

COMPLEX DYNAMIC PHENOMENA IN
ENVIRONMENTAL PLANNING AND MANAGEMENT
Sergio Rinaldi, DEI, Politecnico di Milano, Italy
ENS – Paris – France – 29-30 Avril 2004

1. ENVIRONMENTAL MANAGEMENT AND NONLINEAR DYNAMICS

An overview of the most typical problems one encounters in environmental planning and management. Emphasis on relationships with nonlinear dynamics. Further reading: *Journal of Environmental Management* (1996), 48, 357-373.

2. THE PROBLEM OF FLOATING PLANTS IN RESERVOIRS

Description of the problem through a model of competition between floating and submerged plants. Analysis of the model: alternative stable states. Bifurcation analysis and derivation of possible control actions. Analysis of the history of Lake Kariba on the Zambesi river. Further reading: *PNAS* (2003), 100, 4040-4045.

3. FOREST EXPLOITATION AND ACID RAIN: A DANGEROUS MIX

Description of the problem through a series of minimal models. Existence of catastrophic bifurcations (forest collapse). Cusp bifurcation: negative synergistic effect of acid rain and exploitation.

Further reading: *Vegetatio* (1987), 69, 213-222

Appl. Math. Modelling (1989), 13, 674-681

Theor. Pop. Biol. (1998), 54, 257-269.

4. THE RECLAMATION OF EUTROPHIC WATER BODIES

Description of the problem in terms of minimal models involving algae, zooplankton and planktivorous fish. Analysis of the bifurcations of the model: the appearance and disappearance of clear-water regimes. Biological control.

Further reading: *OIKOS* (1997), 80, 519-532.

5. TOURISM SUSTAINABILITY: AN OVERVIEW

The three components of the problem: tourists, environment and facilities. Detection of possible scenarios. Profitable, compatible and sustainable policies. Adaptivity. The case of alternative classes of tourists and of diversified investments.

Further reading: *Conservation Ecology* (2002), 6(1): 13 [online].

Chaos and Complexity Letters (2004) first issue (in the press).

6. ENRICHMENT AND YIELD MAXIMIZATION

Exploitation of renewable resources. Enrichment and mean yield maximization. Analysis of the case of tritrophic food chains. Optimality at the edge of chaos. Derivation of management rules.

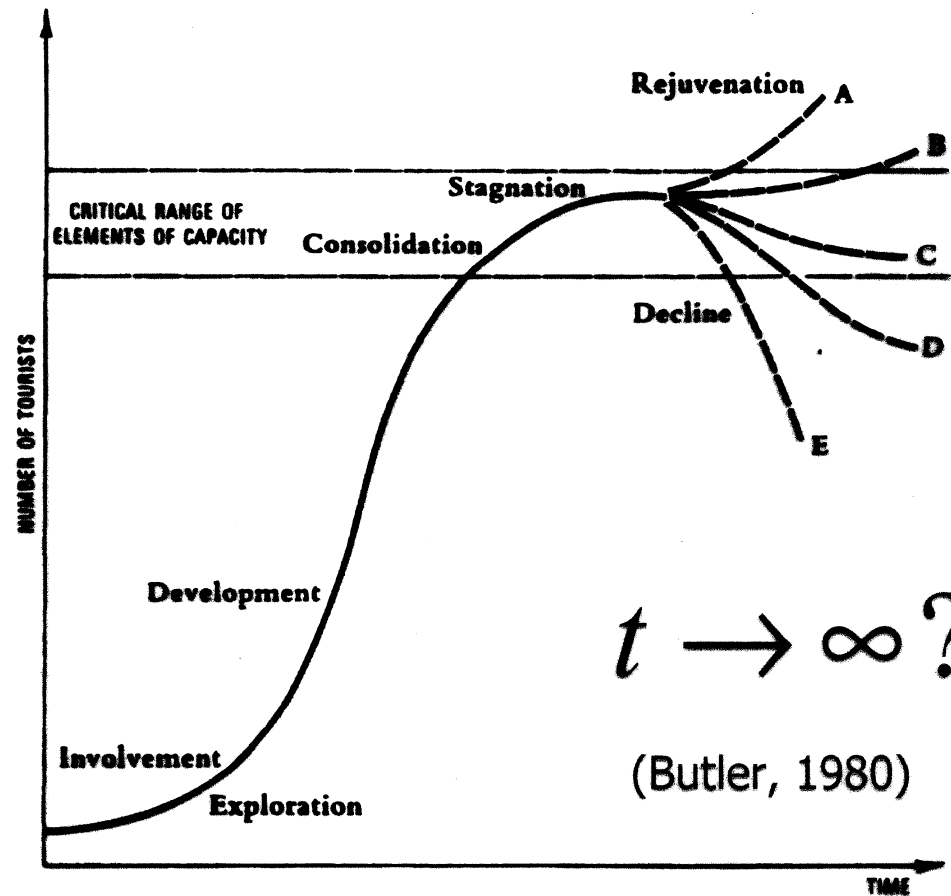
Further reading: *Am. Nat.* (1997) 150, 328-345

Bull. Math. Biol. (1998) 60, 703-719

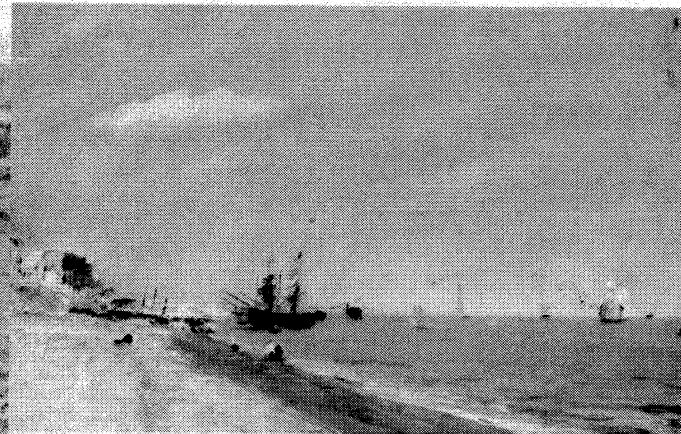
Ecol. Lett. (1999) 2, 6-10

J. Math. Biol. (2002) 45, 396-418.

Sviluppo turistico su scala LOCALE



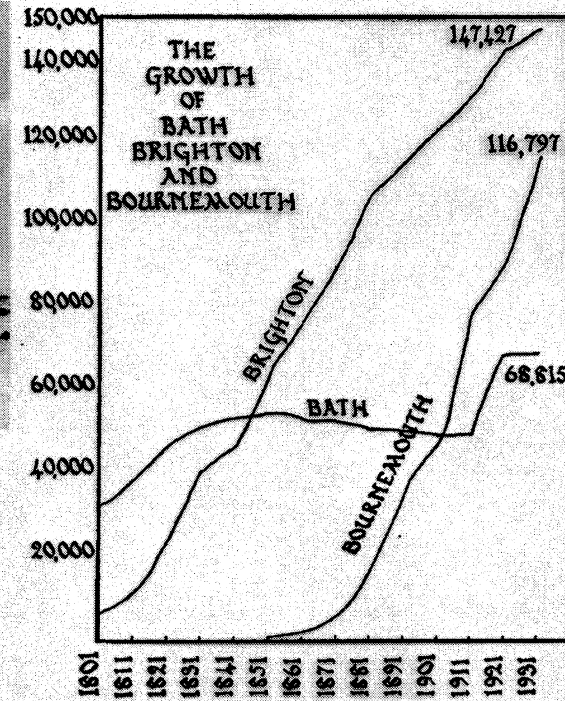
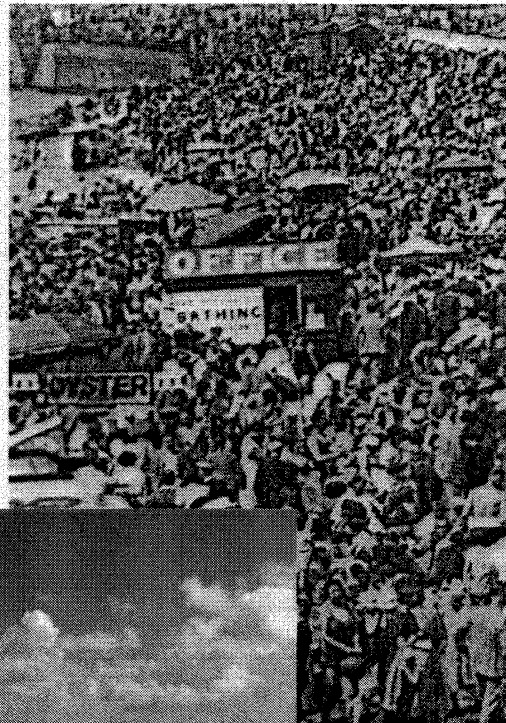
Casi di studio: Brighton (U.K.)



John Constable (1824)



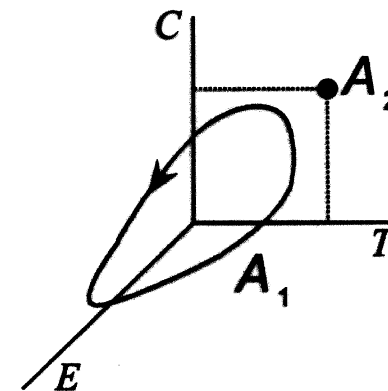
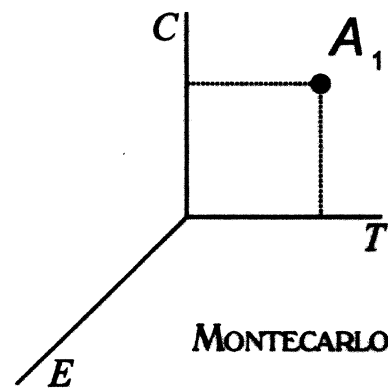
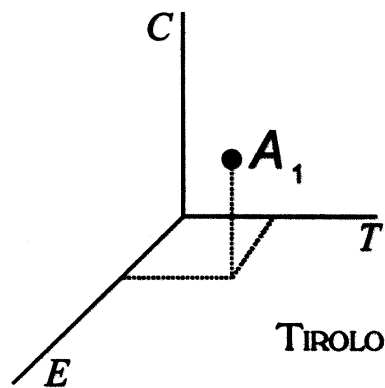
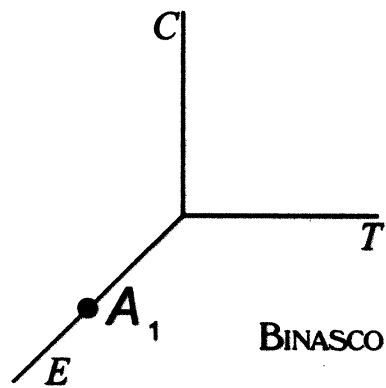
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Un modello minimo

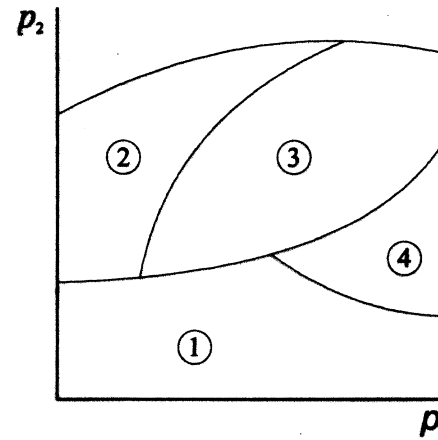
$$\begin{cases} T_{k+1} = T_k + \dots \\ E_{k+1} = E_k + \dots \\ C_{k+1} = C_k + \dots \end{cases}$$

Situazioni



Parametri

(investimento, prezzi, competizione, ...)



analisi delle biforcazioni

Modello

$$\begin{cases} T_{k+1} = T_k + T_k \left[\mu_E \frac{E_k}{E_k + \varphi_E} + \mu_C \frac{C_k}{C_k + \varphi_C T_k + \varphi_C} - \alpha T_k - a \right] \\ E_{k+1} = E_k + E_k \left[r \left(1 - \frac{E_k}{K} \right) - \beta C_k - \gamma T_k \right] \\ C_{k+1} = C_k - \delta C_k + \varepsilon T_k \end{cases}$$

Quali parametri?

Legati alla **POLITICA**
(*dipendenti* dagli agenti)

Esempi:

- β = impatto ambientale
- ε = investimento

Legati al **SISTEMA**
(*indipendenti* dagli agenti)

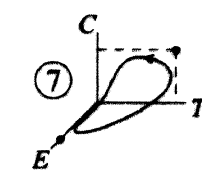
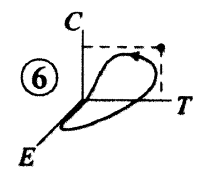
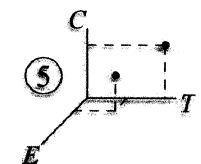
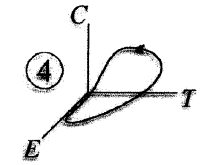
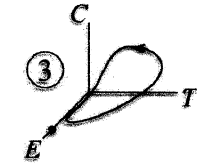
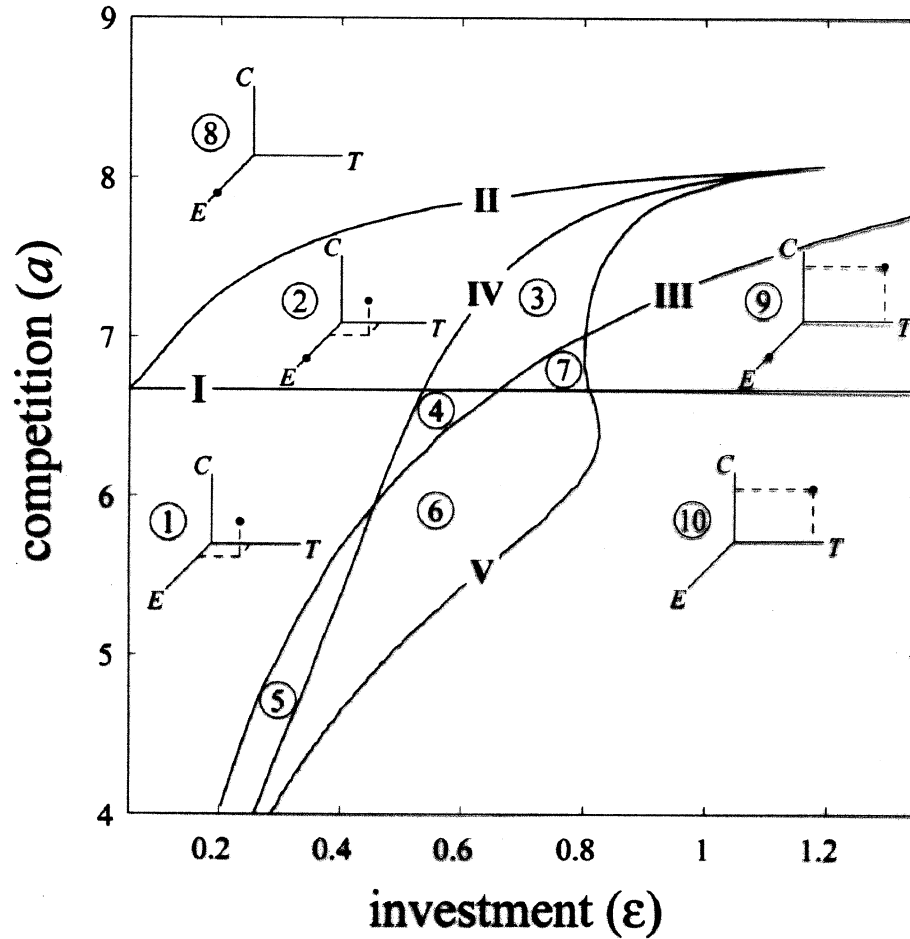
Esempi:

- μ, φ = cultura dei turisti
- a = competizione

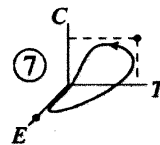
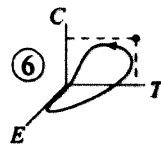
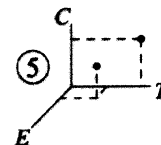
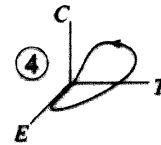
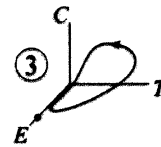
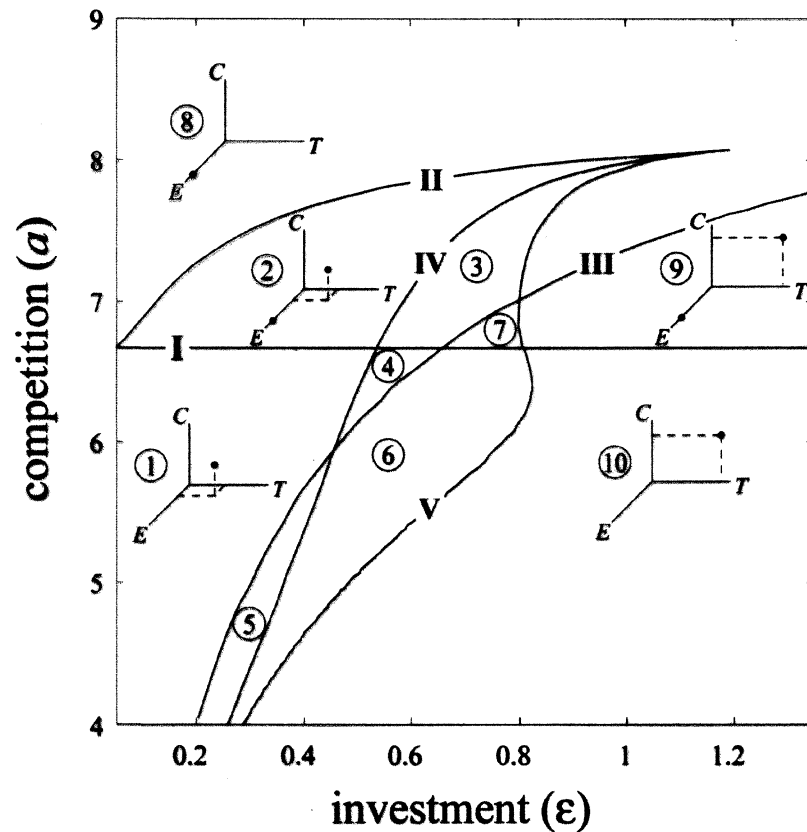
Come classificare le politiche?

Giudizio

Proprietà strutturali degli attrattori



Punto di vista ECONOMICO



Definizione:

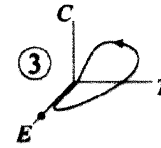
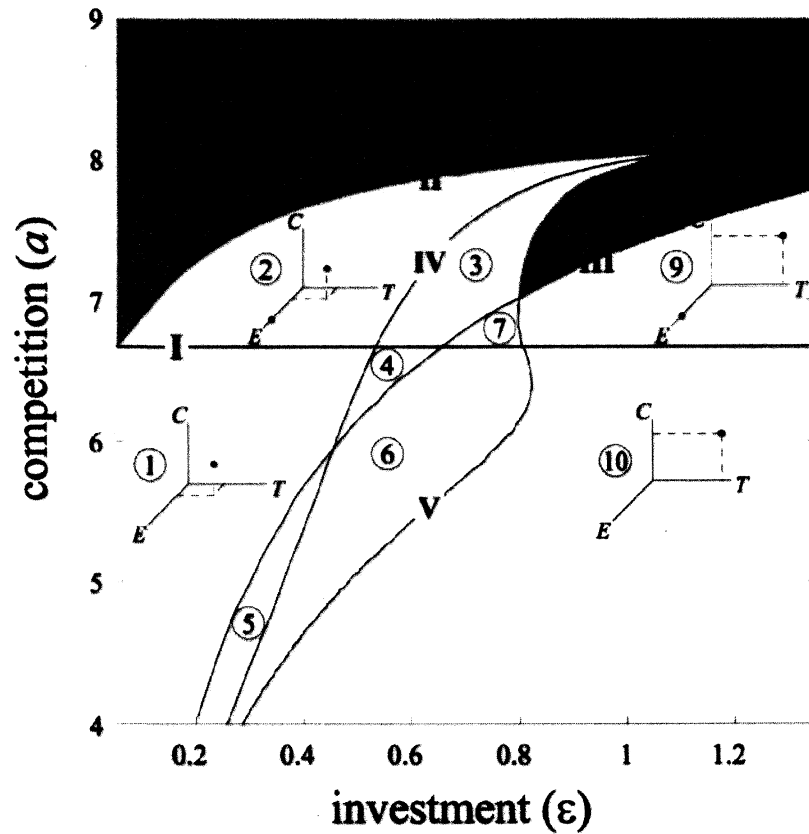
Una politica si dice economicamente

REDDITIZIA se
 $\exists A_i$ tale che $T > 0$

NON REDDITIZIA
 altrimenti

Nota: Diversa dalla usuale definizione di sviluppo sostenibile degli economisti

Punto di vista ECONOMICO

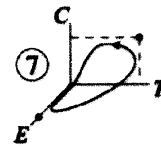
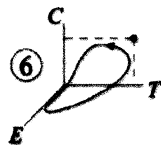
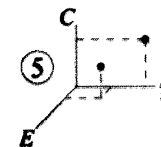
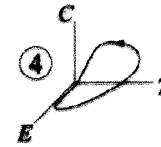


Definizione:

Una politica si dice economicamente

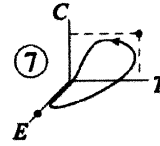
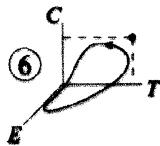
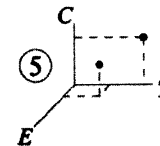
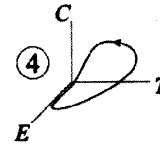
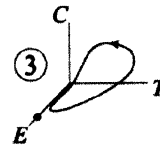
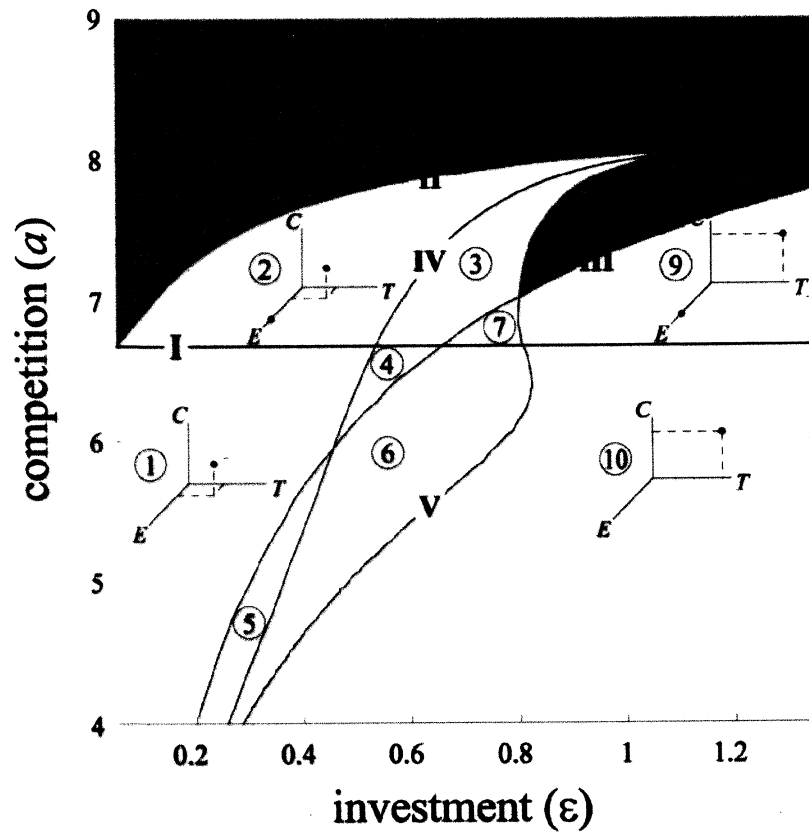
REDDITIZIA se
 $\exists A_i$ tale che $T > 0$

NON REDDITIZIA
 altrimenti



Nota: Diversa dalla usuale definizione di sviluppo sostenibile degli economisti

Politiche REDDITIZIE



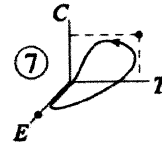
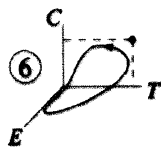
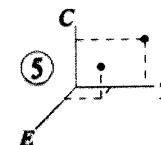
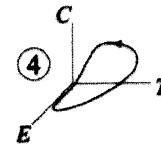
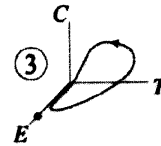
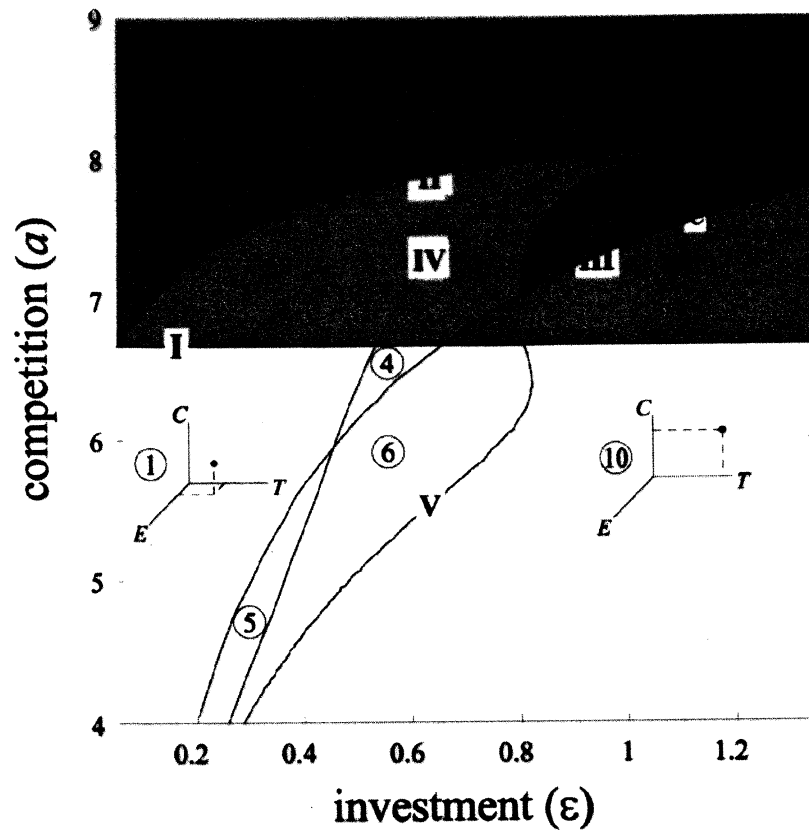
Ulteriore suddivisione:

Una politica redditizia
si dice

a RISCHIO se
 $\exists A_j$ tale che $T = 0$

SICURA
altrimenti

Politiche REDDITIZIE



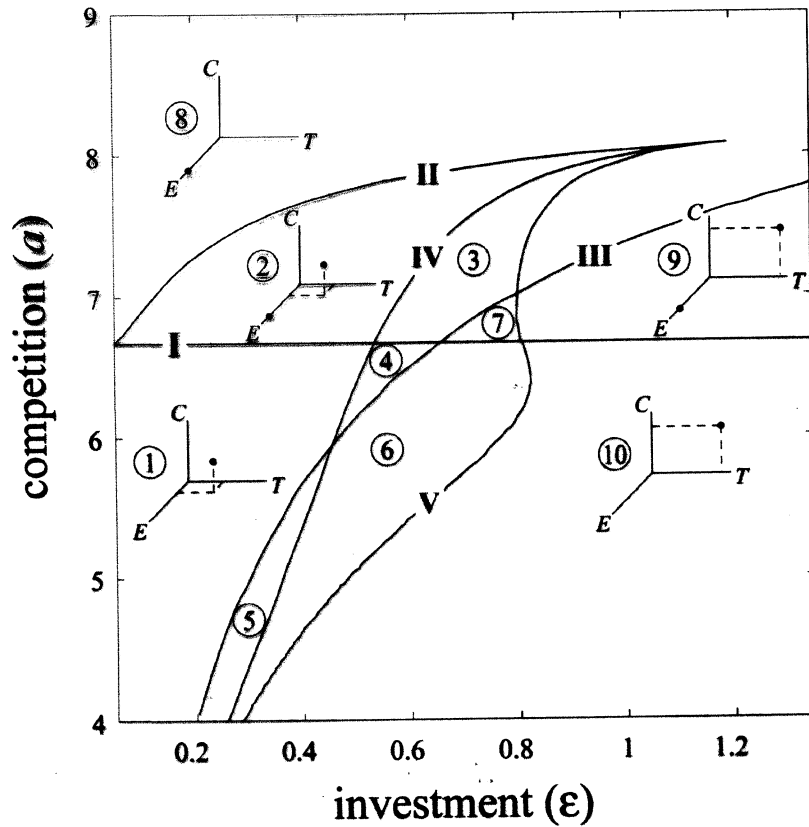
Ulteriore suddivisione:

Una politica redditizia
si dice

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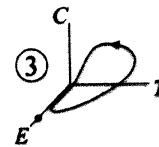
SICURA
altrimenti

Punto di vista AMBIENTALE

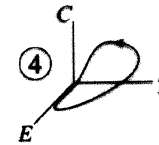


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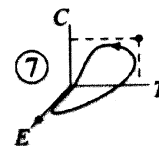
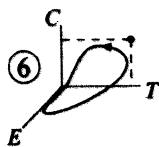
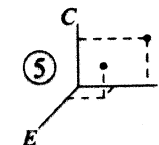
Una politica si dice
ambientalmente



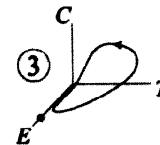
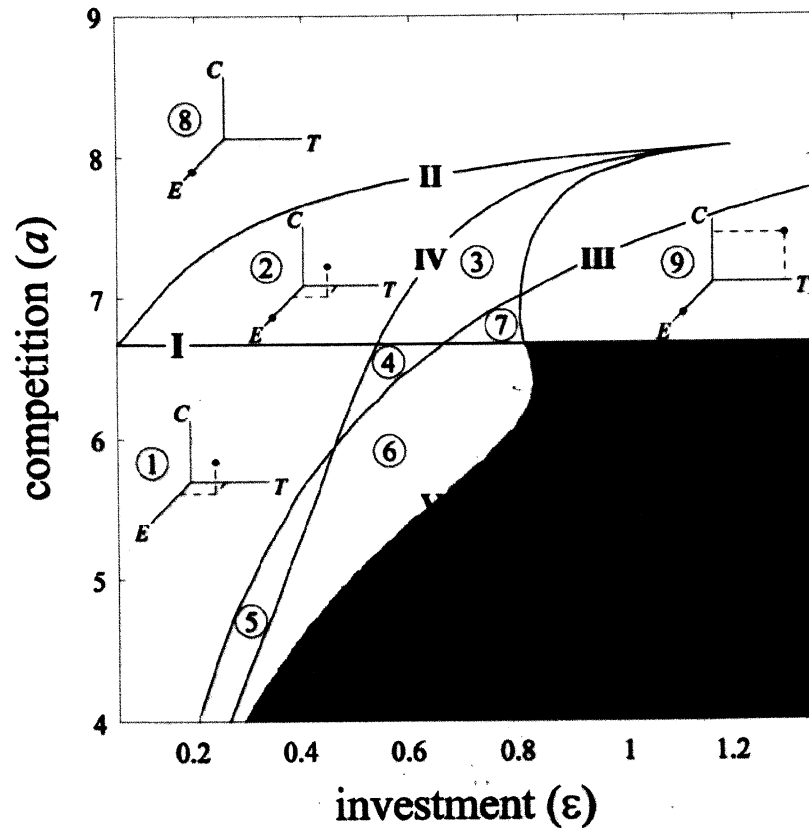
COMPATIBILE se
 $\exists A_i$ tale che $E > 0$



NON COMPATIBILE
altrimenti

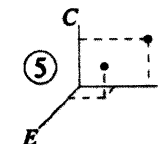
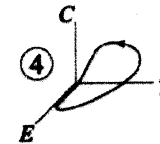


Punto di vista AMBIENTALE



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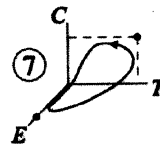
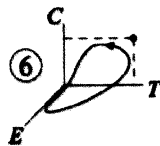
Una politica si dice
ambientalmente



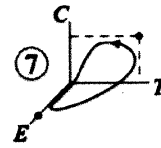
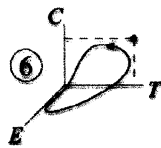
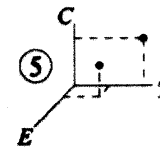
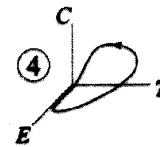
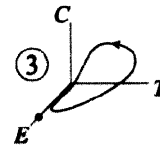
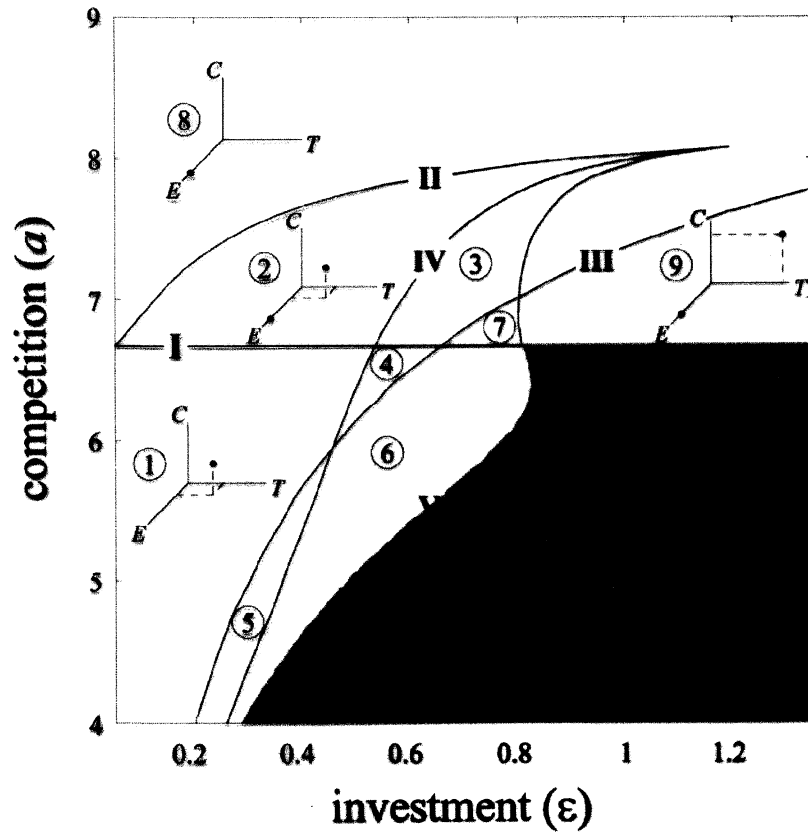
COMPATIBILE se

$\exists A_i$ tale che $E > 0$

NON COMPATIBILE
altrimenti



Politiche COMPATIBILI

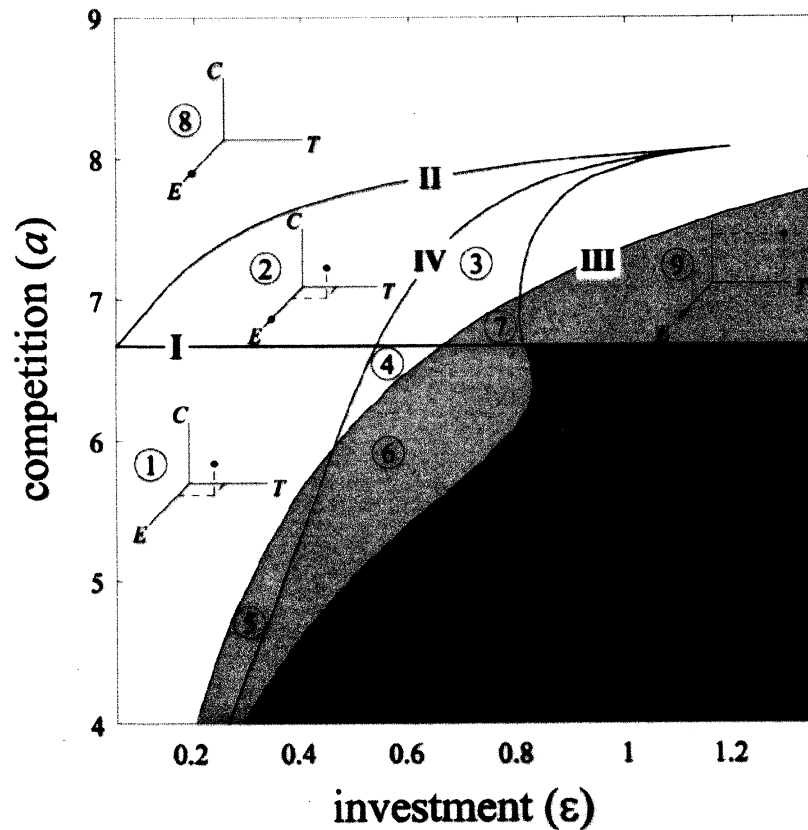


Ulteriore suddivisione:

Una politica compatibile
si dice

a RISCHIO se
 $\exists A_k$ tale che $E = 0$
 SICURA
 altrimenti

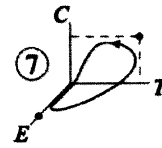
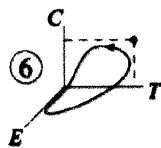
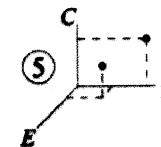
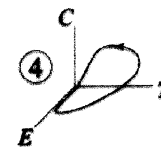
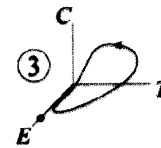
Politiche COMPATIBILI



Ulteriore suddivisione:

Una politica compatibile
si dice

{ a RISCHIO se
 $\exists A_k$ tale che $E = 0$
 SICURA
 altrimenti



Politiche SOSTENIBILI

Def:
Una politica
si dice

SOSTENIBILE se
 $\exists A_i$ tale che $T, E > 0$

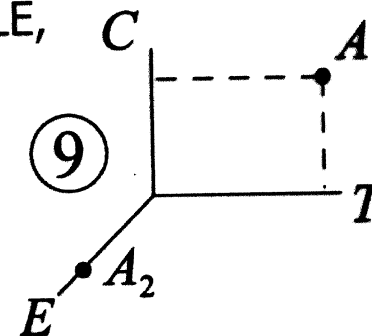
NON SOSTENIBILE
altrimenti

a RISCHIO ECONOMICO se
 $\exists A_j$ tale che $T = 0$

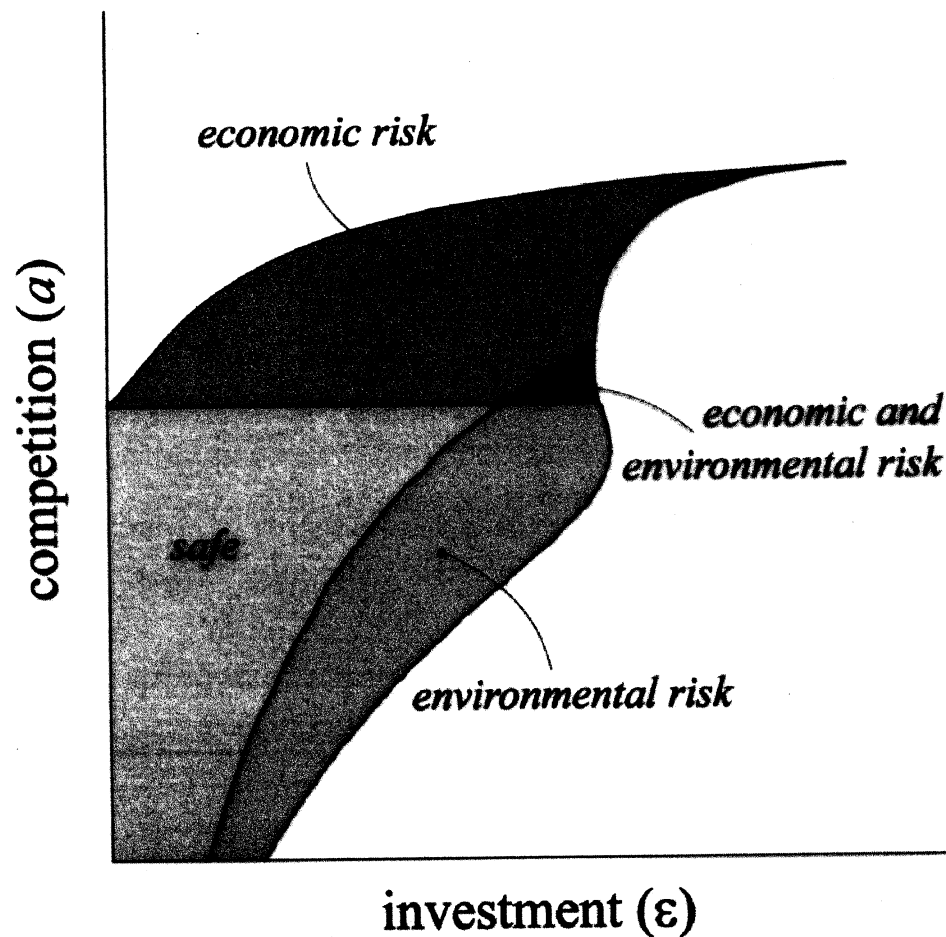
a RISCHIO AMBIENTALE se
 $\exists A_j$ tale che $E = 0$

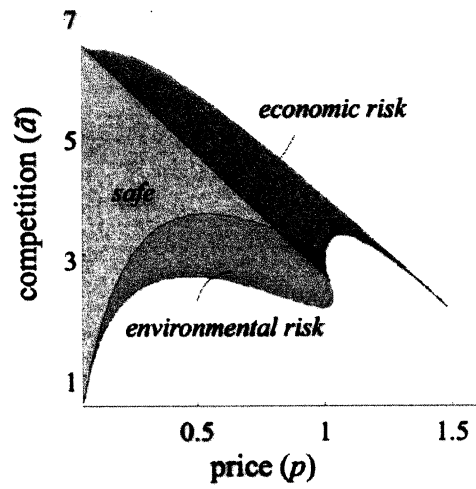
SICURA se
 $\forall i A_i$ tale che $T, E > 0$

Nota: SOSTENIBILE \rightarrow REDDITIZIA e COMPATIBILE,
ma non viceversa!

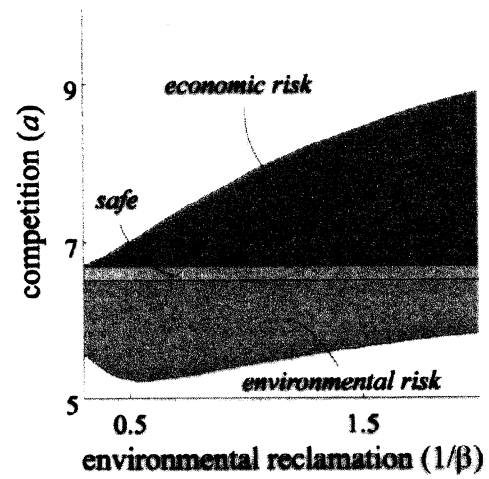


Quadro di sostenibilità

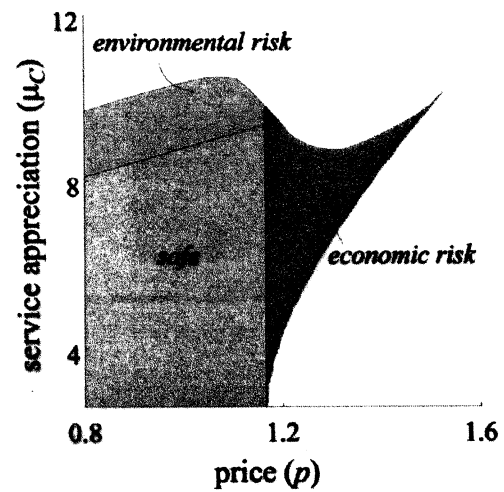




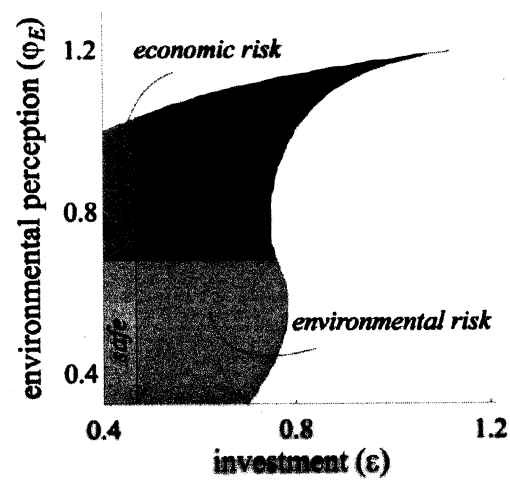
(a)



(b)



(c)



(d)