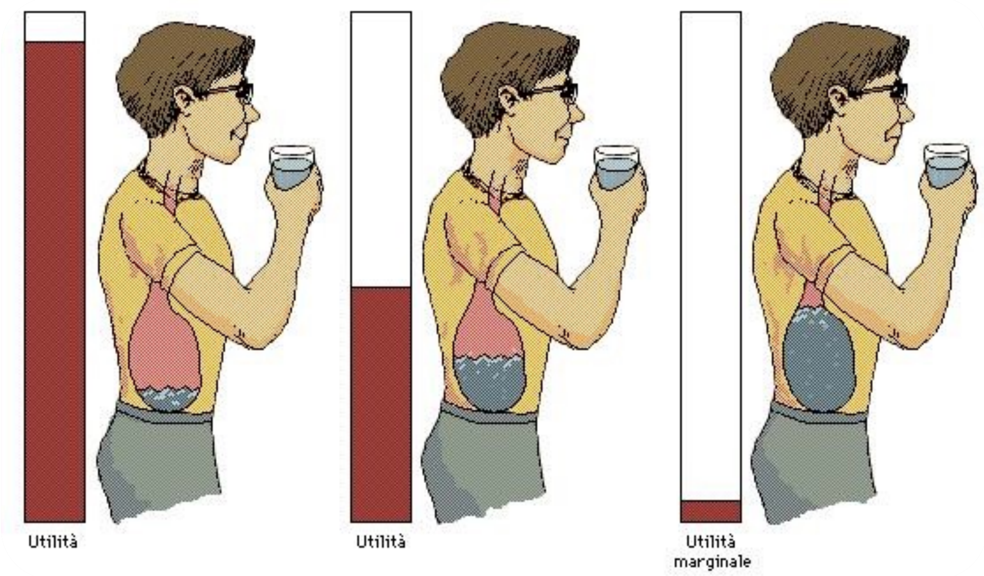
PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course



Lecture 10-2: Elements of engineering economics, Marginal analysis

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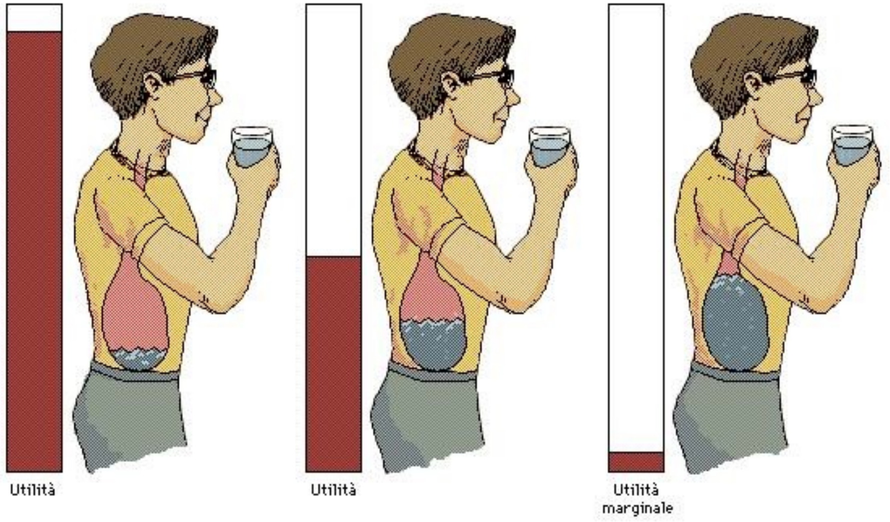
Marginal analysis

- Aristoteles (*Πολιτικα*) writes

  ...external goods have a limit, like any other instrument, and all things useful are of such a nature that where there is too much of them they must either do harm, or at any rate be of no use...

(Economists often criticize this viewpoint...but we are not economists)

What is marginal analysis in economic theories?



Marginal analysis assesses the concept of utility of a given good in relation to its amount

Marginal use and marginal utility

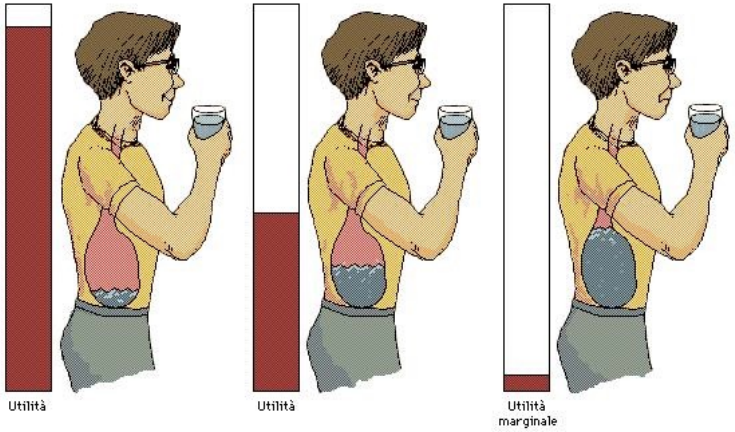
- Marginal use of a good or service is the specific use to which an agent would put a given increase, or the specific use of the good or service that would be abandoned in response to a given decrease

What are marginal use and marginal utility?

- Marginal utility of a good or service is the utility of its marginal use.

- The „law of diminishing marginal utility“ (Gossen‘s First Law)

  «As additional amounts of a good or service are added to available resources, their marginal utilities are decreasing»



Total benefit and marginal benefits

- The total benefit is the cumulative change in benefit that arises for increasing quantity being allocated (or used), i.e. the function

B = B(Q)

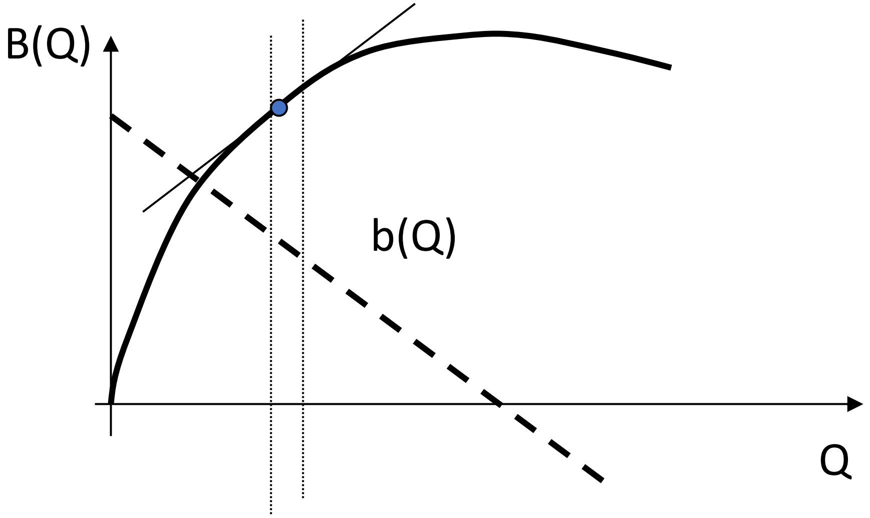
What are the total and the marginal benefits related to quantity allocation?

- The marginal benefit is the relative change in benefit for increasing the quantity being allocate of one unit

$$b = \frac{dB(Q)}{dQ},$$

hence

$$B = \int_0^Q b(q)dq$$



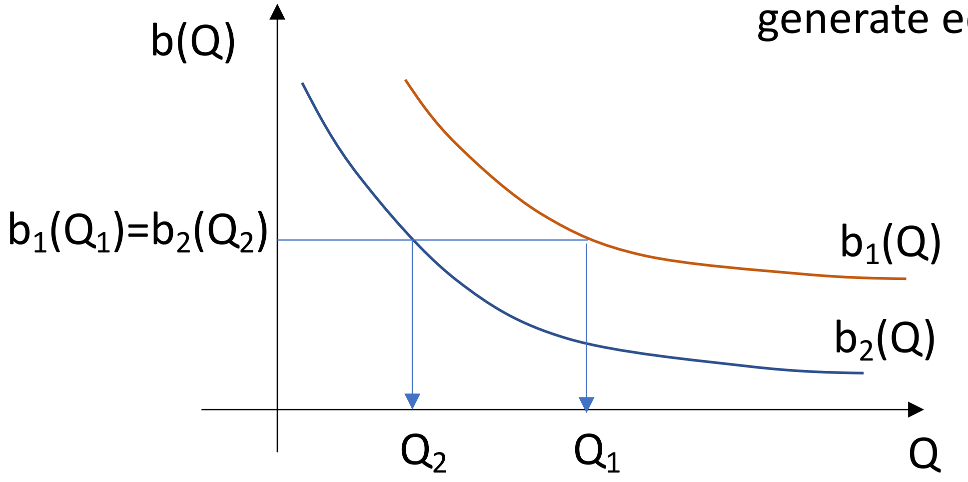
The Principle of Equal Marginal Utility (PEMU)

Two users characterized by marginal benefits $b_1(Q)$ and $b_2(Q)$, and sharing at a time a common resource (e.g., water volume), will generate the maximum total benefit when the amount of resource is shared between the two uses such that the two marginal benefits are equal, that is:

The total benefit $$B_T = \sum_{i=1}^{n} \int_0^{Q_i} b_i(q)dq$$

for sharing the resource such that $Q_1+Q_2=Q$ is maximum when

$$b_1(Q_1)=b_2(Q_2)$$



What does the PEMU means in practice?

The PEMU states that the optimal allocation of a common good between two uses generates the maximum total benefit when the good is shared in proportions that generate equal marginal benefits

How can the PEMU be proved? (optional)

The PEMU generally holds for unbounded problems, i.e., in the case there are no active constraints (e.g., physical, economic, political, social) affecting allocation among the activities. If there is no significant storage at the diversion node, and assuming that both mbf are positive monotonically decreasing functions, the objective function TB can be analytically maximized, i.e., by finding

$$Max|_{\mathbf{Q},T_h}\left[\sum_{i=1}^{2}\int_{T_h}\int_{0}^{Q_i} f_{\mathrm{act}}(\tau)b_i(q;\mathbf{r}_i(\tau))\mathrm{d}q\mathrm{d}\tau\right], \qquad I = q_1 + q_2$$

$$\frac{\mathrm{d}}{\mathrm{d}Q_2}\left(\int_{T_h}\int_{0}^{I-Q_2} f_{\mathrm{act}}(\tau)b_1(I-q_2;\mathbf{r}_1(\tau))\mathrm{d}(I-q_2)\mathrm{d}\tau\right) + \frac{\mathrm{d}}{\mathrm{d}Q_2}\left(\int_{T_h}\int_{0}^{Q_2} f_{\mathrm{act}}(\tau)b_2(q_2;\mathbf{r}_2(\tau))\mathrm{d}q_2\mathrm{d}\tau\right) = 0.$$

$$\int_{T_h}\frac{\mathrm{d}}{\mathrm{d}Q_2}\left(\int_{0}^{I-Q_2} f_{\mathrm{act}}(\tau)b_1(I-q_2;\mathbf{r}_1(\tau))\mathrm{d}(I-q_2)\right)\mathrm{d}\tau + \int_{T_h}\frac{\mathrm{d}}{\mathrm{d}Q_2}\left(\int_{0}^{Q_2} f_{\mathrm{act}}(\tau)b_2(q_2;\mathbf{r}_2(\tau))\mathrm{d}q_2\right)\mathrm{d}\tau = 0.$$

By gathering now the two domains of integration and making the derivative one obtains

$$\int_{T_h} f_{\mathrm{act}}(\tau)\left(b_1(I-Q_2;\mathbf{r}_1(\tau))\,\frac{\mathrm{d}(I-Q_2)}{\mathrm{d}Q_2} + b_2(Q_2;\mathbf{r}_2(\tau))\right)\mathrm{d}\tau = 0,$$

which finally reduces to the condition

$$\int_{T_h} f_{\mathrm{act}}(\tau)(-b_1(I-Q_2;\mathbf{r}_1(\tau)) + b_2(Q_2;\mathbf{r}_2(\tau)))\mathrm{d}\tau = 0.$$

By making use again of the continuity at the node

$$b_1(Q_1;\mathbf{r}_1(t)) = b_2(Q_2;\mathbf{r}_2(t)).$$

Type of costs

Both fixed costs *Cfix* and variable costs *Cvar* affect the total cost *C*

$$C(Q) = C_{fix} + C_{\mathrm{var}}(Q)$$

$$\Downarrow$$

$$c = \frac{dC}{dQ} = \frac{dC_{\mathrm{var}}}{dQ}$$

Fixed costs do not affect marginal costs!

What are fixed and variable costs for a project?

Fixed cost occur at once and are independent of the use of the resource (e.g., setting up a contract for energy allocation). Variable costs depend on the amount of the service or good being used

Economies of scale

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Compare now the marginal cost *c(Q*)* for a given demand *Q** to the average cost

$$\overline{C} = \frac{C_{fix} + C_{\mathrm{var}}(Q^*)}{Q^*}$$

$c < \bar{C}$	Economy of scale (additional units are produced for less than the previous unit)
$c > \bar{C}$	Diseconomy of scale (diminishes marginal productivity)

What is intended with economies of scale?

This is the relationship existing between the increasing production amount followed by a unitary cost decrease. The marginal cost (not affected by fixed costs) is used as a term of comparison with the average total cost (affected by fixed costs)

Cournot dilemma: resistency to monopolium of productive structures

Externalities

- Negative externalities: marginal social costs of production are greater than that of the private cost function (e.g., a given private production pollutes the environment and this affect social costs)

- Positive externalities: marginal social costs of production are less then that of the private cost function (e.g., education of people)

What is meant with externalities?

Externalities are costs or benefits that are caused by a given use of the resource and affect other users (e.g., a producer who pollute the environment and other pay the price for that)

Financial vs economic efficiency

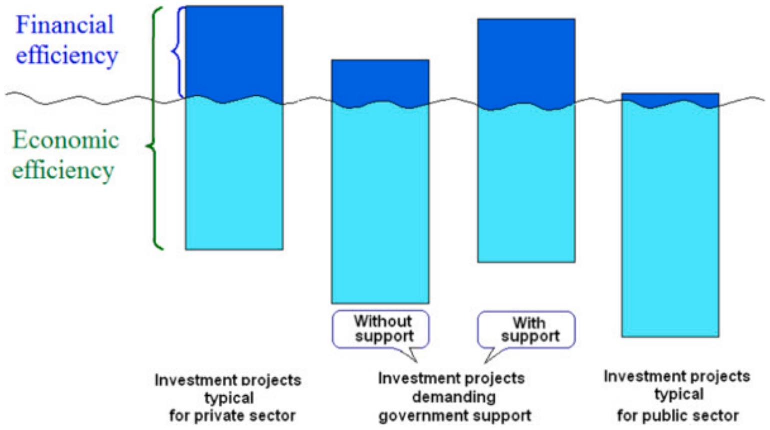
- <u>Financial efficiency</u>

  Is concerned only with money flow, a good or a service is of value only if money changes hands when it is exchanged or consumed. It improves if the net financial return increases

- <u>Economic efficiency</u>

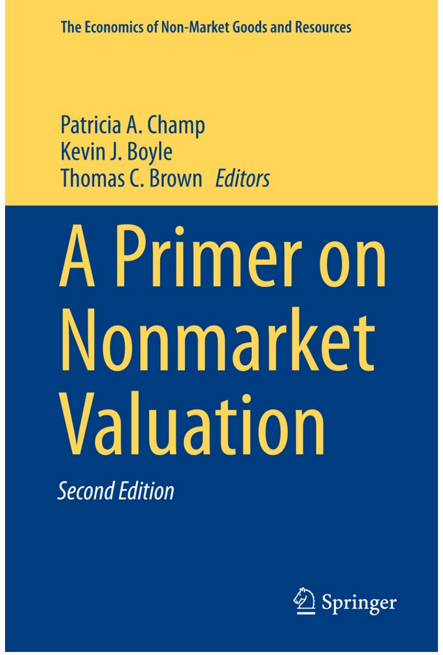
  Is concerned with all goods and services valued by the public regardless of whether consumption is accompaniend by monetary exchange (e.g., willingness to pay for something). It improves if the net wealth of society increases

What is the difference between financial and economic efficiency?



Source: Novikova, 2022
https://doi.org/10.1016/j.evalprogplan.2021.102018

Market vs non-market (or non-valuable) goods



Topic: ecosystem services

Value: (ecology meaning) that which is desirable or worthy of esteem for its own sake; thing or quality having intrinsic worth (Webster's New World Dictionary)

Value: (economist meaning) a fair or proper equivalent in money, commodities, etc. (Webster's New World Dictionary)

Ecology view → philosophic intrinsic value (valuable in and for itself. Independently of any utility)

Economist view → philosopic instrumental value (as a mean to some other end or purpose, e.g. increased human well-being

What are market and non-market goods and resources?

Marked goods have assigned an instrumental value

Non-marked goods have assigned an intrinsic value

Benefits-costs analysis becomes then very problematic in the absence of a common agreement about the value of non-market goods or resources (e.g., ecosystem services)

Contingent (i.e. survey-based) valuation methods

There are several methods available, we focus here at the "People willingness to pay", as an example

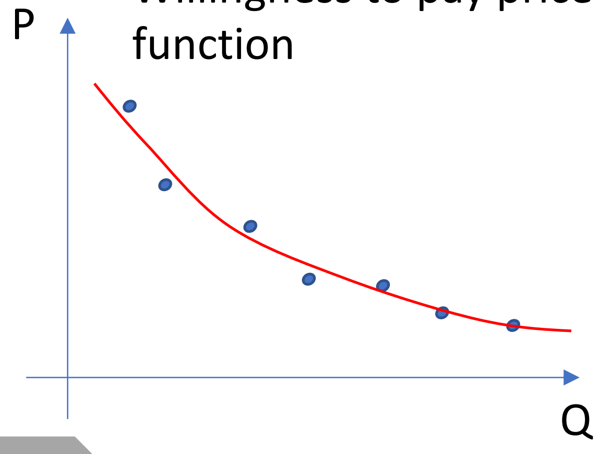
The "Willingness to pay" is based on conducting operational surveys on a sample population interested by the specific ecosystem services to be assessed

People are asked to assess how much they would pay for increasing units of environmental "goods" that sustain related ecosystem services (e.g., amount of flow, or water depth in a river, etc.)

Problem: the method is subjective and results strongly dependent on personal uses or the "vicinity" to the service to be assessed

Can the economic value of financially non/valuable goods be assessed?

Willingness to pay price function



The value of the world's ecosystem services and natural capital

Robert Costanza, Ralph d'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton & Marjan van den Belt

The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US\$16–54 trillion (10^{12}) per year, with an average of US\$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US\$18 trillion per year.

NATURE | VOL 387 | 15 MAY 1997

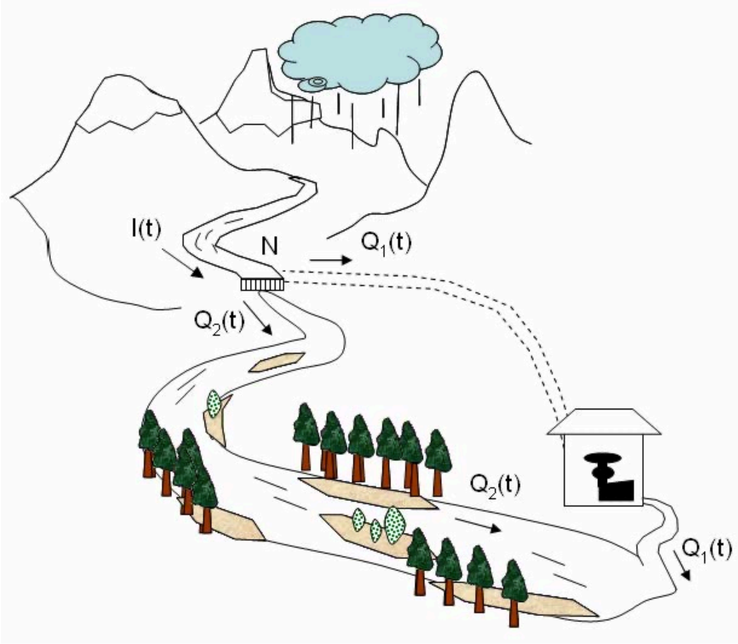
Pricing Biodiversity and Ecosystem Services: The Never-Ending Story

BY MARINO GATTO AND GIULIO A. DE LEO

April 2000 / Vol. 50 No. 4 • BioScience 347

The case of environmental flows

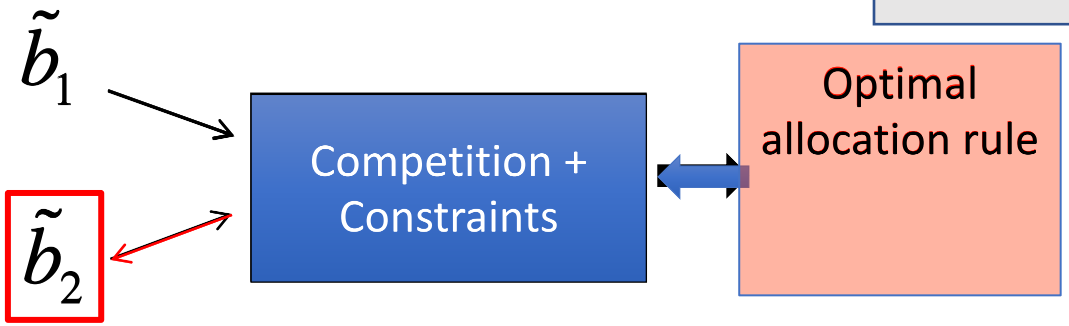
Perona et al., JEMA (2013)



We think in terms of marginal benefits, e.g.

$$\tilde{b}_1 = \tilde{a}_{11} - \tilde{a}_{12}\tilde{Q}_1$$
$$\tilde{b}_2 = \tilde{a}_{21} - \tilde{a}_{22}\tilde{Q}_2$$

Can we use PEMU to value environmental water uses?

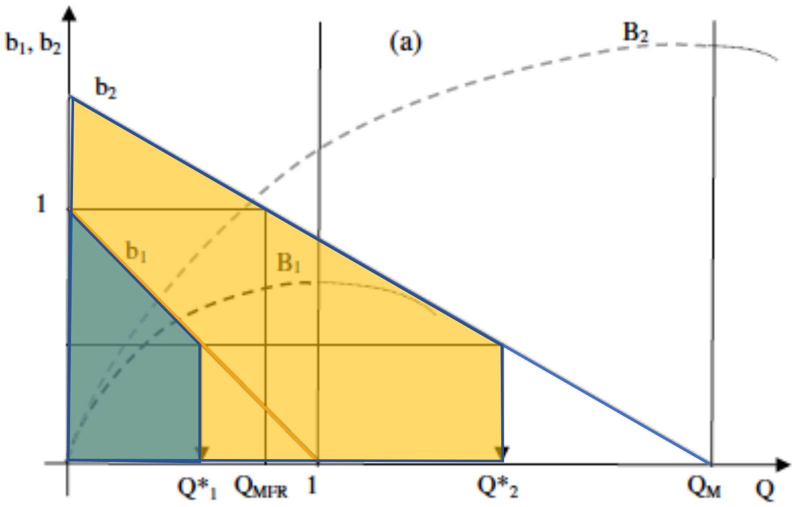


The idea is to show that assigning allocation rules implicitly means to define benefit functions even for non-valuable goods, e.g. like the environmental use of water

$$Max|_{\mathbf{Q},T_h} \left[\sum_{i=1}^{N} \int_{T_h} \int_0^{Q_i} f_{act}(\tau) b_i(q; \mathbf{r}_i(\tau)) dq d\tau \right]$$

$$b_1(Q_1; \mathbf{r}_1(t)) = b_2(Q_2; \mathbf{r}_2(t)).$$

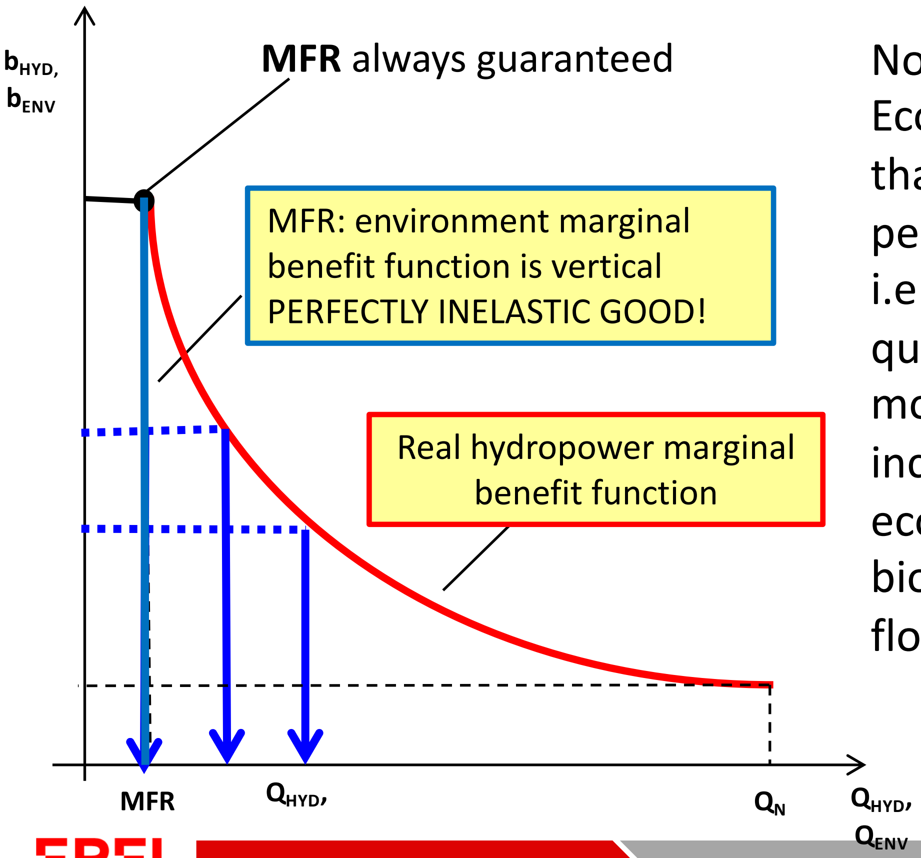
PEMU



Allocation rules and price elasticity of env water use

Minimal Flow POLICY

$$\begin{cases} I = Q_{hyd} + Q_{MFR} \\ b(Q_{hyd}) = b(Q_{env}) \end{cases} \qquad \text{(PEMU)}$$



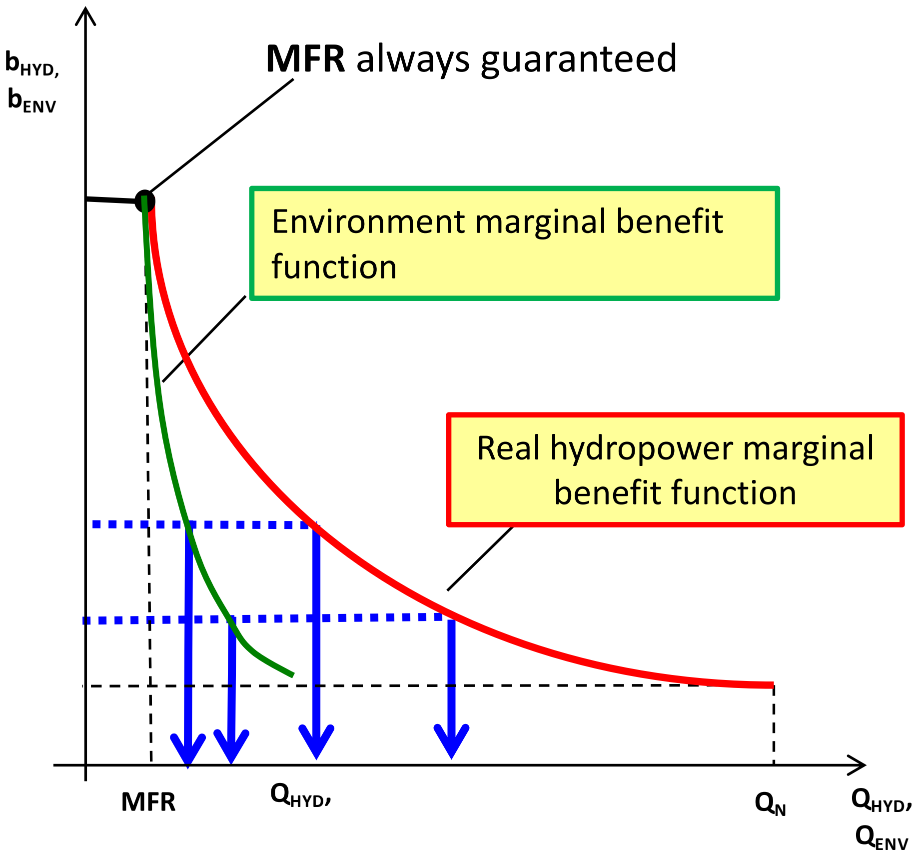
Is minimal flow a good policy?

No, it is not. Economically this means that env use would be a perfectly inelastic good, i.e. asking for a precise quantity of water and no more, which is inconsistent with the ecological principle that biodiversity arises from flow variability

Perona et al., JEMA (2013)

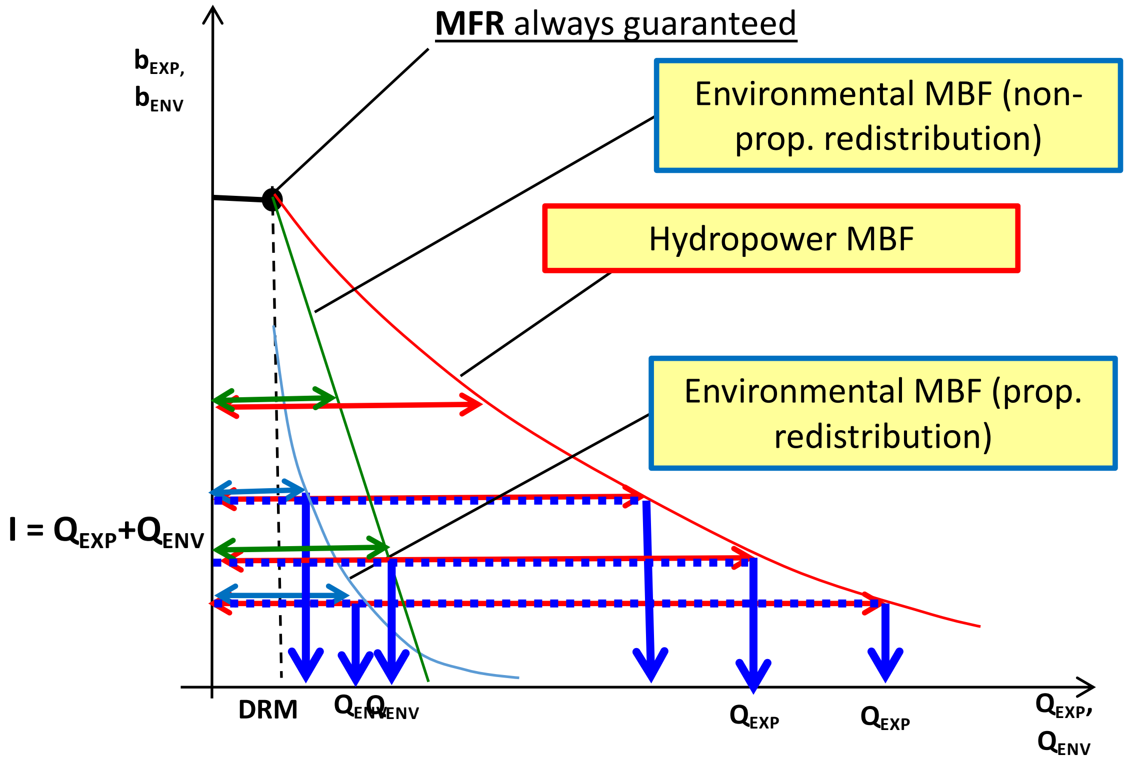
Proportional redistribution POLICY

$$\begin{cases} I = Q_{hyd} + Q_{env} \\ \text{AND} \\ b(Q_{hyd}) = b(Q_{env}) \end{cases} \qquad \frac{Q_{env} - Q_{MFR}}{Q_{hyd}} = p$$



Meaning for non-proportional allocation

$$\begin{cases} I = Q_{hyd} + Q_{env} \\ \text{AND} \\ b(Q_{hyd}) = b(Q_{env}) \end{cases} \qquad \frac{Q_{env} - Q_{MFR}}{Q_{hyd}} = p$$



Are dynamics policies (prop./non-pro.) better?

Yes, they are because they allow to maintain part of the natural flow regime variability by simply changing allocation percentages as the inflow naturally changes.
This allows to reconciliate economy and ecology, that is with the principle that flow variability is important forecological functions and richness of biodiversity