Preventing over-exploitation in a dynamic CPR game with heterogeneous players: A comparison of awareness, communication and advice in the lab

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Abstract

Rivalry in extractive CPR, like groundwater, implies that agents extract as much as they need, and even more if they fear that others behave the same way (Gardner et al., 1990; Walker et al., 1990 and 2000), leading to the 'tragedy of the commons' (Hardin, 1968). Users depleting a groundwater CPR typically face two types of appropriation externalities (Gardner et al., 1997): a static externality, whereby individuals' extraction costs at any given date are affected by the total level of extraction at that date, and a dynamic externality, whereby the extraction cost any later date is affected by past cumulative extractions.
Groundwater is a very important source of irrigation water, the latter representing more than 70% of the total water uses on earth (FAO, 2022). In North Africa half of the current groundwater water withdrawals exceed natural rates of water recharge (Mayaux et al., 2022). Maghreb Countries are highly dependent on their groundwater resources for their agricultural development. The public policies of the last decades triggered radical changes in newly irrigated areas (extension areas) and in traditional oases (Kadiri et al., 2022). This resulted in a quick intensification of local agriculture, like in Tunisia, where oases are currently facing sustainability concerns due to "uncontrolled expansion of irrigated areas, overexploitation of groundwater resources, and soil degradation" (Ghazouani *et al.*, 2009; Mekki *et al.*, 2013).

In Tunisia, the Complex terminal aquifer in Kebili is under the threat of overexploitation, as its exploitation leads to a 1 meter lowering of the watertable/year. This is due to the combination of a very low level of water recharge and high level of water use for irrigation mainly (Trigui et al., 2021).

In Tunisian oases, traditional farmers are organised in water users associations, called GDA

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(French acronym for Agricultural Development Groups), which coexist with newly settled extension farmers. Many GDA farmers have also plots in the extensions, where, like the extension farmers they dig illicit private boreholes that are not declared to the local authority for water management (CRDA) (Farolfi et al., 2022).

Unregulated water extraction in the extensions is a major cause for groundwater overexploitation (Mekki *et al.*, 2013), a situation that is likely to lead to the collapse of the system in the short or medium term. Urgent and drastic policy measures are therefore needed (Petit et al., 2017) to prevent such adverse outcome.

Current policies to match the problem are limited to the attempt by the CRDA to reduce access to water by limiting the number of boreholes. However, the overwhelming presence of illicit boreholes in Tunisian newly irrigated areas shows clearly the ineffectiveness of the measure. Alternative governance tools are necessary in order to face groundwater overexploitation in the Tunisian oases.

We address the issue of designing appropriate policy instruments to prevent overexploitation, based on laboratory experiments and lab-in-the-field experiments. Our aim is to compare several feasible instruments that can potentially be implemented in the field, by adopting a step-by-step experimental approach. In a first step, we will try to establish the effectiveness of the aforementioned alternative instruments to address the issue of overexploitation in a framed laboratory setting. This is done with standard student subjects, using the LEEM facility. In a second step, we replicate the standard laboratory experiments with Tunisian students of the INAT. The final step will be to replicate the lab experiment with Tunisian farmers directly involved in the exploitation of groundwater in the oasis of Kebili, in a lab-in-the-field setting. Step 1 will allow us to provide causal evidence of the effectiveness of the instruments and internal validity. Step 2 will allow us to control for the nationality of the student subjects and the robustness of the lab-findings according to location (Montpellier vs Tunis). The final step will provide external validity of the experimental findings of steps 1 and 2, following the methodology of Bchir (2014).

The theoretical framework of our experiments is based on the dynamic model of groundwater extraction (Gardner et al., 1997), which involves static and dynamic externalities as mentioned above. The novelty of our approach, is that we extended this model to two player-types, that correspond to the two types of farmers described above (GDA members and farmers exploiting extension surfaces). These types are documented in Farolfi et al. (2022), presenting the results of a survey on the Jemna oasis, Governorate of Kebili in Southern Tunisia. We assume a recharge rate = 0, which is adapted to the local situation, as indicated by Trigui et al. (2021). We consider a five-player dynamic extraction game over 7 periods. 3 players are GDA-members and 2 players are external with respect to the GDA. All GDA members benefit from a fixed (imposed) amount of resource in each period, corresponding to their weekly water turn. One of them depends exclusively from this weekly water turn. The two other players have also access to water that they pump in an extension (GDA members who have built an extension). Finally, the two remaining players do not belong to the GDA and extract only in an extension area. This set-up is common knowledge to the players in the game and to the subjects in the experiment.

The experiment involves 4 treatments, *laissez-faire, awareness, communication and advice*, thereafter. In the *laissez-faire* treatment, players can exploit the CPR without regulation. This treatment serves as a control for our test treatments, which all implement a mechanism to prevent adverse externalities due to over-exploitation. In the *awareness* treatment, subjects can use a simulator to get aware of the impact of their withdrawals on the static and dynamic externalities. We expect that, being aware will lower their extraction if subjects are motivated by the maximization of the group outcome (Charness & Rabin, 2002). In the *communication* treatment, in addition to the simulator, players are allowed to communicate through a chat room. They can therefore share information about their beliefs about the game, recommendations for the group and about their simulations. Finally, in the *advice* treatment, subjects will get expert feedback about their strategies in addition to the simula-

tor. In summary, the awareness treatment allows us to estimate the impact of being aware of externalities, the communication treatment allows us to estimate the additional impact of communication on top of awareness and the advice treatment allows estimating the additional impact of advice on top of awareness.

All subjects perform two sequences of the extraction game. Sequence 1 is common to all sessions and consists of the baseline *laissez faire* treatment. In sequence 2, subjects are involved in one of the 4 treatments discussed above. The reference groups play the *laissez-faire* treatment in both sequences.

We present preliminary results of our lab setting. We run 3 sessions (60 subjects) of each treatment. We rely on difference-in-differences estimation to identify the effect of the introduction of policy measures relying on variation in the level of extraction both across groups and over sequences. Extraction levels are compared before and after policy implementation in treated groups with the extraction level of the baseline groups without policy.

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