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Inequality and Rule Performance in the Governance of Water Resources

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Outline:

1. Rationale and objectives of the paper
2. Related literature
3. Setup of the model
4. Results
5. Discussion of results and future extensions

Rationale and objectives

- The ability to cooperate in collective activities - such as the construction/maintenance of irrigation infrastructures - is a key determinant of economic performance (Bandiera et al., 2005)
- Which factors may favour or discourage cooperation in collective action?
- *Groups size*: the smaller the group and the stronger its ability to perform collectively (Baland&Platteau, 1996; Agrawal&Goyal, 2001)
- More controversial is the role of ***inequality***…

- How does inequality affect rule performance?
  - How well a rule 'works' may very as initial conditions change…

- This paper investigates the interaction between land-inequality and optimal water allocation rules through the *joint* incentives to cooperate that those generate…

Related literature

Olson (1965) contended that economic inequality may *favour* the provision of collective goods:

"In small groups marked by considerable degrees of inequality there is the greatest likelihood that a collective good will be provided; for the greater the interest in the collective good of any single member, the greater the likelihood that that member will get such a significant proportion of the total benefit from the collective good that he will gain from seeing that the good is provided, even if he has to pay all of the cost himself." (1965:34)

This is highly dependent on a number of assumptions… especially on assumptions about the technology of production of the collective good (Hirshleifer, 1983)

Baland et al (2007):

- Main finding: perfect equality of shares is the most efficient division rule 'long before' the point of perfect complementarity of efforts…

- But: agents are assumed to be ex-ante identical. This does not allow to capture the *effect of inequality on the performance of different allocation rules*.

Empirical literature:

- Importance of such effect, but the nature of the relationship between inequality and allocation rules is not straightforward.

- See: **Dayton-Johnson (2000), Bardhan (2000), Khwaja (2001)**…

Bardhan et al. (2006):

- *U-shaped* relationship: efficiency tends to increase with greater equality up to a certain threshold after which inequality may favour collective action…

My paper:

- Adopts the idea of a private input which is complementary in production with the collective input.

- Seeks to illustrate the interaction between inequality and water allocation rules through the *joint* incentives to cooperate that those generate.

- Allows for agents' contributions to have different degrees of complementarity - both Bardhan et al. (2006) and Dayton-Johnson (2000) assume perfect substitution…

Setup of the model

- Two types of farmers, 1 and 2 – each endowed with a positive amount of land

- Total amount of land: $l \equiv l_1 + l_2$

- Farmers' endowments: $l_1 = \lambda \times l, \; l_2 = (1-\lambda) \times l, \; with\, \lambda \in (0,1)$

- Collective-maintenance of an irrigation network:

$$Z = F(e_1, e_2) = [e_1^\sigma + e_2^\sigma]^{\frac{1}{\sigma}}, \; with \;\; \sigma < 1 \qquad [1]$$

- Effort is *unobservable* (or not enforceable)

Setup of the model (cont)

- Collective output (Z) is divided according to an *allocation rule:*

$$\Gamma = (\gamma_1, \gamma_2),\ \textit{with}\ \gamma_1, \gamma_2 \geq 0\ \textit{and}\ \gamma_1 + \gamma_2 = 1$$

When convenient: $\gamma_1 = \gamma$; $\gamma_2 = 1 - \gamma$.

- Farmer i's amount of water: $z_i = \gamma_i Z\ \ with\ \ i = \{1, 2\}$

- Famer i's payoff: $\Pi_i = f(l_i, z_i) - e_i$

- Assumptions:

  (i) The cost of e_i units of effort is simply e_i

  (ii) $f(l_i, z_i) = (z_i)^{\alpha}(l_i)^{1-\alpha},\ \ with\ \ \alpha \in (0,1)$

Each farmer chooses the level of effort that maximizes her own payoff, given the contribution made by the other:

$$\max_{e_i \geq 0} \Pi_i = f(l_i, z_i(e_i, \bar{e}_j)) - e_i$$

where $i,j=\{1,2\}$, and $i \neq j$.

Solving the individual *max*-problem

Type 1' s max-problem:

$$\max_{e_1 \geq 0} \Pi_1 = (\gamma Z)^{\alpha} (\lambda)^{1-\alpha} - e_1$$

$$with \quad Z = [e_1^{\sigma} + e_2^{\sigma}]^{\frac{1}{\sigma}}$$

FOCs:

$$\frac{\partial \Pi_1}{\partial e_1} = 0 \quad \Rightarrow$$

$$\alpha \times [(\gamma)^{\alpha} (\lambda)^{1-\alpha}] \times (Z)^{\alpha-\sigma} \times (e_1)^{\sigma-1} - 1 = 0 \qquad [2]$$

From [2]:

$$(e_1)^{\sigma} = (\alpha)^{\frac{\sigma}{1-\sigma}} \times [(\gamma)^{\alpha}(\lambda)^{1-\alpha}]^{\frac{\sigma}{1-\sigma}} \times (Z)^{\frac{\sigma(\alpha-\sigma)}{1-\sigma}} \qquad \textbf{[3]}$$

Similarly, from type 2's max-problem:

$$(e_2)^{\sigma} = (\alpha)^{\frac{\sigma}{1-\sigma}} \times [(1-\gamma)^{\alpha}(1-\lambda)^{1-\alpha}]^{\frac{\sigma}{1-\sigma}} \times (Z)^{\frac{\sigma(\alpha-\sigma)}{1-\sigma}} \qquad \textbf{[4]}$$

By substituting [3] and [4] into [1]:

$$Z^{*} = \phi \times \left\{[(\gamma)^{\alpha}(\lambda)^{1-\alpha}]^{\beta} + [(1-\gamma)^{\alpha}(1-\lambda)^{1-\alpha}]^{\beta}\right\}^{\mu} \qquad \textbf{[5]}$$

where $\phi \equiv (\alpha)^{\frac{1}{1-\alpha}}$, $\beta \equiv \frac{\sigma}{1-\sigma}$ *and* $\mu \equiv \frac{1-\sigma}{\sigma(1-\alpha)}$.

Looking for the optimal allocation rule

The optimal allocation rule is defined as the rule γ that max the collective output produced in equilibrium (Z*):

$$\max_{0\leq\gamma\leq1} Z^* = \phi \times \left\{ [(\gamma)^{\alpha}(\lambda)^{1-\alpha}]^{\beta} + [(1-\gamma)^{\alpha}(1-\lambda)^{1-\alpha}]^{\beta} \right\}^{\mu} \qquad \textbf{[6]}$$

where $\phi \equiv (\alpha)^{\frac{1}{1-\alpha}}$, $\beta \equiv \frac{\sigma}{1-\sigma}$ *and* $\mu \equiv \frac{1-\sigma}{\sigma(1-\alpha)}$.

Solutions to [6]:

- For $\sigma < 1/(1+\alpha)$, the problem in (6) admits the following *interior* solution:

$$\gamma^* = \frac{\lambda^\theta}{\lambda^\theta + (1-\lambda)^\theta} \qquad [7]$$

$where: \theta \equiv \frac{(1-\alpha)\sigma}{(1-\sigma-\alpha\sigma)}.$

- For $\sigma > 1/(1+\alpha)$, Z* is still increasing in γ at the value γ=1 → γ^*=1.

A closer look at equation [7]:

- A weighted index of the degree of inequality;

- The 'weight' θ is a function of:

  (i) The strategic importance of agents' efforts in the realization of the collective good (σ);

  (ii) The relative importance of water compared to land in the production of the final good (α).

Inequality and optimal allocation rule

From [7], we have:

$$\frac{\partial \gamma^*}{\partial \lambda} = \frac{\theta \times [\lambda(1-\lambda)]^{\theta-1}}{[\lambda^{\theta} + (1-\lambda)^{\theta}]^2}$$

It can be shown that:

- for $\lambda \in (0,1)$ the sign of $\partial\gamma^*/\partial\lambda$ solely depends on θ;
- $\theta<0$ for $\sigma<0$; and $\theta>0$ for σ□$(0,1/(1+\alpha))$.

…to summarize:

- For $\sigma < 0 \longrightarrow \partial\gamma^*/\partial\lambda < 0$;
- For σ □$(0,1/(1+\alpha)) \longrightarrow \partial\gamma^*/\partial\lambda > 0$;
- For σ □$(1/(1+\alpha),1) \longrightarrow \gamma^* = 1$, □$\lambda > 0.5$

What does all this mean?

Two types of forces affecting the distribution of the collective good (water) in opposite directions:

- *Efficiency-based force;*
- *Incentive-based force*

Efficiency-based force (EBF):

- Productive-efficiency pushes the distribution of water in favour to the agent with the higher MPW.

- From the complementarity between *land* and *water* in the production of the final good, MPW is increasing in land

⇨ More water to the *large landowner*

Incentive-based force (IBF):

- MPW increasing in land also means that the *intrinsic* incentive to exert maintenance effort is lower for a small landowner.

- Idea behind IBF: using water as an incentive mechanism

⇨ More water to the agent with the lower intrinsic incentive*

** This may represent the 'constrained' optimum when other contracting possibilities are not available (Ex: effort unobservable; contracting over output difficult due to lack of commitment or limited enforcement capacity…)*

The relationship between land-inequality and optimal water allocation rule is determined by the *trade-off between EBF and IBF*.

How does this trade-off resolve?

- With high substitutability, EBF prevails → More inequality may favour the provision of the collective good. (In line with Olson).
  - Note: Olson's result is implicitly based on the assumption that the richest agent is the one benefiting more from the collective good produced.

- With sufficient complementarity, the participation of both types is important → IBF plays a crucial role…

Cobb-Douglas production technology:

$$Z = F(e_1, e_2) = e_1^{\sigma} e_2^{(1-\sigma)}, \quad with \;\; \sigma \in (0,1)$$

From farmers' max-problem:

$$\left(e_1^* = g_1^{\left(\frac{1-\alpha(1-\sigma)}{1-\alpha}\right)} \times g_2^{\left(\frac{\alpha(1-\sigma)}{1-\alpha}\right)};\; e_2^* = g_1^{\left(\frac{\alpha\sigma}{1-\alpha}\right)} \times g_2^{\left(\frac{1-\alpha\sigma}{1-\alpha}\right)} \right)$$

Collective output produced in equilibrium:

$$Z^* = (e_1^*)^{\sigma} (e_2^*)^{(1-\sigma)} = g_1^{\left(\frac{\sigma}{1-\alpha}\right)} \times g_2^{\left(\frac{1-\sigma}{1-\alpha}\right)}$$

$$where: g_1 \equiv \alpha\sigma\gamma^{\alpha}\lambda^{(1-\alpha)}, and\; g_2 \equiv \alpha(1-\sigma)(1-\gamma)^{\alpha}(1-\lambda)^{(1-\alpha)}.$$

It can be shown that:

$$\frac{\partial Z^*}{\partial \gamma} = 0 \Rightarrow \frac{\sigma}{\gamma} - \frac{(1-\sigma)}{1-\gamma} = 0 \Rightarrow \gamma^* = \sigma$$

The optimal allocation rule depends solely on the marginal productivity of agents' effort in the production technology of the collective good.

With Cobb-Douglas technology:

- EBF and IBF *perfectly* offset each other;
- γ^* independent of the degree of inequality in land-holding.

Future extensions:

- *Endogenizing* the allocation-rule choice decision.
  - This is another collective action issue ('second-order collective dilemma' – Ostrom, 1990)

- The paper focuses on the under-provision of public goods in rural collective action (e.g. insufficient services to irrigation maintenance). What are the implications of this analysis regarding *water overuse* and how to avoid it?

Thank you!