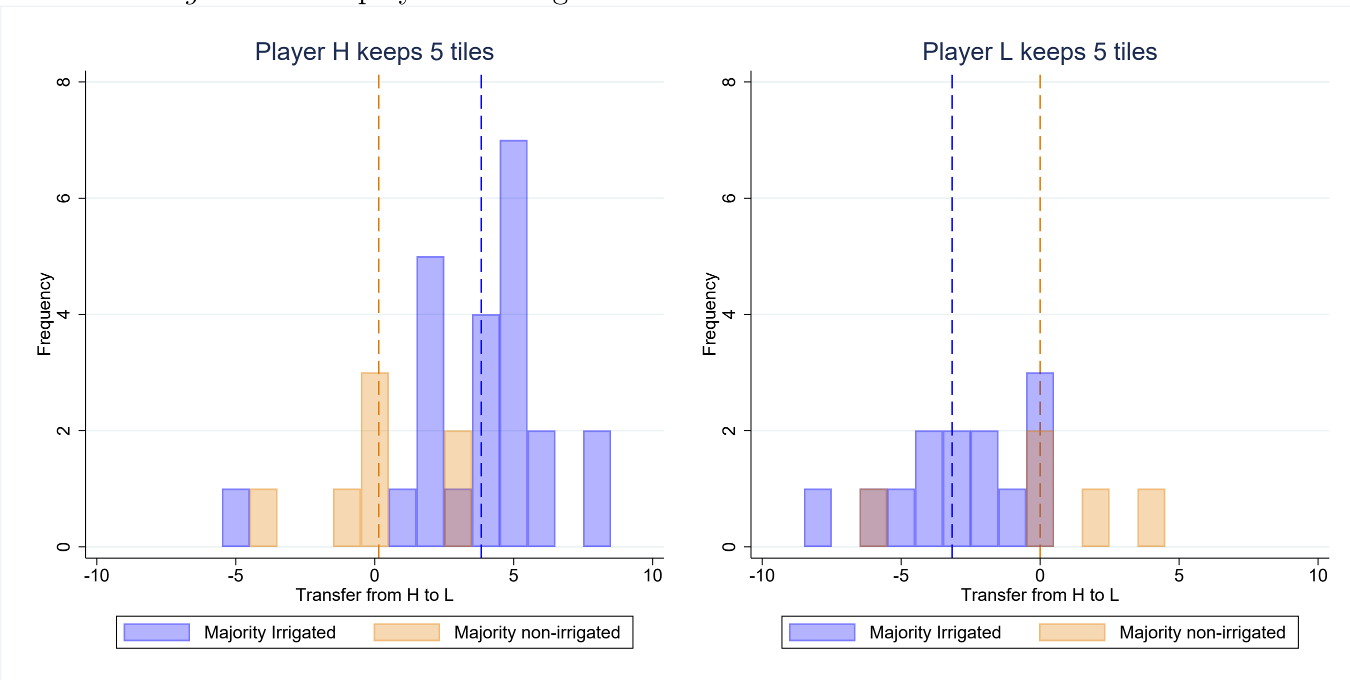
The left panel in Figure 3 presents the distribution of transfers from Player H to Player L, when $\ell_H = 5$, for the *Majority irrigated* and *Majority non-irrigated* configurations. In the *Majority irrigated*, all token transfers but one are positive, with an average value of 3.83 (see Table 2). By contrast, in the *Majority non-irrigated*, the mean transfer is 0.143, and the median is 0. The difference between configurations is 3.69 tokens. Recall that, if participants only considered the water conveyance cost induced by the rules of the game, this difference should have been of 1 unit. We thus find that the reported difference is more than three times the induced cost.

Similarly, the right panel in Figure 3 displays the distribution of transfers from Player H to Player L for the irrigation configurations when $\ell_H = 4$. When Player L keeps five tiles, the mean transfer for the *Majority irrigated* is -3.17 (see Table 2), whereas the mean

[10] By the time of the activity, this average payment corresponded to roughly 7.2 USD, and represents between 1.1 and 1.4 times the daily agricultural wage in the area of study.

[11] `https://osf.io/z49s2/?view_only=5024e61ff11e418582306407e79926ab`

Figure 3: Distribution of transfers with [5:4] (left panel) and [4:5] (right panel) land allocations. The land configurations *Majority irrigated* are displayed in blue, and *Majority non-irrigated* are displayed in orange.



Note: In the *Majority irrigated* configuration, the player keeping five tiles holds three irrigated plus two non-irrigated tiles. In the *Majority non-irrigated* configuration, the player keeping five tiles holds two irrigated plus three non-irrigated tiles. Negative values in the horizontal axis represent a transfer from Player L to Player H. Dashed vertical lines correspond to the average transfer for the allocation of the corresponding color.

transfer for the *Majority non-irrigated* is zero.[12] The negative sign, by convention, indicates that transfers go from Player L (who keeps more tiles) to Player H. Although the difference in mean transfers between the two land configurations is 3.17 tokens, our smaller number of observations is insufficient to reject the null hypothesis that this difference is statistically equal to 1.

These results suggest that players are willing to pay more than three times the induced irrigation cost in the game. According to our model of water overvaluation in Subsection 2.6, this result suggest that at least one player has preferences over water beyond the induced cost on the game. Below, we explore this pattern further with a regression analysis offering two additional insights. First, we can explore water valuation for the sample of egalitarian land allocation (i.e., one player keeps five tiles) and the entire sample. Second, we can control for observed and unobserved heterogeneity by adding municipality fixed effects, individual

[12]Since the labels *Majority irrigated* and *Majority non-irrigated* refer to the irrigation configuration and not to the identity of the player holding more tiles, we hold the same interpretation of these labels.

Table 2: Average Transfer for [5:4] and [4:5] Land Configurations: Rural Sample

Land Division		**N**	**Mean Transfer**	**Difference**
$[\ell_H : \ell_L]$	**Configuration**			($p-$value)
[5:4]	H: Majority irrigated	24	3.833	3.690
[5:4]	H: Majority non-irrigated	7	0.143	(0.021)
[4:5]	L: Majority irrigated	12	-3.167	3.167
[4:5]	L: Majority non-irrigated	5	0.000	(0.170)

Note: $p-$value from $t-$test for the null of mean differences equal to 1 in parenthesis. Sample size N corresponds to bargaining pairs, meaning we have twice this number of players.

controls, and the interactions between individual controls across players. The latter allows us to account for potential asymmetries in bargaining power that arise from heterogeneity in players' individual characteristics, providing an estimate of the average token transfer adjustment, conditional on these potential asymmetries in bargaining power.

4.2 Regression analysis

We estimate the following baseline equation:

$$T_i = \alpha_0 + \alpha_1 \ell^I_{H,i} + \alpha_2 \ell_{H,i} + \boldsymbol{X_i \beta} + \epsilon_i, \tag{8}$$

where T_i represents the token transfer from Player H to Player L of bargaining pair i, $\ell_{H,i}$ represents the total number of land plots accrued by Player H, and $\ell^I_{H,i}$ her irrigated tiles. ϵ_i is a random error. We include a set of control variables $\boldsymbol{X_i}$ to capture potential heterogeneity across players in their bargaining ability. These variables include players' gender, age, marital status, and land tenure (or possession), municipality indicators, and the dice spread (see footnote 3). In the Appendix, we report alternative specifications including interactions between individual characteristics across players. These consider the differences across player's bargaining ability stemming from a bargaining scenario with a counterpart with specific characteristics (e.g., the bargaining ability of a woman might be different when interacting with another woman or a man).

Since $\ell^I_{H,i}$ and ℓ_H are simultaneously included in the regression, the coefficient α_1 captures the effect on the token transfer of changing one irrigated tile for one non-irrigated tile, keeping constant the total number of land plots accrued by Player H. In other words, α_1 directly captures the additional transfer (per tile) for the irrigation attribute. Recall that the value induced in the game for this attribute is one token. We explore whether there is evidence of overvaluation of irrigation water by testing if α_1 is equal to 1, against the alternative hypothesis that α_1 is greater than 1. We interpret a rejection of the null hypothesis as evidence that the intrinsic preferences over water can explain a token transfer exceeding the induced cost of water.

The coefficient α_2 captures the effect on the token transfer of an additional land tile allocated to Player H. The Nash bargaining solution in Equation 7 suggests that this coefficient is an average of players' expected yields weighted by their bargaining ability. Besides, the non-cooperative solution presented in Appendix A.1 suggests that it is proportional to Player H's expected yield. Therefore, we expect this coefficient to fall between 3 and 4, particularly for the egalitarian land allocations that align with our sequential bargaining approach.

We perform two additional econometric exercises to study potential heterogeneity in our results. In the first one, we include in the estimation the interaction between the number of irrigated tiles and a measure of water availability in the municipality. In the second one, we include the interaction between the number of irrigated tiles and the frequency of *water mentions* during the unstructured bargaining. The specification we estimate is

$$T_i = \alpha_0 + \alpha_1 \ell^I_{H,i} + \alpha_2 \ell_{H,i} + \alpha_3 \ell^I_{H,i} \times z_i + \alpha_4 z_i + \boldsymbol{X_i \beta} + \epsilon_i. \tag{9}$$

Here, z_i represents the added covariate of interest. We are primarily interested in its interaction with $\ell^I_{H,i}$, captured in the coefficient α_3. In the first exercise, this coefficient provides information on the external validity of our results. It allows us to assess whether players' choices in the game respond to external factors that determine the value of water in their context (e.g., due to scarcity).[13] In the second exercise, this coefficient provides information on internal validity. It captures the correlation between the transferred amount associated with irrigated tiles and the salience of water during the bargaining interactions. The details of such "water mentions" are provided below.

Table 3 reports the regression results. In Panel A, we display the coefficients for the subsample of egalitarian land allocations, and in Panel B, the coefficients for the entire sample. In both panels, columns 1 to 3 correspond to the specification in Equation 8, and columns 4 and 5 to the specifications derived from Equation 9.

Let us start with Panel A. Recall that, due to the restriction of having contiguous tiles to minimize border costs, if Player H accrues 4 or 5 tiles, only 2 or 3 of those can be irrigated (see Table 1). Hence, we re-scale the independent variables ℓ_H and ℓ^I_H to take the values of 0 and 1. This facilitates the interpretation of the constant term in the estimation. Column 1 shows that when Player H keeps the fifth tile, regardless of the irrigation attribute, she transfers, on average, three tokens to her counterpart (5.24-2.24). The constant term of -2.24 indicates that Player H receives, on average, a transfer of 2.24 as compensation for accruing only four tiles.

[13]Note that, since z_i varies at the municipality level, it is collinear with the fixed effects in the estimation, and we can not identify the coefficient α_4.

Table 3: OLS Estimations: Token Transfers for [5:4] and [4:5] land allocations (Panel A) and the entire sample (Panel B).

	(1)	(2)	(3)	(4)	(5)
Panel A: [5:4] and [4:5] Allocations					
ℓ_H	5.24***	3.56***	3.31**	3.33**	3.28**
	(0.92)	(0.98)	(1.47)	(1.52)	(1.60)
ℓ_H^I		3.48***	3.37**	3.31**	3.67**
		(0.91)	(1.07)	(1.30)	(1.42)
$\ell_H^I \times$ High Supply				0.25	
				(2.58)	
$\ell_H^I \times$ Water Mentions					-0.031
					(0.14)
Constant	-2.24**	-3.26***	-3.62	-3.70	-3.79
	(0.75)	(0.65)	(2.16)	(2.41)	(2.35)
Observations	48	48	48	48	47
R^2	0.42	0.57	0.64	0.64	0.64
(1) *p-val.* coeff. $\ell_H^I = 1$		0.0092	0.034	0.087	0.072
(2) Coeff. $\ell_H^I + \ell_H^I \times$ High Supply				3.55 (0.25)	
(3) Coeff. $\ell_H^I + \ell_H^I \times 50^{th}$ Water Mentions					3.57 (0.05)
(4) Coeff. $\ell_H^I + \ell_H^I \times 90^{th}$ Water Mentions					3.11 (0.30)
Panel B: All Allocations					
ℓ_H	1.00***	-0.13	-0.027	0.82	0.18
	(0.28)	(0.65)	(0.68)	(0.81)	(0.69)
ℓ_H^I		2.06*	2.18**	3.23**	0.96
		(1.08)	(1.06)	(1.16)	(1.28)
$\ell_H^I \times$ High Supply				-2.81*	
				(1.61)	
$\ell_H^I \times$ Water Mentions					0.22**
					(0.076)
Constant	-3.47**	-3.54**	-3.40	-3.26	-1.27
	(1.42)	(1.44)	(2.70)	(2.49)	(2.75)
Observations	64	64	64	64	63
R^2	0.19	0.24	0.45	0.48	0.50
(1) *p-val.* coeff. $\ell_H^I = 1$		0.33	0.27	0.062	0.97
(2) Coeff. $\ell_H^I + \ell_H^I \times$ High Supply				0.42 (0.71)	
(3) Coeff. $\ell_H^I + \ell_H^I \times 50^{th}$ Water Mentions					1.62 (0.60)
(4) Coeff. $\ell_H^I + \ell_H^I \times 90^{th}$ Water Mentions					4.70 (0.00)
Controls	No	No	Yes	Yes	Yes

Note: Huber-White standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. $\ell_{H,i}$ and $\ell_{H,i}^I$ in Panel A are scaled to take values of 0 and 1. Control variables for each player include gender, age, marital status, a dummy variable for whether the player has a farm, and municipality indicator variables. Row (1), at the bottom of each panel, presents the *p-value* of a test with $H_o : \alpha_1 = 1$. Row (2) presents the sum of the coefficient estimate on the $\ell_{H,i}^I$ and the interaction with High Water Supply (a dummy equal to 1 for municipalities above the sample median) and the *p-value* of a test on whether this sum equals 1. Rows (3) and (4) present the marginal effect of irrigated land plots evaluated at the median and the 90^{th} percentile of the number of water mentions (3 and 17), respectively, and the *p-value* of a test on whether this marginal effect equals 1.

In column 2, we include the dummy variable indicating whether Player H is in the *Majority irrigated* land configuration. By adding this variable, we can disentangle the compensation from having the irrigation attribute in the marginal tile from the compensation paid to keep this fifth tile. Conditional on the total number of land plots kept by Player H, she transfers, on average, 3.48 additional tokens for an additional irrigated tile. As shown in column 3, this coefficient is robust to introducing individual controls and municipality fixed effects, suggesting that individual characteristics and unobservable municipality heterogeneity are not likely to drive our results. As a formal test of the observed overvaluation, we report at the bottom of Panel A the $p-$values for a test on whether the coefficient of the variable $\ell^I_{H,i}$ is equal to 1. The observed rejection of this hypothesis in columns 2 and 3 confirms that the irrigation attribute is overvalued in our game.

Panel B reports the results for the entire sample. That is, we added the 16 observations in which the outcome of the bargaining game was less egalitarian (i.e., one player keeps at least six tiles).[14] With this estimation, we check whether our results are robust to a broader set of bargaining outcomes.

Column 1 shows that, before we consider the distribution of irrigated plots, an additional land tile that Player H accrues increases the transfer by one token, on average. Interestingly, this coefficient decreases in magnitude and loses its statistical significance once we include in the estimation the number of irrigated tiles ℓ^I_H (column 2). The coefficient estimate on α_1 indicates that conditional on the total number of land plots of Player H, she transfers, on average, two tokens in exchange for a unit of irrigation. As before, this coefficient is robust to including individual controls and municipality indicators. However, we cannot reject the null hypothesis of $\alpha_1 = 1$ due to large standard errors in our estimation.

The regressions in Table 3 control for the individual characteristics of participants. Nevertheless, in face-to-face dyadic interactions, some traits evoking power differences within the pair may interplay and affect bargaining outcomes. For instance, the bargaining process between a male and a female can differ systematically from bargaining between two males (or analogously, between participants with similar or different wealth levels). We thus include the interactions between Player H's and Player L's characteristics (gender, civil status, and land ownership status) to the regressions reported in Tables A.2 and A.3, in the Appendix. The interactions between Player H's and Player L's characteristics are not statistically different from zero, and the coefficient estimate on the number of irrigated plots remains unchanged, suggesting that our findings are not driven by bargaining power asymmetries between players.

A second concern with face-to-face interactions is that some bargaining pairs could over-

[14] In all 64 bargaining outcomes, the disagreement payoff was never implemented.

hear others, causing an uncontrolled influence on others' bargaining outcomes. To address this concern, we coded whether the two pairs within a session reached similar outcomes, as follows: (*i*) the same allocation and transfer (6%), (*ii*) the same allocation and a different transfer (19%), or (*iii*) a different allocation (75%). We then randomly matched bargaining pairs into synthetic sessions, and repeated the same coding of similarity in outcomes. We created 1,000 repetitions of these synthetic sessions and compared the average distribution of the resulting coding with the observed in our data. A Chi-squared test revealed no differences ($p = 0.479$), suggesting that bargaining pairs were unlikely to influence each other in achieving the same outcomes.

Heterogeneity in water overvaluation

We explore the potential heterogeneity of our results for different water availability conditions across bargaining pairs' municipalities. Column 4 in Table 3 reports the estimation of Equation 9, with an interaction between Player H's irrigated plots and an indicator variable for water supply. This variable takes the value of one when the water supply in the municipality of the bargaining pair i is above the sample median and zero otherwise.[15]

The results differ between the whole sample and the sample of egalitarian pairs. Panel A reveals that the valuation of in-plot irrigation water does not differ across municipalities with low and high water supply in the egalitarian sample. Nevertheless, we find evidence of heterogeneity in water valuation in Panel B by including the whole sample of bargaining pairs. In particular, players are willing to pay 3.23 additional tokens for an irrigated plot in municipalities with a relatively low water supply. This coefficient is statistically different from 1. By contrast, in municipalities with a relatively high supply, players pay, on average, 0.42 (resulting from 3.23-2.81) tokens for an irrigated plot. In this case, we cannot reject the hypothesis of equality to 1. This is evidence in favor of the external validity of our results. When considering the whole sample, the overvaluation of in-plot irrigation water comes from bargaining pairs in municipalities with a relatively lower supply in periods of water scarcity. With this interpretation, we are implicitly arguing that water becomes a more contentious good in scenarios of scarcity, and therefore both bargaining parties agree on a higher transfer to keep the latter irrigated tile. Thus, we conjecture that the interplay between the framing in our game and the context of our participants is a relevant component in the estimated overvaluation.

We use the information from the oral recordings to explore whether players' mentions of the word "water" when bargaining over possible land allocations have explanatory power on the observed overvaluation. There was at least one mention of water among roughly

[15]Note that our municipality indicators absorb the direct effect of this variable on token transfers.

sixty percent of the bargaining pairs, and water was mentioned on average 5.7 times in each. As a reference, in the game where players were not allowed to divide the land, water mentions occurred in thirty percent of the bargaining interactions, with an average of 0.7 times per pair. Wilcoxon rank-sum tests for the between-treatment comparisons yield a $p-$value < 0.001. This difference is validated in Figure A.1 (see Appendix), plotting the frequency of water mentions when land could and could not be divided. Aware that water mentions were noteworthy when land could be divided, we explore whether both players were equally engaged in discussing water as part of their bargaining allocation proposals. We find that Player H mentions water slightly more often than Player L (3.1 versus 2.7 times), although this difference is not statistically significant (see Figure A.2). Moreover, there is a strong positive correlation (0.6) between the number of times that Players H and L mention water within bargaining pairs.

Moving to the regression outcomes, column 5 of Table 3 displays the results when we add the frequency of water mentions in the explicit bargaining stage. As occurred with our water supply measure by municipality, we only find evidence of potential heterogeneity in water valuation with the whole sample of bargaining pairs. In Panel B, the coefficient capturing the interaction of interest is positive. Its magnitude indicates that at the median number of water mentions (3), Player H transfers, on average, 1.62 tokens to Player L. By contrast, for bargaining pairs in the 90^{th} percentile of water mentions (17), the irrigation attribute induces an average transfer of 4.70. This effect is statistically different from 1.

We offer a conjecture for the lack of heterogeneous effects in the sample of egalitarian land allocations. In line with our sequential bargaining model and Equation 7, it might be that in very disputed bargaining processes (i.e., with participants having similar bargaining abilities or with an *ex-ante* goal of accruing at least four tiles), the additional valuation of water is implicit in the offered transfer. When bargaining abilities are less symmetric, or players can foresee the distribution of larger expected profits despite the higher land inequality, water valuation becomes an explicit argument affecting the transfers.

5 Discussion

5.1 Can our bargaining game be easily adapted to study other overvaluation problems?

In Appendix A.2 we present a more general theoretical framework that can guide the analysis of overvaluation in other contexts. Based of this framework, a bargaining game is suitable to detect overvaluation if it meets the following properties: *(i)* two players are jointly endowed with a good that is divisible into smaller units, as with the farm divided into nine land plots (or tiles); *(ii)* at least one of these units possesses an attribute having an associated cost per unit, as with the four non-irrigated tiles with a cost of 1 token for irrigation; and *(iii)* both bargaining parties can propose monetary transfers using some endowed tokens in exchange for a larger share of the jointly endowed good.

In the model presented in Appendix A.2, two assets yield the same returns but one of them has a cost F per unit. We show that the optimal transfer adjusts by exactly F when a player substitutes one unit of the costless asset with one unit of the costly asset. This result holds for the cooperative solution, where players decide how to share the surplus of an agreement (Roth and Malouf, 1979); and for the non-cooperative solution, where a player submitting a final take-it-or-leave-it offer extracts most of the rents from the agreement (Rubinstein, 1982). If there not overvaluation, the optimal transfer adjustment does not depend on the utility function or the relative bargaining power. This is because optimality arises from the equality of marginal returns of total assets, which remains unaffected by reallocating costless and costly assets. Instead, the equilibrium transfer perfectly adjusts for any changes in the associated attributes' cost.

Appendix A.3 expands this general model to include the overvaluation of the costly asset. When a player substitutes one unit of the costless asset with a unit of the costly asset, the transfer adjusts to account for the induced cost (F) and the intrinsic value of the associated attribute. This intrinsic value is the weighted average of players' overvaluation parameters.

5.2 Overvaluation and bargaining power: some final thoughts

The identification of overvaluation has some theoretical limitations. Let us define $\tilde{\gamma}(p)$ as the magnitude of the identified overvaluation. The estimations reported in Table 3 suggest that $\tilde{\gamma}(p)$ has a value around 2.3-2.7 (i.e., the coefficient for ℓ_H^I minus the induced cost, 1). Recall from Equation 7 that $\tilde{\gamma}(p)$ is an average of γ_i across the players, weighted by their respective bargaining power, p. Theoretically, this condition imposes two caveats on the interpretation of $\tilde{\gamma}(p)$: one related to the fact that asymmetries in player's bargaining ability and not only their preferences over water influence the magnitude of $\tilde{\gamma}(p)$, and the other one related to the potential heterogeneity in $gamma_i$. Below, we discuss the extent of these potential caveats in light of our empirical results.

First, we argue that bargaining outcomes in our game are suggestive of a relatively even distribution of bargaining power among players. In particular, the predominance of egalitarian land allocations, despite the associated inefficiencies and the fact that in Table A.3 none of the observables related to relative bargaining power (e.g., gender, civil status, farm ownership), nor their interactions, are statistically significant in explaining the transfer size, suggest that asymmetries in bargaining power do not drive the observed outcomes.

Second, regarding the asymmetry in γ_i, the bargaining nature of our game requires some convergence in the implicit degree of overvaluation (i.e., γ_H and γ_L close enough). Otherwise, an agreed transfer is less likely to exist. Imagine that the keeper of the marginal irrigated tile has a much larger γ than the transfer recipient. She would not have incentives to reveal this information, as she would need to transfer more. By contrast, if the transfer recipient has a much larger γ, then the keeper would be unwilling to pay the associated larger transfer. Since we observe transfers above the induced cost of irrigation and disagreements are absent in our game, the bargaining nature of the players' interaction likely led them to (implicitly) agree on close values of γ_i.

Summing up, water overvaluation in our bargaining pairs seems to result from relatively close values of γ_i and balanced bargaining abilities, reducing concerns about identification and unobserved heterogeneities in $\tilde{\gamma}(p)$

5.3 Implications of overvaluation and bargaining for water policy

The use of policy instruments in water management might be sensitive to the reported patterns of overvaluation among small farmers. Three key components in designing such instruments are: the degree of conflict resulting from water reallocation, the level of co-operation required to sustain water-related services and public goods (e.g., water quality or flood control), and the responses to uncertainty in water availability, which can become more important with climate change.

The use of transfers that capture the upstream-downstream externalities is a good example of addressing the dimension of conflict. For instance, in Costa Rica and Ecuador, downstream users pay watershed owners and managers for watershed services (Rogers, 2002). Hence, water overvaluation among upstream users may facilitate internalizing the value of (and compensation for) watershed services. The gains from trade in markets reallocating water-use rights also dampen this conflict dimension. Nevertheless, these gains may concentrate on the buyers (e.g., see (Hearne and Easter, 1997) for evidence on the Chilean case) without fully incorporating such overvaluation elements that could improve the distribution of the welfare gains from reallocating water.

The overvaluation may also shape how users of a common water source cooperate. In terms of local private provision or the collective action efforts that improve the interactions with the state, this additional valuation of water might help explain why some communities are more successful in managing their water systems. Overvaluation may translate into an intrinsic valuation of water that increases cooperativeness, measured as a willingness to improve the collective maintenance of state-provided irrigation systems, to contribute to private systems, or to the development of rules that foster good collective management beyond the financing mechanisms (Meinzen-Dick, 2007).

Our results are silent regarding the dimension of uncertainty because our identification of overvaluation depends on deterministic elements (i.e., a known and transferrable irrigation cost). However, if the main concern about uncertainty is the more frequent and extreme periods of water scarcity, our comparison across municipalities yields one informative result. Recall that overvaluation was more pronounced in locations with low water supply in periods of scarcity. Overvaluation may play a more prominent role in water policy (e.g., via water pricing) as the alterations to the water cycle accentuate. Further research may explore the interplay of overvaluation and loss aversion as a tool to account for the costs of uncertainty in water supply.

6 Conclusions

We report water overvaluation in a lab-in-the-field bargaining game. In this game, farmers divided a land plot and could use a token transfer to reach an acceptable allocation of the nine tiles that make up the land plot, four of which had a known irrigation cost and therefore induced a value of water in the game. To infer the overvaluation, we compared the accepted transfers across bargaining outcomes having the same total tiles but a different number of irrigated tiles. The observed transfers reflected that the players paid between 2 and 3 times the induced value of irrigated water.

We complement our empirical contribution with two theoretical insights. First, the observed outcomes can be interpreted by using a model of sequential Nash bargaining with overvaluation. The parameter capturing overvaluation depends–in theory–on the relative bargaining abilities. However, the prevalence of egalitarian outcomes and the lack of explanatory power from individual characteristics in the regressions, suggests that bargaining abilities were balanced in our game. Second, we characterized some properties required in a bargaining game to be adapted for an overvaluation exercise. The key element is that, holding the asset division constant, the different configurations of the burden from the costly attribute yields a transfer comparison that may reveal its overvaluation. We show that this holds in the cooperative and non-cooperative bargaining frameworks and is also a best-response function for out-of-equilibrium proposals.

Bargaining experiments might provide additional estimates of water valuation that can complement standard valuation techniques. The obtained estimates inform about the value of water services to be internalized and ultimately can nourish policies that compensate upstream users. Besides, these games may contribute to understanding bargaining behavior at the micro level (Carraro et al., 2007) and the potential of collaboration between parties. This better understanding of the notions of conflict and cooperation among upstream users may help develop strategies for successful water management.

We close by discussing two relevant elements when designing future bargaining experiments in the environmental realm. First, there is a trade-off between framing and complexity. Bargaining games need to be sufficiently simple to guarantee that the purpose of the game is clear to the respondents and sufficiently loaded (or framed) to ensure that participants connect elements of their identity with the costly attribute (Cárdenas and Ostrom, 2004). Whereas our land division game increased framing at the cost of some complexity in explaining the game rules, the implementation of the general model from Appendix A.2 can be more straightforward. In our case, the additional time devoted to explaining the irrigation rules paid off: the connection between mentions of water and transfers suggests a successful relationship between the experiment's framing and the relevance that irrigation water has outside the game. An empirical question is whether simpler game rules can keep a sufficiently appealing context for the valuation exercise. This adherence to the game's context, in addition to the monetary incentives standard in economic experiments, may help counter the methodological issues for valuing water in developing countries due to lack of trust.

Second, the calibration of induced costs is fundamental and requires further research. The efforts to connect the relative overvaluation in the game to any conclusion reflecting an absolute valuation of this attribute are left for future research. Having said this, we believe that detecting the overvaluation patterns could be helpful *per se*, especially in contexts where other methods may yield undervaluations due to low disposable income levels.

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A Appendix

A.1 Sequential bargaining

Below, we present all derivations for the results in Section 2.6. As in Gáfaro and Mantilla (2020) players first agree on a land allocation that solves the Nash bargaining problem:

$$(\ell_H, \ell_L) = \arg\max \ (\ell_H - 4)^p (\ell_L - 4)^{2-p} \quad (10)$$
$$s.t.$$
$$\ell_H + \ell_L \leq 9,$$

where $p \in (0, 2)$ represents the bargaining ability of Player H. Gáfaro and Mantilla (2020) show that [5:4] and [4:5] are solutions to this bargaining game.

Conditional on the chosen tile allocation $[\ell_H^* : \ell_L^*]$, players engage in a second bargaining stage to define the token transfer and the allocation of irrigated tiles. With expected land yields y_H and y_L, payoffs in 1 and 2 are

$$m_H = 10 - T + y_H \ell_H^* - (\ell_H - \ell_H^I) - c^{B_H}$$

$$m_L = 10 + T + y_L \ell_L^* - (\ell_L - \ell_L^I) - c^{B_L}.$$

Substituting the endowment constraints $\ell_H^* + \ell_L^* = 9$, $\ell_H^I + \ell_L^I = 5$, we have

$$m_H(\ell_H^I, T) = \ell_H^*(y_H - 1) + \ell_H^I - T + C_H \quad (11)$$

$$m_L(\ell_H^I, T) = -\ell_H^*(y_L - 1) - \ell_H^I + T + C_L, \quad (12)$$

with $C_H = 10 - c^{B_H}$ and $C_L = 6 + 9y_L - c^{B_L}$.

The Nash bargaining formulation for a negotiation with payoffs 11 and 12 is

$$(T^*, \ell_H^I) = \arg\max \ \left(m_H(\ell_H^I, T) - d_H\right)^p \left(m_L(\ell_H^I, T) - d_L\right)^{2-p}$$
$$s.t.$$
$$\ell_H^I \leq 5,$$
$$|T| \leq E_T,$$

with disagreement payoffs d_H and d_L. The first order conditions with respect to T and ℓ_H^I lead to

$$p(m_L(T, \ell_H^I) - d_L) = (2 - p)(m_H(T, \ell_H^I) - d_H),$$

Substituting 11 and 12, and solving for T we get Expression 6 in Section 2.6 .

Similarly, the non-cooperative solution to the second stage bargaining is given by

$$\begin{gathered}(T^{nc}, \ell_H^{w^{nc}}) = \arg\max\, m_L(\ell_H^I, T) \\ s.t. \\ m_H(\ell_H^I, T) \geq d_H \\ \ell_H^I \leq 5, \\ |T| \leq E_T.\end{gathered} \tag{13}$$

with

$$T^{nc} = \ell_H^*(y_H - 1) + \ell_H^I + C_H - d_H. \tag{14}$$

With the overvaluation payoffs, Equations 11 and 12 become

$$m_H(\ell_H^I, T) = \ell_H^*(y_H - 1) + \ell_H^I(1 + \gamma_H) - T + C_H \tag{15}$$

$$m_L(\ell_H^I, T) = -\ell_H^*(y_L - 1) - \ell_H^I(1 + \gamma_L) + T + C_L, \tag{16}$$

where $C_H = 10 - c^{B_H}$ and $C_L = 6 + 9y_L - c^{B_L} + 5\gamma_L$.

The token transfer and the allocation of irrigated tiles in the Nash bargaining solution to 10 with payoffs 15 and 16 satisfy

$$T^{n,o} = \frac{1}{2}\left[\ell_H^*\left((2-p)(y_H - 1) + p(y_L - 1)\right) - D + \ell_H^{w^{n,o}}\left((2-p)(1+\gamma_H) + p(1+\gamma_L)\right)\right]. \tag{17}$$

And the solution to the non-cooperative bargaining with symmetric water valuation $\gamma_H = \gamma_L = \gamma$ becomes

$$T^{nc.o} = \ell_H^*(y_H - 1) + \ell_H^I(1 + \gamma) + C_H - d_H. \tag{18}$$

A.2 A general bargaining model with costly attributes

Two players denoted by subscript $i = \{1, 2\}$ bargain over the allocation of E^x and E^y jointly endowed units of assets, x and y. Let x_i and y_i be the units of each asset allocated to Player i. While the returns of the assets differ among players, both assets produce identical returns once a given player accrues them. We denote by $u_1(x_1 + y_1)$ the returns function of Player 1 and by $u_2(x_2 + y_2)$ the returns function of Player 2. Despite the equality of returns, assets differ in their costs. While asset x has an attribute that allows for cost savings (*i.e.,* water), asset y lacks this attribute. In particular, Player i has to pay a cost Fy_i when holding an amount y_i of this asset.

Each player has an endowment of tokens E^T that she can use to make a transfer to her counterpart when bargaining over an asset allocation. We denote by $T > 0$ a transfer from Player 1 to Player 2 (conversely, $T < 0$ is a transfer from Player 2 to Player 1). In case of disagreement, players earn fixed payoffs denoted by d_1 and d_2.

Given the assets returns, costs, and endowments, players' payoffs from an agreement (x_1, x_2, y_1, y_2, T) are given by

$$
\begin{aligned}
W_1(x_1, y_1, T) &= u_1(x_1 + y_1) - Fy_1 - T + E^T \\
W_2(x_2, y_2, T) &= u_2(x_2 + y_2) - Fy_2 + T + E^T.
\end{aligned}
$$

These payoff functions imply that, for a given amount of total asset allocation $x_i + y_i$, the player holding a larger share of the costly asset y can be directly compensated through a transfer T. For example, Player 1 can increase her transfer by F tokens to accrue one more unit of x rather than one more unit of y. We now show this is the case for the interior solution to the Nash bargaining problem. Below, we extend these results to non-cooperative solutions and broader solution concepts.

For simplicity, we assume that the returns functions are continuous and twice differentiable with $u_1', u_2' > 0$, $u_1'' < 0$, and $u_2'' < 0$. We focus on the interior solution when the token constraint is not binding.[16]

A.2.1 Nash bargaining solution

First, we assume that the game parameters are such that there exists an interior solution.

[16] Note that in the corner solution, when the token constraint is binding, the token transfer cannot fully adjust to variations in the distribution of the costly asset.

Assumption 1: *The disagreement payoffs, the endowments, and the attribute's cost are such that bargaining is individually beneficial. That is, there exist an allocation* (x_1, y_1) *and a transfer* T *such that* $x_1 \leq E_x$, $y_1 \leq E_y$, $|T| \leq E_T$, $u_1(x_1 + y_1) - Fy_1 - T + E_T > d_1$, *and* $u_2(E_x + E_y - x_1 - y_1) - F(E_y - y_1) + T + E_T > d_2$. *Moreover, both players derive positive net returns from the costly asset,* $F < u_1'(z)$ *and* $F < u_2'(z)$ *for any* $z < E_x + E_y$.

The Nash bargaining solution $(x_1^*, x_2^*, y_1^*, y_2^*, T^*)$ satisfies

$$(x_1^*, x_2^*, y_1^*, y_2^*, T^*) = \arg\max \quad (W_1(x_1^*, y_1^*, T^*) - d_1)^p \, (W_2(x_2^*, y_2^*, T^*) - d_2)^{2-p} \tag{19}$$
$$s.t.$$
$$x_1 + x_2 \leq E_x$$
$$y_1 + y_2 \leq E_y$$
$$|T| \leq E_T,$$

where $p \in (0, 2)$ represents the relative bargaining ability of Player 1.

We focus on the solution to the maximization problem in Expression 19, when the token endowment constraint is not binding. In this case, there is a direct correspondence between the allocation of the costly asset and the transfer.[17]

The first order conditions with respect to the x_1 and x_2 are

$$p\,(W_1 - d_1)^{p-1}\,(W_2 - d_2)^{2-p}\,\frac{\partial W_1}{\partial x_1} = \lambda_x \tag{20}$$
$$(2-p)\,(W_1 - d_1)^{p}\,(W_2 - d_2)^{1-p}\,\frac{\partial W_2}{\partial x_2} = \lambda_x \tag{21}$$

where λ_x is the Lagrange multiplier associated to the endowment constraint of asset x. Equations 20 and 21 together imply

$$\frac{p\,(W_2 - d_2)}{(2-p)\,(W_1 - d_1)} = \frac{u_2'}{u_1'} \tag{22}$$

The first order conditions with respect to the y_1 and y_2 are

[17] Note that in the corner solution, when the token constraint is binding, the token transfer cannot fully adjust to variations in the distribution of the costly asset.

$$p\left(W_1-d_1\right)^{p-1}\left(W_2-d_2\right)^{2-p}\frac{\partial W_1}{\partial y_1}=\lambda_y \tag{23}$$

$$(2-p)\left(W_1-d_1\right)^{p}\left(W_2-d_2\right)^{1-p}\frac{\partial W_2}{\partial y_2}=\lambda_y \tag{24}$$

where λ_y is the Lagrange multiplier associated to the endowment constraint of asset y. Equations 23 and 24 together imply

$$\frac{p\left(W_2-d_2\right)}{(2-p)\left(W_1-d_1\right)}=\frac{u_2'+F}{u_1'+F} \tag{25}$$

From Equations 22 and 25, we see that in the interior solution, the marginal returns should equalize across players:

$$u_1'(x_1^*+y_1^*)=u_2'(x_2^*+y_2^*) \tag{26}$$

Also, when the token endowment is not binding, the first order condition of problem 19 with respect to the token transfer is

$$p\left(W_1-d_1\right)^{p-1}\left(W_2-d_2\right)^{2-p}\frac{\partial W_1}{\partial T}+(2-p)\left(W_1-d_1\right)^{p}\left(W_2-d_2\right)^{1-p}\frac{\partial W_2}{\partial T}=0$$

Substituting the payoff functions and its derivatives, we have

$$T^*=\frac{1}{2}\left[(2-p)\left(u_1(x_1^*+y_1^*)+E^T-d_1\right)-p\left(u_2(E^x+E^y-x_1^*-y_1^*)-FE^y+E^T-d_2\right)\right]-Fy_1^*$$

Given Player 1's total endowment, $z_1^*=x_1^*+y_1^*$, if she accrues one more unit of the costly asset, the transfer is adjusted by, exactly, the cost of a unitary change in y_1^*. That is,

$$\left.\frac{\partial T^*}{\partial y_1^*}\right|_{z_1^*}=-F$$

A.2.2 Non-cooperative solution

In the non-cooperative solution, Player 2 can make a *take-it or leave-it* offer to Player 1 about an asset allocation and a transfer.[18] If Player 1 rejects the offer, both players get their disagreement payoffs, d_1 and d_2.

The equilibrium allocation in this non-cooperative framework, $(x_1^*, x_2^*, y_1^*, y_2^*, T_{NC}^*)$, is characterized by

$$
\begin{gathered}
(x_1^*, x_2^*, y_1^*, y_2^*, T_{NC}^*) = \text{arg max } \ W_2(x_2, y_2, T) \\
s.t. \\
W_1(x_1, y_1, T) \geq d_1 \\
x_1 + x_2 \leq E_x \\
y_1 + y_2 \leq E_y \\
|T| \leq E_T
\end{gathered}
$$

Given Assumption 1 and the assumptions about the returns functions, the asset endowment constraint and the participation constraint of Player 1 are satisfied with equality. We focus on the case when the token endowment constraint is not binding. We can solve for the total allocation of the total assets, $z_1 = x_1 + y_1$, and the F-absorbing transfer, $\hat{T} = T + Fy_1$. We maximize the function

$$
\mathcal{L} = u_2(E^x + E^y - z_1) - FE^y + \hat{T} + E_T - \lambda \left(d_1 - u_1(z_1) + \hat{T} - E^T \right).
$$

In the interior solution, z_1^* satisfies condition 26 and $\hat{T}_{NC}^* = u_1(z_1^*) - d_1 + E^T$. Thus, any x_1^* and y_1^* that satisfy $x_1^* + y_1^* = z_1^*$ are equilibrium allocations in the non-cooperative solution, and

$$
T_{NC}^* = u_1(z_1^*) - d_1 + E^T - Fy_1^*.
$$

Therefore, if z_1^* is held constant, the transfer perfectly absorbs the cost of asset y_1:

[18] For brevity, we present the case in which Player 2 makes the final offer, as it matches our experimental paradigm. However, the solution will be identical for Player 1 having this advantageous position.

$$\left.\frac{\partial T^*_{NC}}{\partial y^*_1}\right|_{z^*_1} = -F.$$

A.3 The general bargaining model expanded with overvaluation

In the framework presented above, the token transfer perfectly adjusts to compensate for the allocation of the asset with the cost-savings attribute. We now propose an extension to this framework, allowing for an overvaluation of this attribute.

If players have idiosyncratic preferences over the asset with the cost-saving attribute, and they take these preferences into account when bargaining over an asset allocation, their payoff functions can be written as

$$W_1(x_1, y_1, T) = u_1(x_1 + y_1) - Fy_1 + \gamma_1 x_1 - T + E^T$$
$$W_2(x_2, y_2, T) = u_2(x_2 + y_2) - Fy_2 + \gamma_2 x_2 + T + E^T,$$

where $\gamma_1, \gamma_2 > 0$ capture players preferences over the asset with the cost-savings attribute.[19]

We thus have the following first order conditions, for $i = \{1, 2\}$

$$\frac{\partial W_i}{\partial x_i} = u'_i(x_i + y_i) + \gamma_i$$
$$\frac{\partial W_i}{\partial y_i} = u'_i(x_i + y_i) - F$$

Substituting into 20 and 21

$$u'_1(x^*_1 + y^*_1)(\gamma_2 + F) + F(\gamma_1 - \gamma_2) = u'_2(x^*_2 + y^*_2)(\gamma_1 + F) \tag{27}$$

And the equilibrium allocation in the Nash bargaining solution satisfies

[19]For simplicity, here we assume linear preferences. This should satisfy the regularity condition that either $\gamma_1, \gamma_2 < F$ or $\gamma_1, \gamma_2 > F$. Similar results hold with more flexible functional forms.

$$
\begin{aligned}
\frac{u_1'(x_1^* + y_1^*)}{\gamma_1 - F} &= \frac{u_2'(x_2^* + y_2^*)}{\gamma_2 - F} \\
x_1^* + x_2^* &\leq E^x \\
y_1^* + y_2^* &\leq E^y.
\end{aligned}
\tag{28}
$$

As before, any combination of assets (x_i, y_i) that satisfy conditions 28 is an equilibrium allocation, and the token transfer adjusts according to the distribution of the costly asset. In particular, the equilibrium token transfer is

$$
\begin{aligned}
T^* = \frac{1}{2} &\left[(2-p)\left(u_1(z_1^*) + E^T - d_1\right) - p\left(u_2(E^z - z_1^*)E^T - d_2\right)\right] \\
&+ \frac{1}{2}\left[(z_1^* - y_1^*)\left((2-p)\gamma_1 + p\gamma_2\right) - p\gamma_2 E^x\right] \\
&+ \frac{1}{2}\left[pFE^y - 2Fy_1^*\right]
\end{aligned}
$$

with

$$
\frac{\partial T^*}{y_1^*} = -\frac{1}{2}\left[(2-p)\gamma_1 + p\gamma_2\right] - F.
$$

Conditional on Player 1's total amount of assets, $(x_1 + y_1)$, a decrease in the asset with the cost-savings attribute x_1 (vis-a-vis an increase in her amount of y_1) decreases the transfer she makes to her counterpart. This transfer includes the additional costs F she is bearing, and a weighted sum of players' preferences over the cost-savings asset. In the special case in which $\gamma_1 = \gamma_2 = \gamma$, we have

$$
\frac{\partial T^*}{y_1^*} = -\gamma - F
$$

When sacrificing one unit of asset x in exchange of a unit of asset y, the net transfer decreases by the increase in costs and utility losses given player's preferences for the asset x.

A.4 Additional Tables and Figures

Table A.1: Main characteristics of municipalities in the sample

Municipality	Population	Share Rural	Main Crop	Mean Rainfall	Water Supply Dry Year	Water Supply Humid Year
California	2020	45.64	Potato	822.27	46.88	34.69
Confines	2698	84.95	Coffee	2602.15	110.82	56.52
El Playón	11520	51.2	Cocoa	1817.91	583.49	431.78
Matanza	5201	79.12	Coffee	999.55	99.46	73.60
Ocaña	99741	9.14	Tomato	1032.82	227.15	124.93
Rionegro	26680	74.38	African palm oil	1832.38	1108.56	820.33
Simacota	7593	67.07	African palm oil	2264.21	1289.92	799.75
Vélez	18932	45.7	Sugar cane (Panela)	2086.48	784.38	400.04

Note: Population and the share of rural population (%) from CEDE municipality data. Mean rainfall measures the average of yearly rainfall between the 1950s until the 2020s in the closest IDEAM station in mm, water supply from ENA-IDEAM by type of year as classified by in 10^6 cubic meters.

Table A.2: OLS Estimations with interacted controls: Token Transfers for [5:4] and [4:5] land allocations.

	(1)	(2)	(3)	(4)
ℓ_H	5.24***	3.56***	3.31**	3.18**
	(0.92)	(0.98)	(1.47)	(1.50)
ℓ_H^I		3.48***	3.37**	3.88**
		(0.91)	(1.07)	(1.08)
H is male			0.18	0.50
			(0.99)	(1.37)
L is male			0.89	0.87
			(0.83)	(1.31)
H is married			0.98	-0.98
			(1.38)	(1.90)
L is married			-0.26	-3.39
			(0.96)	(2.62)
H owns farm			0.12	3.59
			(1.04)	(2.50)
L owns farm			-0.052	1.35
			(1.95)	(1.96)
$\text{Male}_H \times \text{Male}_L$				-0.080
				(2.11)
$\text{Married}_H \times \text{Married}_L$				3.94
				(2.70)
$\text{Owns Farm}_H \times \text{Owns Farm}_L$				-4.15
				(2.62)
Constant	-2.24**	-3.26***	-3.62	-3.77
	(0.75)	(0.65)	(2.16)	(2.68)
Observations	48	48	48	48
R^2	0.42	0.57	0.64	0.70
Controls	No	No	Yes	Yes
Fixed effects	No	No	Yes	Yes
(1) *p-val.* coeff. $\ell_H^I = 1$		0.0092	0.034	0.013

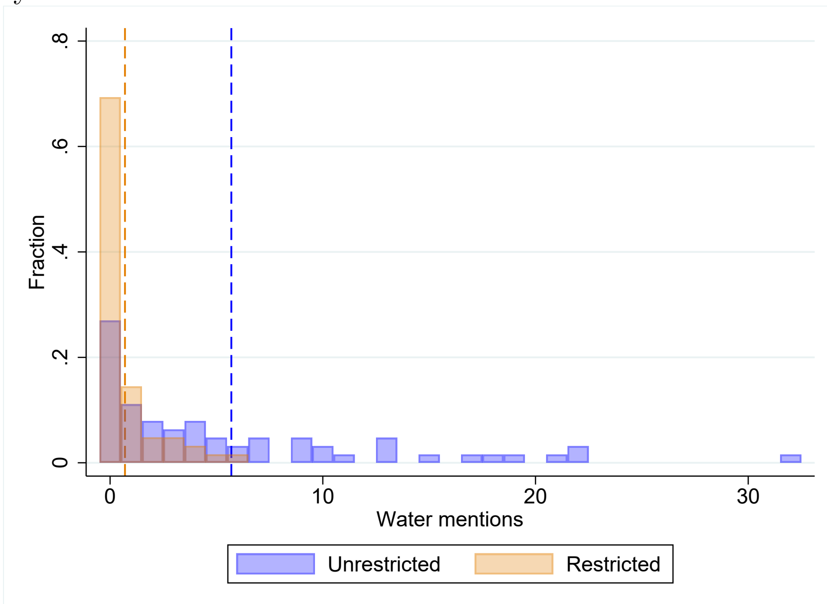
Note: Huber-White standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. $\ell_{H,i}$ and $\ell_{H,i}^I$ are scaled to take values of 0 and 1. Huber-White standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Row (1), at the bottom of each panel, presents the *p-value* of a test with $H_o : \alpha_1 = 1$.

Table A.3: OLS Estimations with interacted controls: Token Transfers for the entire sample.

	(1)	(2)	(3)	(4)
ℓ_H	1.00***	-0.13	-0.027	-0.17
	(0.28)	(0.65)	(0.68)	(0.71)
ℓ_H^I		2.06*	2.18**	2.65**
		(1.08)	(1.06)	(1.11)
H is male			-0.81	-0.90
			(0.85)	(1.27)
L is male			0.79	0.72
			(0.87)	(1.37)
H is married			3.08**	2.09
			(1.06)	(1.85)
L is married			-0.17	-1.69
			(1.04)	(2.10)
H owns farm			-0.28	2.21
			(1.32)	(2.90)
L owns farm			-1.26	0.62
			(1.73)	(1.75)
$\text{Male}_H \times \text{Male}_L$				0.15
				(2.26)
$\text{Married}_H \times \text{Married}_L$				1.78
				(2.30)
$\text{Owns Farm}_H \times \text{Owns Farm}_L$				-3.43
				(3.11)
Constant	-3.47**	-3.54**	-3.40	-4.73
	(1.42)	(1.44)	(2.70)	(3.26)
Observations	64	64	64	64
R^2	0.19	0.24	0.45	0.47
Controls	No	No	Yes	Yes
Fixed effects	No	No	Yes	Yes
(1) *p-val.* coeff. $\ell_H^I = 1$		0.33	0.27	0.14

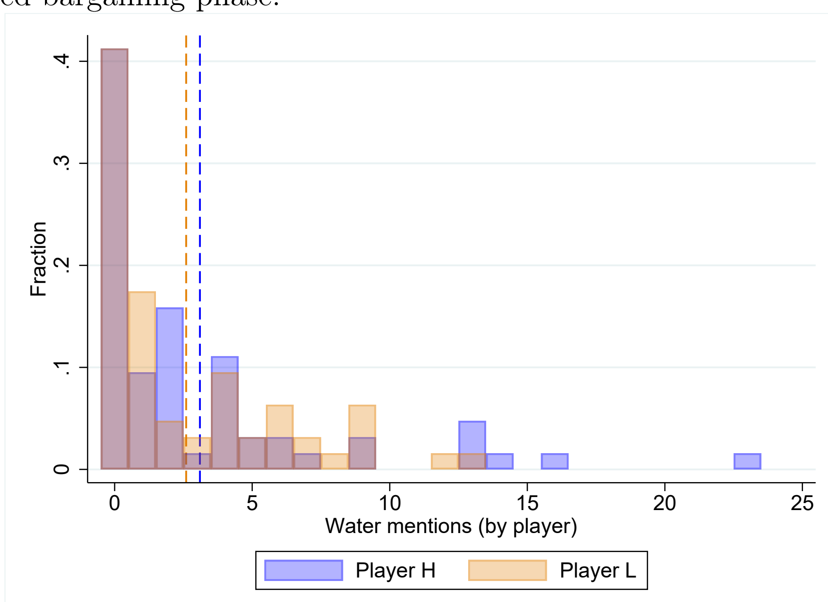
Note: Huber-White standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Row (1), at the bottom of each panel, presents the *p-value* of a test with $H_o : \alpha_1 = 1$.

Figure A.1: Distribution of the frequency of 'water' mentions during the unstructured bargaining phase by treatment variations.



Note: The unconstrained treatment corresponds to the treatment variation in which players are allowed to split the land (our sample of study).

Figure A.2: Distribution of the number of times participants H and L said 'water' during the unstructured bargaining phase.



Note: Dashed vertical lines correspond to the average number of times Player H (in blue) and Player L (in orange) mentioned 'water' during the bargaining phase.

Supplementary material

Water valuation using incentivized bargaining games

I Game Protocol: Translated Version

General Instructions

Welcome. We want to thank you for your participation in this activity, which will last for approximately one hour. It includes the explanation of the game (about 35 minutes), playing the game (10 minutes) and a short survey at the end (10 minutes). Once the survey is completed we will give you the earnings from the game. This activity has been funded by Universidad (undisclosed for peer review).

This is a bargaining game in which you and the person with whom you are matched to play the game have jointly inherited a land plot that you will have to divide. Each one of you have also inherited some tokens that represent cash. You can use these tokens in case you want to keep a larger share of the plot. We will explain how are computed your earnings based on the number of tokens and the number of tiles from the land plot you keep at the end of the game.

It is important to clarify that earnings from this game do not correspond to a participation fee, so we expect that you participate in other research activities in the future, even if there will be no payment. We introduce earnings to make sure your game decisions have economic consequences, so they seem closer to your everyday decisions. The other participants in this activity will not know, during or after the experiment, anything about your earnings or about your responses in the survey. The game rules you are about to hear might be different from the rules that apply when other participants from this municipality took part in the game. Therefore, the comments you might have heard do not necessarily apply.

Introduction: the Land Division

This activity aims at understanding the production and division decisions of agricultural land in {name of municipality}. You have jointly inherited the plot "The Triangle," composed of nine smaller tiles of equal size. In addition, each one of you have inherited 10 tokens.

`(The monitor delivers the triangular map and the tokens)`

At the end of the game, for each tile you own you will receive a die. If you keep one tile, you receive one die; you keep two tiles, you receive two dice, and so on. All dice will be rolled simultaneously inside a box. The sum of all dice outcomes will be your total output, which will be exchanged for tokens. We will explain later other land production rules in this game.

Keeping more tiles means a higher production after rolling the dice, but you will need to agree with the other person how many tokens will be exchanged to accept the proposal. You are allowed to use all your tokens in the bargaining game. It is possible that one of you keep all nine tiles, or that you find an acceptable division of the plot.

Keeping all, or most, of the tiles is good because you will roll more dice, so you can produce more tokens. But you will have to bargain on how many of the 10 tokens you will give to the other person.

At the end of the game you will receive $1.000 (Colombian pesos) for every token you own. All the yellow (originally endowed) tokens and all the output tokens are taken into account to compute your earnings.

Land Production

The output of each tile in the land plot could be good, average, or poor. Since not every person is equally productive with land, one of you will roll big dice and the other one will roll small dice at the end of the game. With the big dice, the output per tile could be [**3, 4, or 5 / 2, 4, or 6**] tokens. With the small dice, the output per tile could be [**2, 3, or 4 / 1, 3, or 5**] tokens. Since each number appears twice in each die, the probability that the output of each tile is good, average, or poor is the same.

We will divide you into two groups of players. Each one of you will roll a plastic die. The two persons with the highest number will form and group, and the two persons with the lowest number will form the other group.

Now we will decide who will have the big and the small dice in each group. Each one will roll again the die, and the person in each group with the highest number will keep the big dice and the other will keep the small dice.

```
(The monitor assigns participants into groups based on the dice outcomes,
and then assigns the big and small dice. The monitor delivers one of
the big/small dice to each participant.)
```

Production Costs: Water

Two out of the three triangles sides are marked with a blue line. This blue line represents the water stream that covers some of the tiles. A tile has access to water when one of the sides of the tile is covered by the blue line. If this is the case, a drop of water is drawn in the middle of the tile. In total, five tiles have access to water, and four tiles do not have access to water.

In the tiles with access to water the production cost is zero. In the tiles without access to water the production cost is one. When we compute your earnings, we will substract one token for each tile without access to water.

Production Costs: Boundaries

If you decide to divide the land plot you will need to set the boundaries that divide each person's tiles. When one of you makes a proposal on how to divide the land, we will put one of these red logs to draw the boundaries. Each red log drawing a boundary costs one token to each one of you. When we compute your earnings, we will substract one token for each red log.

`(The monitor draws a division and puts in the map the corresponding red logs)`

Computing Earnings

You will receive $1.000 (Colombian pesos) for every token you kept at the end of the game. Remember there are two strategies to accrue tokens. You can keep your own tokens and demand tokens from the other person in exchange for land tiles; or you can keep tiles and produce additional tokens by rolling the dice. Remember that you will have a deduction in your earnings for each tile without access to water, and for each red log drawing a boundary.

The following is a step-by-step summary of instructions:

1. Use the red logs to mark the proposed land division and decide how many tokens would be acceptable.
2. Verify the minimum and maximum production according to the proposed land division.
3. Subtract one token per tile without access to water, and one token per red log.
4. Sum the minimum and maximum output after costs and your remaining tokens.
5. Multiply by $1.000 (Colombian pesos) the final number of tokens

Example

[See Figure I.1]

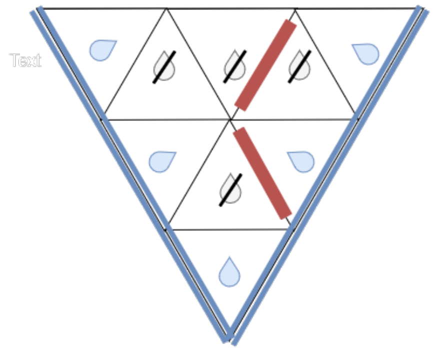


Figure I.1: Example with a [6:3] plot division.

1. You have the big dice. You propose to keep 6 tiles in exchange for 3 tokens.

2. Your minimum output per tile is [**3** / **2**] and your maximum output per tile is [**5** / **6**] tokens. With your six tiles your minimum output is [**18** / **12**] and your maximum output is [**30** / **36**] tokens.

3. Your production cost is 5 tokens. Three tiles do not have access to water and you use two red logs to draw the boundaries.

4. Subtracting your costs and the 3 tokens you give to the other person, your minimum number of tokens will be [**10+18-5-3 = 20** / **10+12-5-3 = 14**] and your maximum number of tokens will be [**10+30-8 = 32** / **10+36-8 = 38**].

5. Your earnings will be between [**$20.000 and $32.000** / **$14.000 and $36.000**] (Colombian pesos) if you reach this agreement.

How to bargain?

You will have 5 minutes to bargain. We will not be present during the bargaining phase, but the conversation will be recorded. This will help us to understand which are the key elements in the bargaining process. Please let us know if you reach an agreement before the time is over.

Any of you can make a proposal. The bargaining might include a transfer, that must be of at most the 10 endowed tokens. You can make an agreement in which the plot is divided, or not, and you might use, or not, the endowed tokens. Once the time is over the player with the big die will make a proposal including the land division, and the proposed tokens to be demanded or given. We will record this proposal in the contract sheet. Then, the player with the small die will decide whether to accept or reject the proposal. In case of rejection, he/she could make a counterproposal including the land division, and the proposed tokens to be demanded or given. This is the last chance to reach an agreement.

What happens when an agreement is not reached?

Each person keeps the 10 endowed tokens and received two tiles with access to water, and two tiles without access to water as is shown in the map (see Figure I.2). Under this land division one of the tiles is lost due to the lawyers' fees to reach this arrangement.

End of the Game

In private, I will give you a die for each tile owned at the end of the game. You will roll all dice inside a box, and only the two of us will know the outcome. In other words, the other person will not know your dice roll outcome nor your final earnings.

`(The coordinator asks if there are questions.)`

If there are no further questions we will read aloud the informed consent. This is a document in which you declare that you are here under your own will and that you have understood the rules of the game. And we declare that all the gathered information will be treated under confidentiality and only with academic purposes.

`(The coordinator reads the informed consent.)`

If you agree with the informed consent, please sign it.

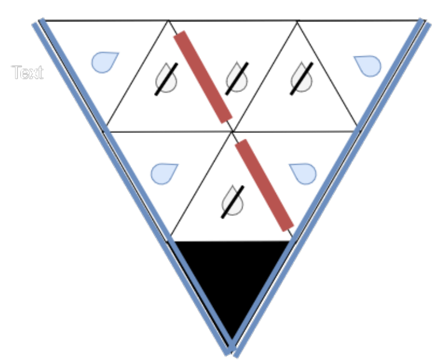


Figure I.2: Land division if an agreement is not reached.

II Game Protocol: Original Version (in Spanish)

Instrucciones Generales

Bienvenidos. Queremos agradecerles por participar en esta actividad que durará aproximadamente una hora. Este tiempo incluye la explicación del ejercicio (35 minutos), el ejercicio como tal (10 minutos) y una corta encuesta al final (10 minutos). Tras finalizar la encuesta, le entregaremos sus ganancias del juego. Los fondos para cubrir estos gastos han sido proporcionados por la Universidad (no revelada para revisión de pares).

Este es un juego de negociación donde usted y la persona con quién jugará han heredado una finca que deberán repartirse. También han heredado unas fichas que representan dinero. Ustedes pueden utilizar estas fichas en la negociación en caso que quieran quedarse con una mayor parte de la finca. A continuación explicaremos cómo se van a calcular sus ganancias según el número de fichas y el número de parcelas con las que quede al final del juego.

Las ganancias del juego no son un pago por participar, por lo que esperamos que participe en futuras actividades de otros investigadores así no haya un pago de por medio. Las ganancias del juego sirven para que sus decisiones tengan consecuencias económicas, y se parezcan más a las decisiones que toma en su vida diaria. Los otros participantes no sabrán durante o después del experimento nada sobre sus ganancias o sus respuestas en la encuesta.

Las reglas del juego pueden ser diferentes a las reglas que aplicaron cuando otros habitantes de este municipio participaron, por lo que los comentarios que usted haya podido escuchar no necesariamente aplican a este juego. Ahora podemos comenzar.

Introducción: la repartición

Este ejercicio busca entender las decisiones de producción y repartición de la tierra en {nombre del municipio}. Ustedes han heredado la finca "El Triángulo," que está compuesta de 9 parcelas pequeñas del mismo tamaño. Además, cada uno ha heredado 10 fichas.

`(El monitor entrega el mapa triangular y las fichas)`

Al final del juego, por cada parcela que tenga, se le entregará un dado.Si al final se queda con una parcela, recibirá un dado; si se queda con dos, se le entregarán dos, y así sucesivamente, hasta recibir nueve dados si se queda con nueve parcelas./ Si se queda toda la finca, con nueve parcelas, usted recibe nueve dados. Luego, los dados se van a lanzar, todos a la vez, dentro de una caja. El resultado del lanzamiento de los dados representará su producción total, la cual se verá traducida en fichas. Más adelante explicaremos las reglas adicionales de la producción.

Tener más parcelas implica mayor producción por lanzar los dados, pero deberá negociar cuántas fichas le da a su compañero por aceptar ese negocio. Usted podrá usar las 10 fichas para negociar la repartición de la finca con su compañero. Es posible que uno de ustedes se quede con toda la finca, o que encuentren una división de la finca.

Quedarse con todas, o la mayoría de parcelas es bueno porque va a recibir más dados, por lo que puede producir más fichas. Pero deberá negociar cuántas fichas, de las 10 que originalmente heredó, le dará a su compañero por aceptar ese arreglo.

Al final del juego usted recibirá $1.000 (pesos colombianos) por cada ficha que tenga. Cuentan todas las fichas amarillas y todas las fichas de la producción tras lanzar los dados.

Producción de la finca

La producción de una parcela puede ser buena, mala o regular. Como no todas las personas producen la misma cantidad cuando trabajan la tierra, uno de ustedes va a tener dados grandes y el otro va a tener dados pequeños. Con el dado grande el producto de cada parcela puede ser de [**3, 4, ó 5 / 2, 4, ó 6**] fichas. Con el dado pequeño el producto de cada parcela puede ser de [**2, 3, ó 4 / 1, 3, ó 5**] fichas. Como cada número aparece dos veces en el dado, usted tiene la misma probabilidad de que la producción sea buena, mala o regular.

Ahora vamos a armar las parejas. Cada uno va a lanzar un dado de plástico. Las dos personas que saquen el número más grande serán la primera pareja, y las dos personas que saquen el número más pequeño serán la segunda pareja.

Ahora vamos a repartir los dados de producción. Cada uno va a lanzar de nuevo un dado de plástico. Quién saque el número más grande se quedará con el dado grande, y quién saque el número más pequeño se quedará con el dado pequeño.

`(El monitor asigna a los participantes en grupos según los resultados del dado, y luego asigna los dados grandes y pequeños. El monitor entrega sólo un dado grande/pequeño a cada participante.)`

Costos de producción: agua

Dos de los tres lados del triángulo tienen marcada una línea azul que simboliza una quebrada o un río que pasa por algunas parcelas de la finca. Una parcela tiene agua cuando uno de los lados de la parcela tiene la línea azul. En esos casos, en el centro de la parcela hay dibujada una gota de agua. Hay cinco parcelas con agua y cuatro parcelas sin agua.

En las parcelas con agua, el costo de producir es cero. En las parcelas sin agua, el costo de producir es 1. Cuando calculemos las ganancias, vamos a restarle una ficha por cada parcela sin agua.

Costos de producción: linderos

Si deciden dividirse la finca, ustedes van a poner linderos que dividan las parcelas de cada uno. Cuando ustedes hagan una propuesta sobre cómo dividir la finca yo pondré una barra roja que marca por dónde pasa el lindero. Cada lindero le cuesta 1 ficha a cada uno. Cuando calculemos las ganancias, vamos a restarle una ficha por cada lindero que divida la finca.

`(El monitor traza una división y pone sobre el mapa las barras rojas)`

Calcular las ganancias finales

Usted recibirá $1.000 (pesos colombianos) por cada ficha que tenga al final del juego. Hay dos formas de acumular fichas. Puede quedarse con las fichas que le fueron entregadas al inicio y pedirle más de esas fichas a su compañero durante la negociación. O usted también puede pedir parcelas y producir fichas adicionales lanzando los dados. Recuerde que reduciremos sus ganancias en una ficha por cada parcela sin acceso a agua y una fichas por cada lindero que divida la finca.

Este es un resumen de las instrucciones:

1. Marcar con la barra roja los linderos de la división que quieren negociar y decidir cuántas fichas intercambiarían por aceptar ese negocio.

2. Verificar la producción máxima y mínima de acuerdo con la división propuesta la finca.

3. Restar una ficha por cada parcela sin agua, y una por cada lindero.

4. Sumar las fichas de producción mínima y máxima después de los costos, y las fichas que le quedan después de negociar.

5. Multiplicar el total de fichas que le quedan por $1.000 (pesos colombianos)

Veamos un ejemplo

[Vea la Figura I.1]

1. Usted tiene el dado grande y propone quedarse con 6 parcelas y entregar a cambio 3 fichas.

2. Su producción mínima por parcela es [**3** / **2**] fichas, y su producción máxima es [**5** / **6**] fichas. Con sus seis parcelas su producción mínima es [**18** / **12**] fichas, y su producción máxima es [**30** / **36**] fichas.
3. Su costo de producción es de 5 fichas. Tres parcelas no tienen agua, y hay dos linderos.
4. Quitando las 5 fichas de sus costos, y las 3 fichas que le da a la otra persona, su total de fichas al final será de mínimo [**10+18-5-3 = 20** / **10+12-5-3 = 14**], y máximo de [**10+30-8 = 32** / **10+36-8 = 38**].
5. Sus ganancias estarán entre [**$20.000 and $32.000** / **$14.000 and $36.000**] (pesos colombianos) si aceptan este negocio.

¿Cómo se realiza la negociación?

Ustedes tendrán 5 minutos para negociar. La conversación que ustedes tengan durante estos 5 minutos será grabada, pero nosotros no estaremos presentes. Esto nos ayudará a entender cuáles son los elementos más importantes en la negociación. Si llegan a un acuerdo antes de los 5 minutos por favor avísennos.

Cualquiera puede proponerle al otro un negocio. La negociación puede incluir una transferencia que sea igual o menor a las 10 fichas que cada uno recibió al inicio. Pueden llegar a un acuerdo en que la finca se divide, o no, y pueden usar o no las fichas como parte del acuerdo. Cuando termine el tiempo de negociación el jugador del dado grande propondrá cómo dividir la finca, y cuántas fichas entrega o pide. Nosotros lo registraremos en la hoja de contrato. Luego, el jugador del dado pequeño decide si acepta la propuesta. Si no la acepta, puede hacerle una contrapropuesta al compañero. En la contrapropuesta propondrá cómo dividir la finca, y cuántas fichas entrega o pide. Esta es la última oportunidad de que lleguen a un acuerdo.

¿Qué pasa si luego de la contrapropuesta no llegan a un acuerdo?

Cada uno mantiene sus fichas iniciales y se queda con dos parcelas con agua y dos parcelas sin agua (ver la Figura I.2). En esta asignación se pierde una de las nueve parcelas, que es equivalente a los gastos de un proceso judicial cuando no logran llegar a un acuerdo.

Finalización del juego

Yo llevaré a cada uno aparte y le entregaré un dado por cada parcela que posea. Cada uno lanzará los dados dentro de la caja, y solo los dos veremos el resultado. Su compañero no sabrá cuáles fueron los números que salieron en los dados y no conocerá su pago final.

`(El coordinador pregunta si hay dudas.)`

Si no hay preguntas vamos a leer en voz alta el consentimiento informado. Este es un documento en el que ustedes declaran que están aquí bajo su voluntad y que han entendido las instrucciones del juego, y nosotros declaramos que los datos serán utilizados de forma confidencial y con fines académicos.

`(El coordinador lee el consentimiento informado.)`

Si está de acuerdo, por favor firme el consentimiento informado que le ha sido entregado.