Chapter 4 – **Coordination failures and institutional responses**

Conflicts over the distribution of the gains to cooperation have sunk many otherwise viable agreements to limit the depletion of resources.

Coordination problems are endemic:
⇨ depletion of reserves of fishing/wood/oil/etc
⇨ traffic congestion
⇨ free-riding in team work
⇨ fiscal competition among nation states
⇨ arm races
⇨ positional goods
⇨ ...

A taxonomy of goods:

	rival	*non-rival*
excludable	private goods	spite goods
non-excludable	common property	public goods

<u>Nonexcludability</u> implies the impossibility to prevent someone from accessing the good.

<u>Rivalry</u> implies that the use of the resource from someone reduces the benefits available to other users.

Common structure for the problem of *common property* and *public goods*:

PUBLIC GOOD CASE

* a group of n members with a common project
* e_i is the individual contribution to the project
* an identical utility function for each member
* positive spillover from individual efforts

$$U_i = be_i + c\gamma - \delta(e_i), \quad i = 1,..,n, \quad \gamma = \gamma\left(\sum_{k=1}^{n} e_k\right), \gamma' > 0$$

* the project is a public good if $c > 0$, is a public bad if $c < 0$.
* the good is non excludable, since $U_i > 0$ even when $e_i = 0$ (free-riding).
* the good is non-rival because for any given γ , U_i is independent from the number of participants.
* for $b = 0$ a *pure public good* (example: taxation)
* for $b > 0$ an *impure public good* (example: education).

General result: public goods are underprovided (as compared to social optimum) and public bads are overproduced.
The reason has to do with the fact that individuals acting noncooperatively do not take account of the benefits their efforts confer on others.

Proof: take the case of a pure public good ($b = 0$). An utilitarian social welfare function is given by

$$V = \sum_{i=1}^{n} U_i = nU = n(c\gamma(ne) - \delta(e))$$

A benevolent dictator will select the optimal level of individual effort from the following problem

$$\max_e V = \max_e n(c\gamma(ne) - \delta(e)) \qquad \Rightarrow \qquad cn\gamma' - \delta' = 0$$

Marginal benefit from effort (including the positive impact onto n individual) must be equal to the marginal disutility of effort.

A single individual will solve a different problem

$$\max_{e_i} U_i = \max_{e_i}\left(c\gamma\left(\sum_{k=1}^{n} e_k\right) - \delta(e_i)\right) \qquad \Rightarrow \qquad c\gamma' - \delta' = 0$$

Since individual marginal benefit is lower than the social one, each individual will optimally select a lower level of effort.

COMMON PROPERTY CASE

* the common benefit $\gamma = \gamma\left(\sum_{i=1}^{n} e_i\right)$ exhibits initially increasing and the decreasing returns.
* the benefit is divided among the members according to their effort, with share $s_i = s_i(e_i),\ s_i' > 0,\ \sum_{1=1}^{n} s_i = 1$ →the good is rival
* individual utility is given by

$$U_i = s_i(e_i)\gamma\left(\sum_{k=1}^{n} e_k\right) - \delta(e_i)$$

* An utilitarian social welfare function is

$$V = \sum_{i=1}^{n} U_i = \sum_{i=1}^{n}(s_i\gamma - \delta) = \gamma\sum_{i=1}^{n} s_i - n\delta = \gamma - n\delta$$

A benevolent dictator will select the optimal level of individual effort from the following problem

$$\max_{e} V = \max_{e}(\gamma(ne) - n\delta(e)) \qquad \Rightarrow \qquad \gamma' - \delta' = 0$$

Once again, marginal benefit equates marginal cost.

* Individual maximisation solves the following problem

$$\max_{e_i} U_i = \max_{e_i}\left(s_i(e_i)\gamma\left(\sum_{k=1}^{n} e_k\right) - \delta(e_i)\right) \quad \Rightarrow \quad s_i'\gamma + s_i\gamma' - \delta' = 0$$

The marginal benefit contains two elements:
⇨ greater effort increases individual share
⇨ greater effort raises the common resources

The general result is that individual maximisation leads to overexploitation of the common resource.

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When the set of actions available to the agent is discrete, both public good case and common resource case take the form of n-person Prisoners' Dilemma game with a Pareto-inferior dominant strategy equilibrium.

Consider a 2-person version of the game (THE TRAGEDY OF FISHERS)

Upper and Lower are two fishermen. The greater effort of one fisher reduces the catch of the other, and vice versa.

$$y = \alpha(1-\beta E)e$$
$$Y = \alpha(1-\beta e)E$$

where y, Y are the catches and e, E are the levels of effort.

Individual utilities are given by

$$u = y - e^2$$
$$U = Y - E^2$$

We look for best response functions (since the space of actions includes all possible values for e, E), i.e. the choice that maximises one's utility conditional on the choice of the opponent.

Do people really behave like this ? More often, we imitate those that are observed doing better than us.

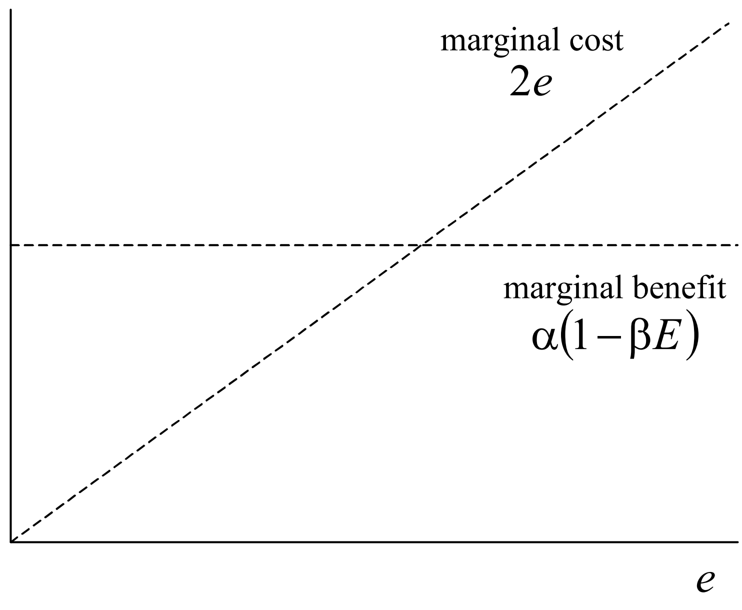
The problem faced by Lower is

$$\max_e \left(y - e^2\right) = \max_e \left(\alpha(1-\beta E)e - e^2\right) \quad \rightarrow \quad u_e = \frac{du}{de} = \alpha(1-\beta E) - 2e = 0$$

while the problem faced by Upper is symmetrical

$$\max_E \left(Y - E^2\right) = \max_E \left(\alpha(1-\beta e)E - E^2\right) \quad \rightarrow \quad U_E = \frac{dU}{dE} = \alpha(1-\beta e) - 2E = 0$$

We can represent the optimal choice by Lower as follows



Her best response function is therefore given by

$$e = \frac{\alpha(1-\beta E)}{2} = e^*(E)$$

Lower reduces her effort whenever Upper raises her own, and vice versa.

Given the symmetry of the problem, we can find the Nash equilibrium as the combination (e^*, E^*) such that $e^* = e(E(e^*))$. In the present case

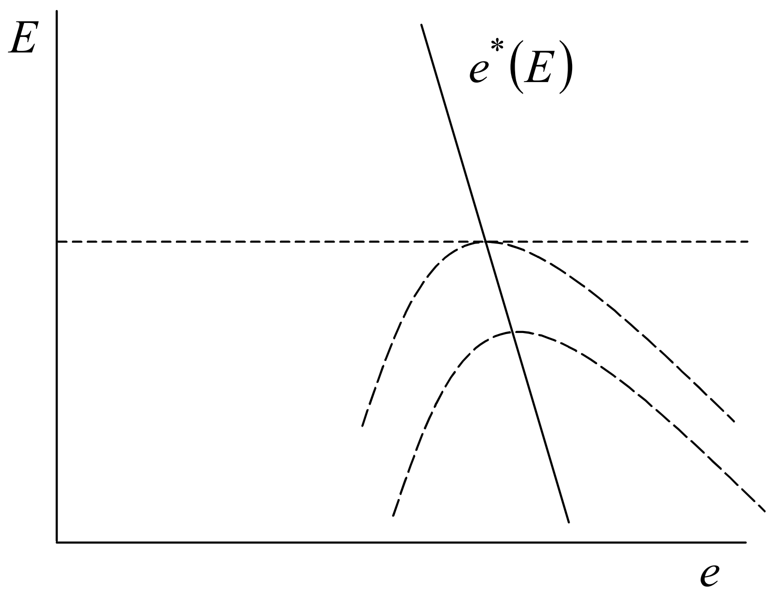
$$e_N = \frac{\alpha(1-\beta E)}{2} = \frac{\alpha}{2} - \frac{\alpha\beta}{2}E = \frac{\alpha}{2} - \frac{\alpha\beta}{2} \cdot \frac{\alpha(1-\beta e)}{2} = \frac{\alpha}{2}\left(1 - \frac{\alpha\beta}{2}\right) + \frac{(\alpha\beta)^2}{4}e =$$

$$= \left(1 - \frac{(\alpha\beta)^2}{4}\right)^{-1} \cdot \left(\frac{\alpha(2-\alpha\beta)}{4}\right) = \frac{\alpha(2-\alpha\beta)}{4-(\alpha\beta)^2} = \frac{\alpha(2-\alpha\beta)}{(2-\alpha\beta)(2+\alpha\beta)} = \frac{\alpha}{2+\alpha\beta}$$

In order to obtain a graphical representation, let us consider the indifference curve in the (e, E) space. Taking the total differential of Lower's utility function

$$du = \frac{du}{de} \cdot de + \frac{du}{dE} \cdot dE = u_e \cdot de + u_E \cdot dE = 0$$

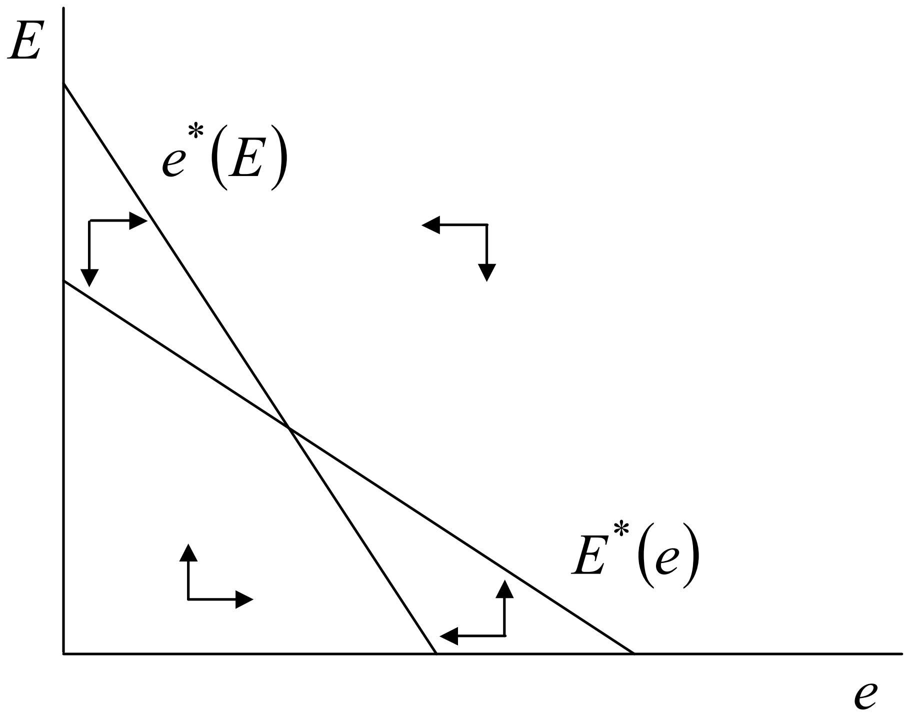
Along any indifference curve $du = 0$, which implies that $\frac{dE}{de} = -\frac{u_e}{u_E}$, a sort of marginal rate of substitution between efforts. The slope of this indifference curve is zero when marginal benefit = marginal cost.



Stability requires that small perturbations of the equilibrium values be self-correcting. If we assume that Lower will raise her effort whenever the marginal benefit exceeds marginal cost, than we can draw the following arrows.

$$\Delta e = \sigma(u_e) = \sigma(\alpha(1-\beta E) - 2e)$$

(Alternative adjustments can be assumed. For example $\Delta e = \gamma(e^* - e)$, a partial adjustment mechanism, as in the textbook).



Under this configuration, the Nash equilibrium is globally stable. Stability requires that Lower's best response function ($e = \frac{\alpha(1-\beta E)}{2}$) be steeper than Upper's one ($E = \frac{\alpha(1-\beta e)}{2}$). That is $\frac{\alpha\beta}{2} < \frac{2}{\alpha\beta} \quad \Leftrightarrow \quad \alpha\beta < 2$.

Intuition: stability requires that actors do not over react.

Stability is a necessary but insufficient condition for the Nash equilibrium being a good predictor of actual behaviour. In most games people do not play Nash strategies (example: mixed strategies in Rock, Paper, Scissors).

Pareto optimality requires tangency of the indifferent curves

$$\frac{u_e}{u_E} = \frac{U_e}{U_E}$$

This condition depicts the *efficient contract locus*. In facts social welfare is maximised whenever

$$\max_{e,E} u + U$$

Taking first order conditions requires

$$\begin{cases} u_e + u_e = 0 \\ u_E + U_E = 0 \end{cases} \Leftrightarrow \begin{cases} u_e = -U_e \\ u_E = -U_E \end{cases} \Leftrightarrow \frac{u_e}{u_E} = \frac{U_e}{U_E}$$

At the Nash equilibrium the two indifferent curves are perpendicular → the Nash equilibrium is not Pareto optimal.

Any agreement to fish less than the Nash equilibrium would not be credible, because each one would take advantage of the other fishing less.

HOW TO REACH A PARETO OPTIMAL CONFIGURATION ?

Three approaches to how converting the common tragedy into a different game:
① privatisation of the commons (market)
② regulation by an external authority (state)
③ regulation through local interaction (community)

① suppose Lower is the owner. She can exclude Upper, or to limit the amount she can fish.

The ***participation constraint*** is given by the condition that Upper will gain at least as much as her best alternative. We assume that in the present case it corresponds to

$$U \geq 0.$$

Lower will select e and E in order to maximise her utility, given the participation constraint for Upper. Two alternatives:
a) Lower sells a fishing permit to Upper
b) Lower hires Upper for a wage and retains the entire catch

a) indicating with F the permit price, Lower will solve the problem

$$\max_{e,E}(u+F) \qquad \text{subject to } \; U-F\geq 0$$

By taking the constraint as equality, it converts to

$$\max_{e,E} u+U=\max_{e,E}\alpha(1-\beta E)e-e^2+\alpha(1-\beta e)E-E^2$$

Lower's allocation plan is determined by setting e and E according to the first order conditions

$$\begin{cases}\alpha(1-\beta E)-2e-\alpha\beta E=0\\ \alpha(1-\beta e)-2E-\alpha\beta e=0\end{cases}$$

The circled additional terms indicate that the owner is able to internalise the spillover effects. The optimal solution becomes

$$e^*=\frac{\alpha}{2+2\alpha\beta}=E^*$$

which is lower than the fishing activity under the Nash equilibrium $\dfrac{\alpha}{2+\alpha\beta}$.

Why Lower does not exclude Upper entirely ? Because under the current participation constraint, the marginal cost of compensating Upper is zero (when $E=0$), while her marginal productivity is positive: thus it is convenient to have some fishing from her.

b) indicating with W the wage paid to Upper, Lower will solve the problem

$$\max_{e,E,W} \underbrace{\alpha(1-\beta E)e+\alpha(1-\beta e)E-e^2-W}_{\text{Lower retains the entire output}} \quad \text{subject to} \quad W-E^2 \geq 0$$

The participation constraint once more gives us $W = E^2$, and the problem becomes identical to the previous case.

Privatisation produces Pareto-efficient outcomes because the decision maker – a residual claimant of the joint surplus - optimises by choosing an allocation that maximises the total utility of the two.

The distributive conflict is solved in advance by the participation constraint.

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② a government may choose two alternatives
a) issuing fishing permits (direct regulation)
b) modify the incentives through taxes and subsidies

a) direct regulation requires the planner solve the following problem

$$\max_{e,E} u+U = \max_{e,E} \alpha(1-\beta E)e - e^2 + \alpha(1-\beta e)E - E^2$$

which yields the same solution that under privatisation

b) the planner proposes a tax on fishing designed to eliminate the discrepancy between social and private marginal costs and benefits of fishing.

By looking at the first order conditions

$$\begin{cases} \alpha(1-\beta E)-2e-\alpha\beta E=0 \\ \alpha(1-\beta e)-2E-\alpha\beta e=0 \end{cases}$$

it is easy to recognise that individual maximisation would replicate them if a tax would be imposed, with tax rates given by $\tau_e = \alpha\beta E$ and $\tau_E = \alpha\beta e$

③Local interactions implies that fishermen possibly know things that the government does not know. In these contexts the threat of retaliation is more effective, the more frequent is the interaction and the fewer are the agents interacting.

a) Interactions may be based on *asymmetries of power*.
Suppose that Lower has the ability to select her level of fishing and commit to it in such a way that upper understood that nothing Upper could do would alter Lower's fishing activity. Thus Lower can be considered as *first mover* (Stackelberg leader).

The first mover anticipates what the second mover will do in response to her action → the first mover maximises her utility conditional on second mover's best response function.

This constraint is different: previously one player maximised her utility under the constraint of granting a given level of utility to the other player, while now the constraint is given by a given behaviour of the other player. This does not ensure the achievement of a Pareto optimal combination.

More formally the solution is obtained by

$$\max_e u \qquad \text{subject to} \quad E^* = E(e)$$

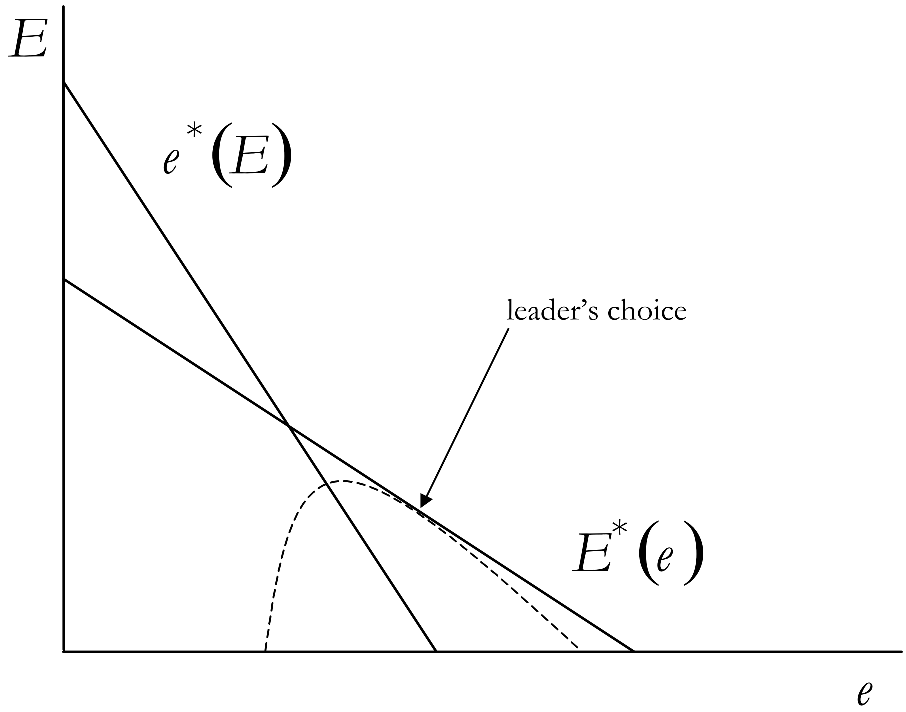
$$\max_e \alpha(1-\beta E)e - e^2 \quad \text{subject to} \quad E = \frac{\alpha(1-\beta e)}{2}$$

$$\max_e \alpha\left(1-\beta\frac{\alpha(1-\beta e)}{2}\right)e - e^2 = \max_e \alpha\left(1-\frac{\alpha\beta}{2}\right)e + \left(\frac{(\alpha\beta)^2}{2}-1\right)e^2$$

which solves into

$$e^* = \frac{\alpha(2-\alpha\beta)}{4-2(\alpha\beta)^2} > e_N^* = \frac{\alpha}{2+\alpha\beta}$$

In graphical terms



b) a more symmetric alternative is a *bargained outcome enforced by mutual monitoring*: ⇨ the two fishers share their information
⇨ decide to fish at the joint surplus-maximising optimum
⇨ using mutual monitoring to detect non-compliance
⇨ threatening to return to fishing at the noncooperative level (*fallback position*) should the other violate the agreement.
This is equivalent to infinite repetition of the prisoners' dilemma.

This solution is often indicated as *cooperative solution*. It is obtained by

$$\max_{e,E} u + U$$

and by construction if yields Pareto optimal solutions.

c) the fishers are characterised by altruistic preferences. For example Lower's utility may be given by

$$u = \alpha(1 - \beta E)e - e^2 + aU, \quad a \in [0,1]$$

and analogously for Upper. a represents the degree of altruism.

In this case the first order conditions obtained by individual maximisations are

$$\alpha(1 - \beta E) - 2e - a\alpha\beta E = 0$$
$$\alpha(1 - \beta e) - 2E - a\alpha\beta e = 0$$

which show that each fisher takes into account a fraction a of the disutility that their fishing impose on the other.

Similarly to taxes, this attenuates the coordination failure. However, Pareto optimal solutions are attained only under complete altruism (i.e. $a = 1$).

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TEAM PRODUCTION

A common pool resource problem arises when a large number of agents contribute to the production of a single good, to be shared by group under the impossibility to detect individual contribution (example: a cooperative owned by its workers).

Suppose an output q is given by the joint effort of a team composed by n members, with a start-up (sunk) cost equal to k

$$q = g \cdot \sum_{i=1}^{n} e_i - k$$

All team member are identically characterised by the same utility function

$$u_i = u(y_i, e_i), u_y > 0, u_{yy} < 0, u_e < 0, u_{ee} > 0$$

where y_i is the output share obtained by individual i.

If each team member would solve the problem in isolation, she would select her level of effort according to

$$\max_{e_i} u(ge_i - k, e_i) \qquad \Rightarrow \qquad u_y g + u_e = 0 \qquad \Rightarrow \qquad g = -\frac{u_e}{u_y}$$

Individual optimality would require equating the marginal productivity of the action to the marginal rate of substitution between effort and goods in the producer's utility function.

Thus a possible solution is dismantling the team and put all members to work in isolation (n Robinson Crusoes). But if team work is required, it must be the case that

$$u(ge_i^* - k, e_i^*) < \overline{u} \text{(outside option)}$$

If the team members try to write a contract in order to achieve the optimal level of effort, they must take into account that following the contract each member will best response to the contract offer → the members' best response function are thus a constraint – the *incentive compatibility constraint* – on the team's optimisation problem.

The team will act as a principal in a principal-multi-agent context, and has to take into account a participation constraint. Suppose a contract is offered such that each member receives $y_i = \frac{q-x}{n}$ where x is retained for common project.

To begin with, x has to satisfy the *participation constraint*

$$u\left(\frac{g\sum_{i=1}^{n} e_i^* - x}{n}, e_i^*\right) \geq \bar{u}(\text{outside option})$$

Each team member will be expected to solve her maximisation problem (*incentive compatibility*), leading to

$$\frac{u_y g}{n} + u_e = 0 \qquad \Leftrightarrow \qquad \frac{g}{n} = -\frac{u_e}{u_y}$$

The incentives of the proposed contract are diluted by the team size: the greater the team, the lower will be the optimal effort chosen by members.

Alternative contract: pay to each member $y_i = y - v$ (the entire output), where v is set such that $y^* - n(y^* - v) = x$. This induces the choice of optimal level of effort identical to Robinson Crusoe, and therefore Pareto optimal.

Alternative solutions to the team problem:
⇨ peer monitoring and punishing norm violators.
If punishing is costly, the $1/n$ problem remains.
⇨ social preferences.
In a 2-person team, each has to choose how to allocate her effort a_i, either to her own project $(1-a_i)$ or to the common project, where $\varphi < 1$.
Team members can be
* self interested

$$U_i = \pi_i = (1-a_i) + \varphi(a_i + a_j) - \mu_{ji}, \qquad a_i \in [0,1]$$

* altruistic/spiteful ($\alpha > 0 / \alpha < 0$) and reciprocators ($\lambda \in [0,1]$ degree of reciprocity)

$$U_i = \pi_i + \beta_{ij}\pi_j = \pi_i + \left(\alpha_i + \lambda_i\left(a_j - a_i^*\right)\right)\pi_j$$

* feeling guilty when violating self-imposed social norms

$$U_i = \pi_i + \beta_{ij}\pi_j - \gamma\left(a_i^* - a_i\right)^2$$

* experiencing shame when violating ad being sanctioned by others

$$U_i = \pi_i + \beta_{ij}\pi_j - \gamma\left(a_i^* - a_i\right)^2 - \sigma\left(a_i^* - a_i\right)\mu_{ji}$$

* punishment is costly

$$U_i = \pi_i + \beta_{ij}\pi_j - \gamma\left(a_i^* - a_i\right)^2 - \sigma\left(a_i^* - a_i\right)\mu_{ji} - \frac{c\mu_{ij}^2}{2}$$

Each individual has two choice variables: how to contribute to the team project (a_i) and how to punish the other (μ_{ij}). Given the parameters of the game, an equilibrium leading to Pareto optimal contributions can be sustained as Nash non cooperative outcome.

Comments:
* altruism and reciprocity may be mutually offsetting (I will not punish my mate if I am sufficiently altruistic)
* those who contribute less because their norm a^* is low, will also suffer less from social sanction
* reciprocal preferences induce positive feedbacks.

A TAXONOMY OF COORDINATION PROBLEMS

Coordination problems emerges whenever the problems take the following form

$$\max_{a_i} u_i(a_i; \overline{a}_{-i}; \overline{p})$$

where $\overline{a}_{-i}$ is the vector of the other players' choices, taken for given, and $\overline{p}$ is the vector of the relevant prices.

Each agent takes for given that $\frac{dp_j}{da_i} = 0, \forall j$ (i.e. the price vector is unaffected by individual choices – *price taking*) as well as $\frac{da_k}{da_i} = 0, \forall k \neq i$ (i.e. the behaviour of the other players is taken for given – *best response function*).

Since each player neglects the spill-over effect of her choice, the non cooperative equilibrium is likely to be Pareto inefficient (i.e. the available surplus is not completely exploited).

Solutions:

⇨ transform the situation into a cooperative set-up by letting a state determine the values of a for each individual (example: social planner)

⇨ alter the institutional setup imposing a participation constraint for all players but one → by construction the outcome is Pareto efficient (*binding participation constraint solution*) (example: privatisation of the lake)

⇨ modify individual actions through charging the appropriate price (incorporating the cost created to the others). Each individual will optimally select actions equating the (subjective) marginal rate of substitution o the (objective) relative prices. But since this is true for each player, their indifference curves will have the same slopes in equilibrium → therefore the indifference curves will be tangent to each other (*complete contracting solution*) (example: taxing fishing activity).

⇨ transform individual preferences in social preferences. "It is sometimes the case that the peer monitoring and sanctioning by a minority of group members who are motivated by other-regarding preferences can induce other individuals to act *as if* they cared about the others." (*social preference solution*)

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Coordination problems have a common structure and a common set of possible institutional responses, but differ in two aspects:
① the sign of the direct effect of the others' actions on one's utility (positive/negative externalities)
② the sign of the effect of others' actions on one's own actions (strategies are either complements or substitutes)

Example 1: in the tragedy of fishers, there were negative externalities, and fishing activities of the two fishers were strategic substitutes.

Example 2: two symmetrical individuals, Lower and Upper.
Neglecting prices, their utilities are given by

$$u = f(a, A), f_1' > 0, f_{11}'' < 0, f_2' \neq 0$$
$$U = f(A, a), f_1' > 0, f_{11}'' < 0, f_2' \neq 0$$

or assuming a specific functional form

$$u = \alpha + \beta a + \gamma A + \delta a A + \lambda a^2$$
$$U = \alpha + \beta A + \gamma a + \delta a A + \lambda A^2$$

which corresponds to the general case whenever $\lambda < 0$ (it may be thought as increasing marginal costs).

Best response functions are obtained by $\max\limits_a u$ and $\max\limits_A U$. By solving the maximisation problem we get

$$a^* = -\frac{\beta + \delta A}{2\lambda}; \quad A^* = -\frac{\beta + \delta a}{2\lambda}$$

Distinction ① (positive/negative externality) has to do with the sign of the cross marginal effect

$$u_A = \gamma + \delta a \gtrless 0$$
$$U_a = \gamma + \delta A \gtrless 0$$

Distinction ② (strategic complementarity or substitutability) concerns the effect of the other action on the marginal utility of one's own action

$$u_{aA} = \delta = U_{Aa}$$

If $\delta < 0$ the actions are *strategic substitutes* (the reaction functions are negatively sloped: the agents best respond by moving in the opposite direction of their opponent).
If $\delta > 0$ the actions are *strategic complements* (the reaction functions are positively sloped: the agents best respond by moving in the same direction of their opponent).

A taxonomy of coordination problems:

	externalities	
strategies	*negative*	*positive*
substitutes	tragedy of fishers	team production
complements	conspicuous consumption arm races	fiscal competition

Should cooperation occur, the distribution of the benefit of cooperation depends on the particular transformation of the game which makes the cooperation possible.

Asymmetries among players will influence the nature of the coordination problem to be implemented. When one agent has a dominant role, it can take advantage of its leadership and, as first mover, implements a Pareto improvement over the Nash equilibrium.

But inequality may also be an impediment to cooperation. Thus the feasibility of an efficient allocation may depend on the distribution of wealth and power and on the extent and kinds of non-economic heterogeneity in a group.

Field experiments suggest that inequality may impede cooperation by obstructing communication.