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Analysis

Inequality and rules in the governance of water resources

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ABSTRACT

This paper considers two types of farmer, with unequal land endowments, who voluntarily contribute to a joint project for the maintenance of an irrigation network. The collective output (water) is distributed according to some allocation rule and used by each farmer in combination with land to produce a final good. The analysis shows that the initial degree of inequality affects the allocation rule that maximises the amount of water collectively provided. Specifically, two forces act in opposite directions. The first 'effort-augmenting' force pushes the distribution of water towards the agent with the higher return to water in the attempt to maximise the *aggregate* level of effort. This is the prominent force when efforts are highly substitute. If efforts display some degree of complementarity, the effort *mix*, alongside with aggregate effort, becomes important. A second 'effort-mix' force then emerges, that favours more egalitarian or even progressive water allocation rules.

1. Introduction

The collective management of water and other natural resources is increasingly being recognised as a key determinant of economic performance, especially in the rural sector of developing economies (Baland and Platteau, 1996; Bardhan et al., 2006; Ostrom, 2003; Platteau, 1991). By its nature, collective action involves interdependency among individuals.[1] This, combined with the non-excludable and rival nature of many natural resources, poses significant challenges and raises the question of whether individuals are capable to successfully manage resources held in common.

Over the past decades, significant advancements have been made in the collective action literature and the earlier conventional wisdom that the users of a common resource are inevitably trapped in a process leading to overuse and degradation (Hardin, 1968) is no longer regarded as the only relevant view. Using multiple methods of analysis, scholars from different disciplines have shown that the tragedy of the commons is not inevitable.[2] Importantly, they have made considerable progress in identifying the conditions that are most likely to influence the success of collective action and collective good provision. These include: (i) users group characteristics, such as group size and heterogeneity; (ii) institutional arrangements; and (iii) physical attributes of common-pool resources (Agrawal, 2007; Ostrom, 2007; Sandler, 1992). Yet, as suggested by Ostrom et al., advancing our understanding of collective action problems requires further investigation of the relationships between these key dimensions, as well as of broader contextual variables (Poteete et al., 2010).

This paper focuses on the mechanisms linking heterogeneity, institutions and incentives within the context of water resources. Specifically, it investigates whether and how land inequality – which is taken here as an exogenous source of heterogeneity – affects the allocation rule that maximises the amount of water collectively provided.[3] In order to trace the fundamental trade-offs that relate initial inequality to the optimal water allocation rule, we introduce a stylised model in which two types of farmer, with unequal land endowments, can voluntarily contribute to a joint project for the maintenance of an irrigation network. Maintenance activity increases the amount of water effectively available. The collective output (water) is then distributed according to some allocation rule and used by each farmer in combination with land to produce a final good.

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[1] For example, the maintenance of an irrigation network requires the stabilisation of the rims and the cleaning of minor channels across farmers' land. In this context, the effort of one farmer is likely to influence the activity of other farmers along the network, thus implying strategic interactions among individual users.

[2] Examples of collective behaviour have been identified in a wide range of contexts. These include the management of fisheries (e.g., Acheson, 2003; Singleton, 1999), forests (e.g., McKean, 1986, 2000; Schoonmaker Freudnberger, 1993), pastures (e.g., Gilles et al., 1992; Netting, 1981; Nugent and Sanchez, 1999), and groundwater resources (e.g., Blomquist, 1992; Marchiori et al., 2012; Trawick, 2003).

[3] The paper approaches the problem from a non-cooperative perspective, by studying how inequality and rules affect agents' incentives to contribute in a Nash equilibrium. This is generally regarded as the natural starting point in this kind of analyses. A possible extension for future research is to study the problem from a cooperative perspective. In a cooperative setting, considerations of bargaining power become particularly important. This may require a more explicit account of possible relationships between inequality and power. Other factors we abstract from here, but may affect cooperative decision-making include reciprocity and social norms. The importance of such factors for the emergence of cooperative behaviours has been shown, for example, by Bicchieri (2006) and, within an evolutionary-game-theoretic framework, by Sethi and Somanathan (1996, 2003) and Noailly et al. (2007).

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We find that the initial degree of inequality does affect the optimal allocation rule, and that the nature of such relationship depends on technological features such as the complementarity between agents' efforts in the realisation of the collective good. More precisely, we identify two key forces, which affect the distribution of water in opposite directions. The first force, which is referred to as 'effort-augmenting', seeks to maximise the *aggregate* level of effort by pushing the distribution of water towards the agent with the higher marginal return to water. Due to the assumed complementarity between land and water in the production of the final good, this is the agent with the larger endowment of land. This force is the prominent force when efforts are highly substitute. Typically, however, the production technology for the collective good displays some degree of complementarity between agents' efforts. In such cases, the effort *mix*, alongside with aggregate effort, becomes critical for the level of collective good provision. Hence, a second force kicks in, which seeks to correct the effort-augmenting effect by distributing water so as to reach the optimal mix of effort. As we will show, this 'effort-mix' force calls for more egalitarian or even progressive water allocation rules.

The role of inequality has been much debated in the collective action literature, with theoretical works suggesting that inequality can have either positive (Alix-Garcia, 2007; Olson, 1965), negative (Ostrom, 1990), non-linear (Baland et al., 2007; Dayton-Johnson and Bardhan, 2002), or ambiguous (Baland and Platteau, 1997; Bardhan et al., 2006) effects on collective action. Much like the theoretical work in this area, the results from econometric and experimental studies are rather mixed with authors finding that inequality tends to reduce public good provision (Anderson et al., 2003; Bergstrom et al., 1986), while others report higher contributions (Cardenas, 2002; Chan et al., 1996; Cherry et al., 2003). A closer look at this wide range of results suggests that inequality often interact with other factors – e.g., technological properties (Baland et al., 2007), and the degree of publicness of the collective good in question (Bardhan et al., 2006) – that may affect the 'sign' of its impact.

One aspect that has emerged as critical from recent empirical analyses is the relationship between inequality and institutions such as the rules that distribute collective outcomes. Institutions may influence the success with which a community undertakes collective action by shaping agents' returns from cooperation. The nature of the relationship between inequality and rules, however, is not straightforward: in some studies (e.g., Dayton-Johnson, 1999, 2000), allocation rules that favour the rich are more frequently observed in communities characterised by relatively high degrees of inequality, while in others relatively fairer rules are observed in more unequal communities (Bardhan, 2000, and Khwaja, 2001).

The forces identified in this paper and the way they depend on technological features contribute to shed some light on the mechanisms linking inequality, rules and incentives. The remaining of the paper is organised as follows. Section 2 illustrates the features of the model. Section 3.1 derives and discusses the main results. Further discussion is provided in Section 3.2, where a special case for the production technology of the collective good is considered. Section 4 concludes.

2. Model Setup

2.1. Definitions and Assumptions

Consider two types of farmers: 1 and 2. Each type is endowed with an amount of irrigable land l_i, with $l_i > 0$ and $i = \{1, 2\}$. Let $l \equiv l_1 + l_2$ denote the total amount of land in the economy. Farmers' endowments can then be defined as: $l_1 = \lambda \times l$ and $l_2 = (1 - \lambda \times l)$, with $\lambda \in (0, 1)$. In the remainder of the paper, we normalise l to one and assume $\lambda > 0.5$. The two types can, therefore, be interpreted as the representatives of two different farmer groups: large landowners (type 1), and small landowner (type 2).

Farmers can voluntarily engage in a joint project for the maintenance of a network of irrigation channels. Collective-maintenance activity increases the supply of water available for irrigation. Better maintenance, for example, leads to lower losses from filtration, leakage and sedimentation. The output of the project, Z, is represented by the average water flow delivered through the system and is a function of farmers' efforts: e_1 and e_2. Specifically, we parameterise the production technology for Z by using a CES production function[4]:

$$Z = F(e_1, e_2) = \left[e_1^{\sigma} + e_2^{\sigma}\right]^{\frac{1}{\sigma}} \tag{1}$$

where $\sigma < 1$ measures the degree of complementarity between individual efforts. Agents' efforts are assumed to be unobservable (or not enforceable). The collective output, Z, is divided among farmers according to some allocation rule $\Gamma = (\gamma_1, \gamma_2)$, where γ_1 and γ_2 are farmers' shares in Z, with $\gamma_1, \gamma_2 \geq 0$ and $\gamma_1 + \gamma_2 = 1$. When convenient, we will simplify the notation as follows: $\gamma_1 = \gamma$, $\gamma_2 = 1 - \gamma$.

The amount of water allocated to a farmer according to the allocation rule Γ is given by $z_i = \gamma_i Z$ with $i = \{1, 2\}$. Each agent uses two inputs, land and water, to produce a final good. Agent i's payoff is defined as:

$$\Pi_i = f(l_i, z_i) - e_i$$

where $f(l_i, z_i)$ is the individual production function for the final good and e_i is i's contribution for the maintenance of the irrigation network.

We assume that the cost of e_i units of effort is simply e_i and that the production technology for the final good is well represented by the following Cobb–Douglas production function[5]

$$f(l_i, z_i) = (z_i)^{\alpha}(l_i)^{1-\alpha}, \quad \text{with} \quad \alpha \in (0, 1). \tag{2}$$

From the complementarity between l_i and z_i in Eq. (2), it follows that the marginal return to water is an increasing function of land.

Although the paper focuses on land inequality as the only source of heterogeneity, an alternative interpretation is possible, which views the parameter λ as capturing some characteristic of an agent, such as skills and locational differences. As long as these characteristics affect the marginal productivity of water, this alternative interpretation is consistent with the analysis.

2.2. Individual Optimisation Problem

Each agent chooses the level of effort that maximises her own payoff, given the contribution made by the other. Specifically, for any given expectation $\bar{e}_2$ about the level of effort exerted by agent 2, type 1 solves the following problem

$$\max_{e_1 \geq 0} \Pi_1 = f(l_1, z_1(e_1, \bar{e}_2)) - e_1 = \left[\gamma\left(e_1^{\sigma} + \bar{e}_2^{\sigma}\right)^{\frac{1}{\sigma}}\right]^{\alpha}(\lambda)^{1-\alpha} - e_1.$$

[4] CES production functions cover the whole spectrum of substitution and complementarity among efforts. For example, when the parameter σ in Eq. (1) tends to one, the production technology for Z approximates a linear production function; as σ approaches zero, the isoquants of the CES looks like the isoquants of the Cobb–Douglas production function; while in the limit case for σ that approaches $(-\infty)$, the CES function approximates a Leontiev technology where efforts are perfect complements. Hence, although they impose a regularity in the shape of isoquants, CES production functions allow considering a wide range of collective action relevant to water resources — from small dam construction to channel maintenance and pollution reduction activities, where the degree of complementarity among individual efforts is progressively increasing.

[5] Although specific, the Cobb–Douglas form has been widely used in economics because it generally fits the data well. Moreover, it displays complementarity between land and water as inputs of production, which seems a realistic feature of the production process for most agricultural products.