Incertitude et analyse du long terme: optimisation et scenarios

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Une introduction à:

1. Typologie des sortes d'incertitude
2. Décision séquentielle
3. Analyse des systèmes
4. L'art des scénarios

1. Dimensions of ignorance

- Error
  - Probability (risk)
  - Imprecision (uncertainty)
  - Incompleteness (unknown unknowns)
- Human dimensions
  - Psychologic and social
  - Strategic

1.1 Degrees of error

- The probabilistic model starts with an exhaustive partition of the future into mutually exclusive states, and assign each state a specific weight
- Uncertainty: states are known, weights are imprecise
- Incompleteness: unknown unknowns

Ellsberg's urn

What is the probability of drawing a red ball from a box ?

We know the box contains:

- 3 colored balls
- 1 is yellow
- The other 2 are red or black

The probability is between 0 and 2/3.

A mental experiment

An investor accepted a risky project paying:

4 in the good case (probability p)

-4 in the bad case

Assume that this is a rational investor.

What do we know about *p* ?

Bets and information

$4\,p + (-4)\,(1-p) > 0$ that is $p > ½$

Market choices reveal the information of economic agents.

Application: finance, prediction markets

Imprecision

Intervalls of probability : $[p^-, p^+]$

- Ellsberg's urn
- Coherent bets (De Finetti)

- Belief/plausibility

Special cases [0, p^+] or [p^- , 1]

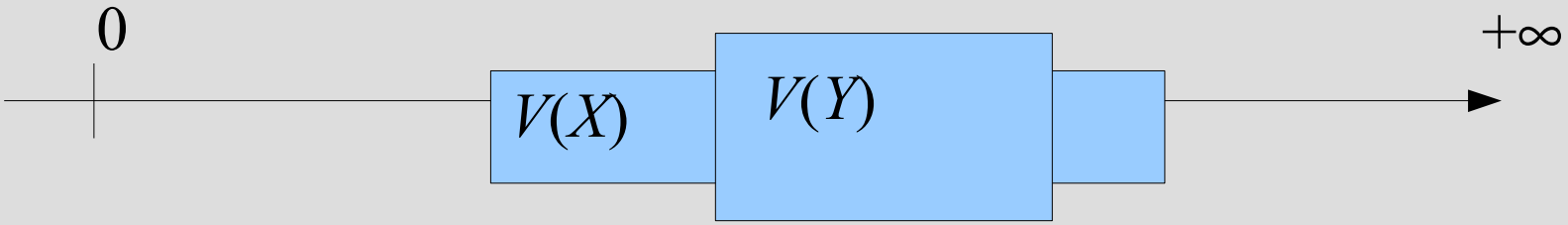
Plausibility level is 0.6 means that
p is lower than 0.6

Scenarios are plausible, not probable.

Imprecision and decision

Expected value is an intervall too

$$V(X)=[\underline{P}(X),\overline{P}(X)]$$



We may not always compare options

1.2 Human dimensions of ignorance

Error: missing information, a desire to get it right

i. Active ignorance

ii. Strategic

i. Active ignorance

Elements excluded from the discourse for psychologic or social reasons

- Surprises
- Metaphysics
- Taboos

Surprise

Unexpected event

Mismatch between a stimulus and pre-established knowledge networks

Surprise ≠ abrupt change

Scenarios can help !

Metaphysics

- Cannot be verified: Faith, values, belief systems
- Parameters of the decision model utility, risk and time preferences, equity

- Warnings
  - Diversity is a source of resilience
  - Dialogue has a role

Taboos

- What the members of a social group must not know or even question
- Essential to the identity of any group, IPCC too
- Plenty of opportunity for interference with Scientific Truth
- Fixes must come from outside

ii. Strategic Ignorance

- Conflicts
- Trust and et coordination

- Example:
  - Free riding
  - Information asymmetries

Conclusions of 1.

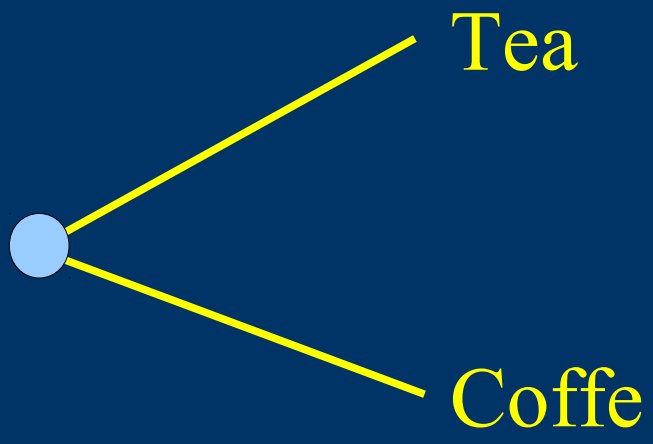
Under uncertainty,
use probability intervalls or bounds.

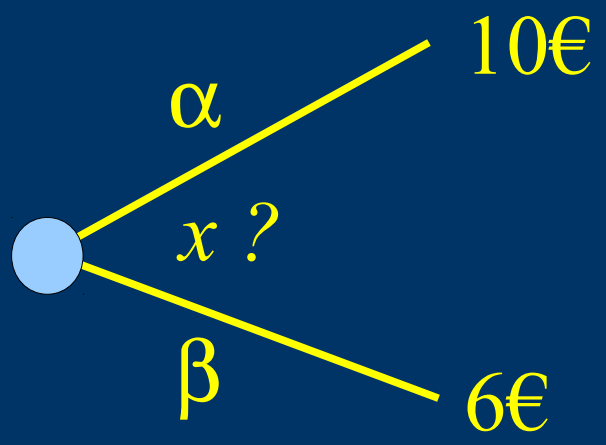
Maximize expected utility
when probabilities are precise

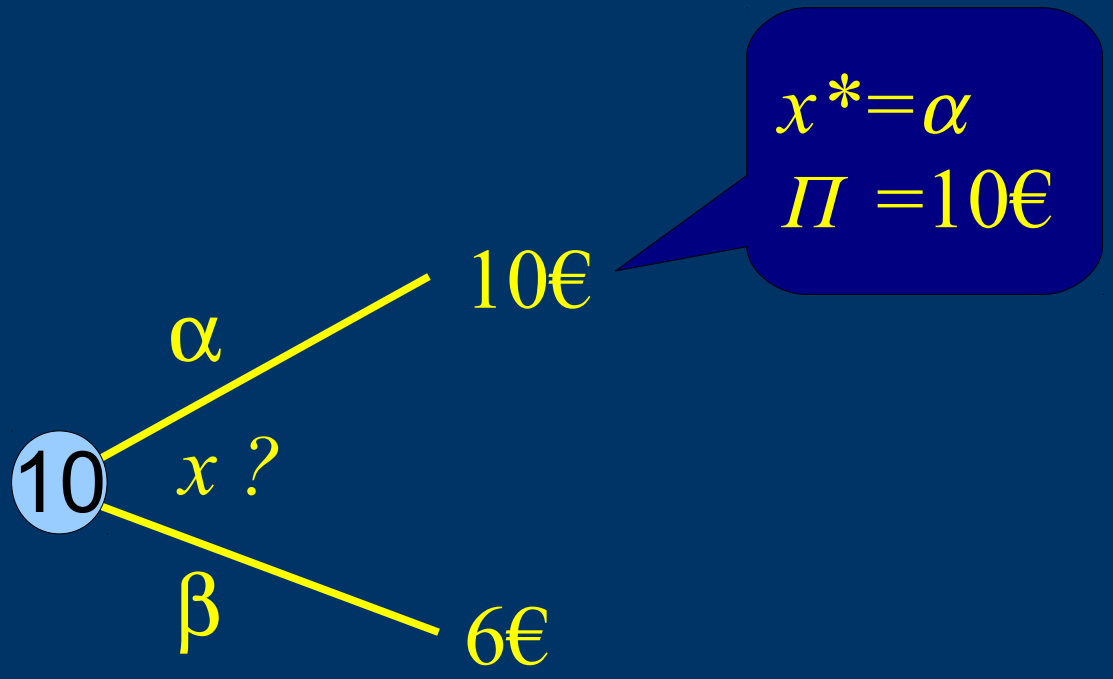
Scenarios are useful tools to analyze the human dimensions of ignorance.

2. Dynamic decision theory

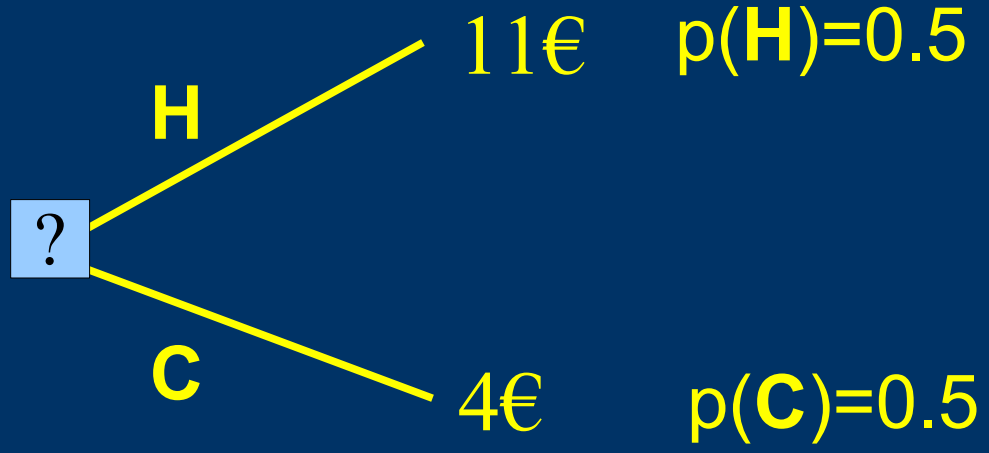
Decision


Tea
Coffe

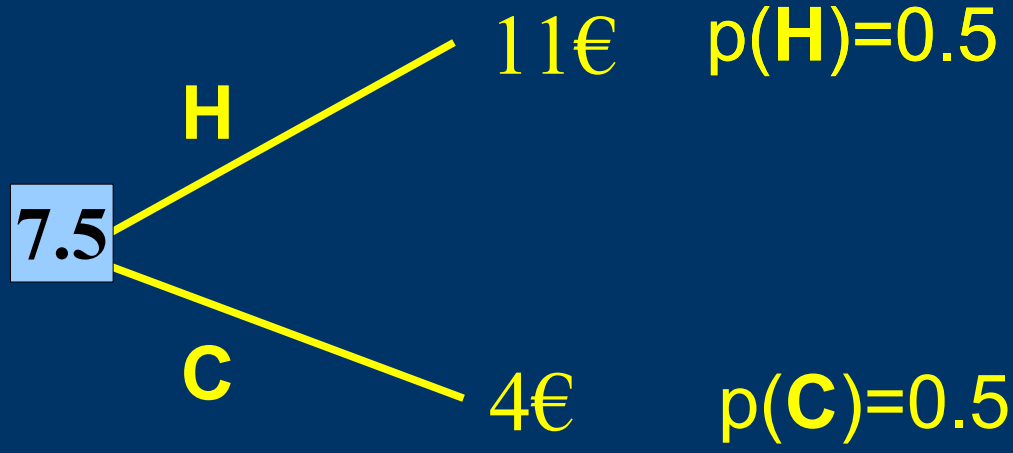

10€
α
x ?
β
6€


$x^*=\alpha$
Π =10€
10€
α
10
x ?
β
6€

Uncertainty

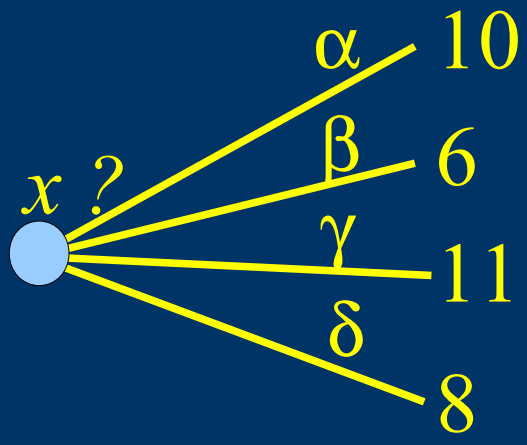

11€
p(H)=0.5
H
?
C
4€
p(C)=0.5

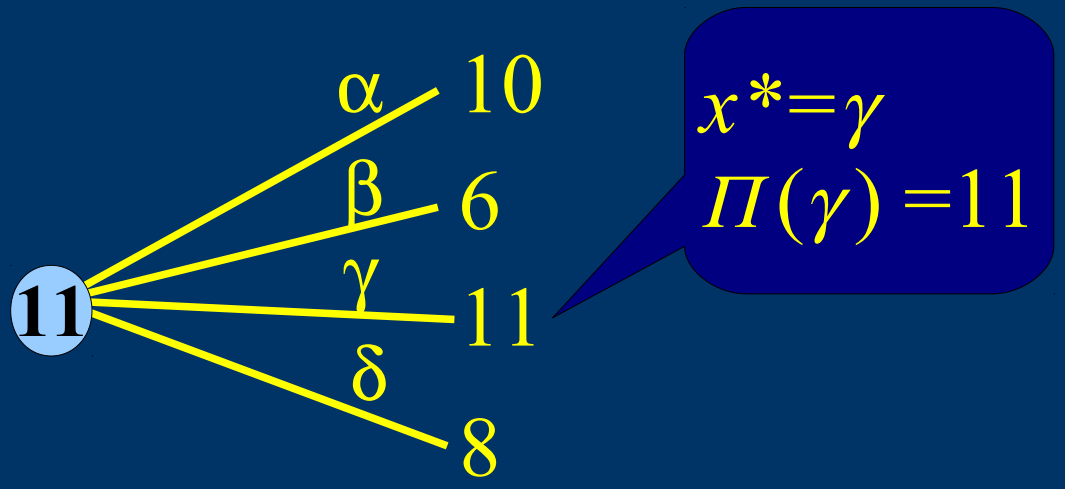
$0.5 * 11 + 0.5 * 4 = 7.5$

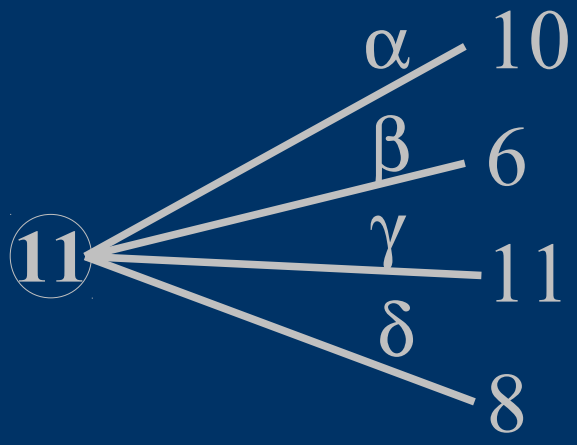


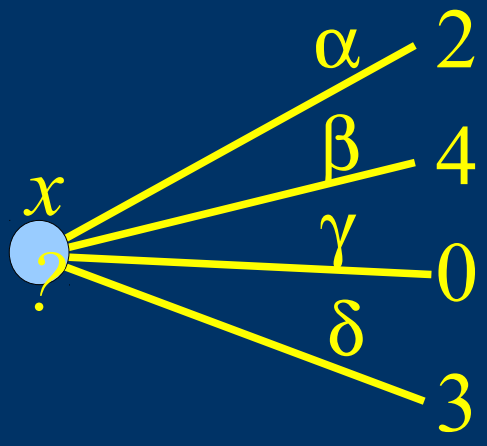
Decision node

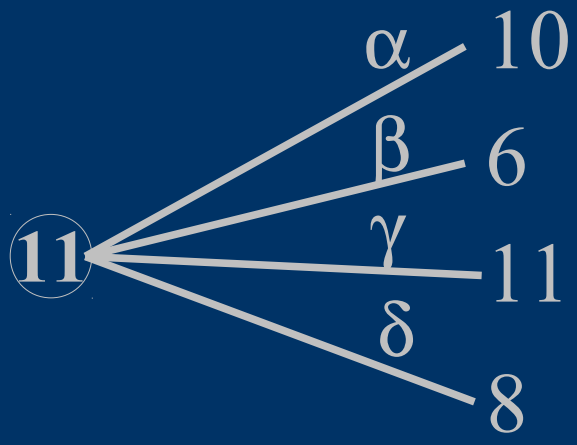
Chance node

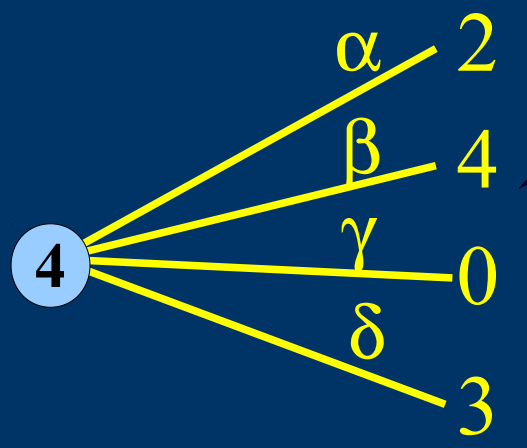

α
10
β
6
x ?
γ
11
δ
8


α
β
γ
δ
10
6
11
8
11
x*=γ
Π(γ) =11


α
β
γ
δ
10
6
11
8
11

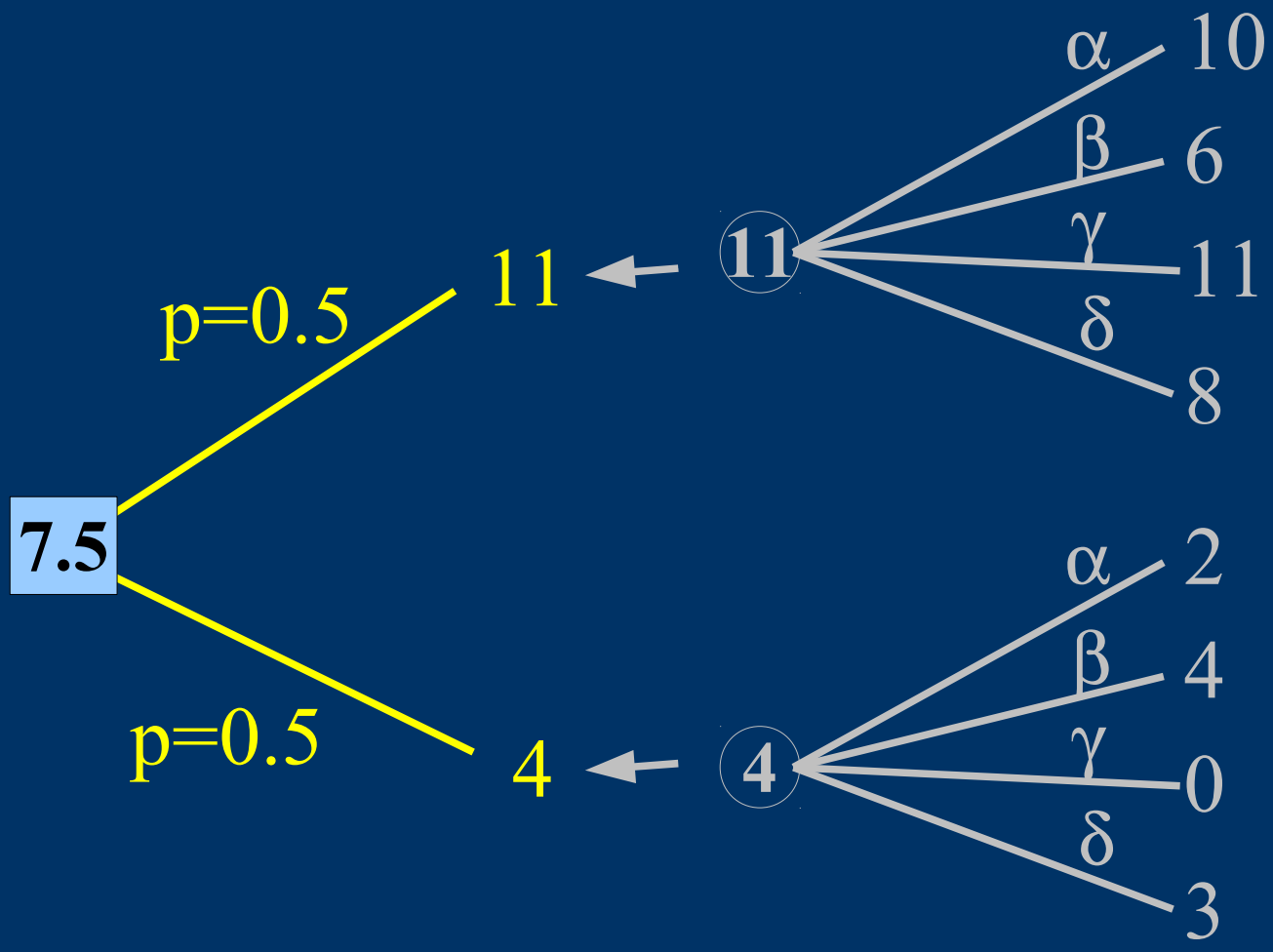

α
β
γ
δ
2
4
0
3
x
?

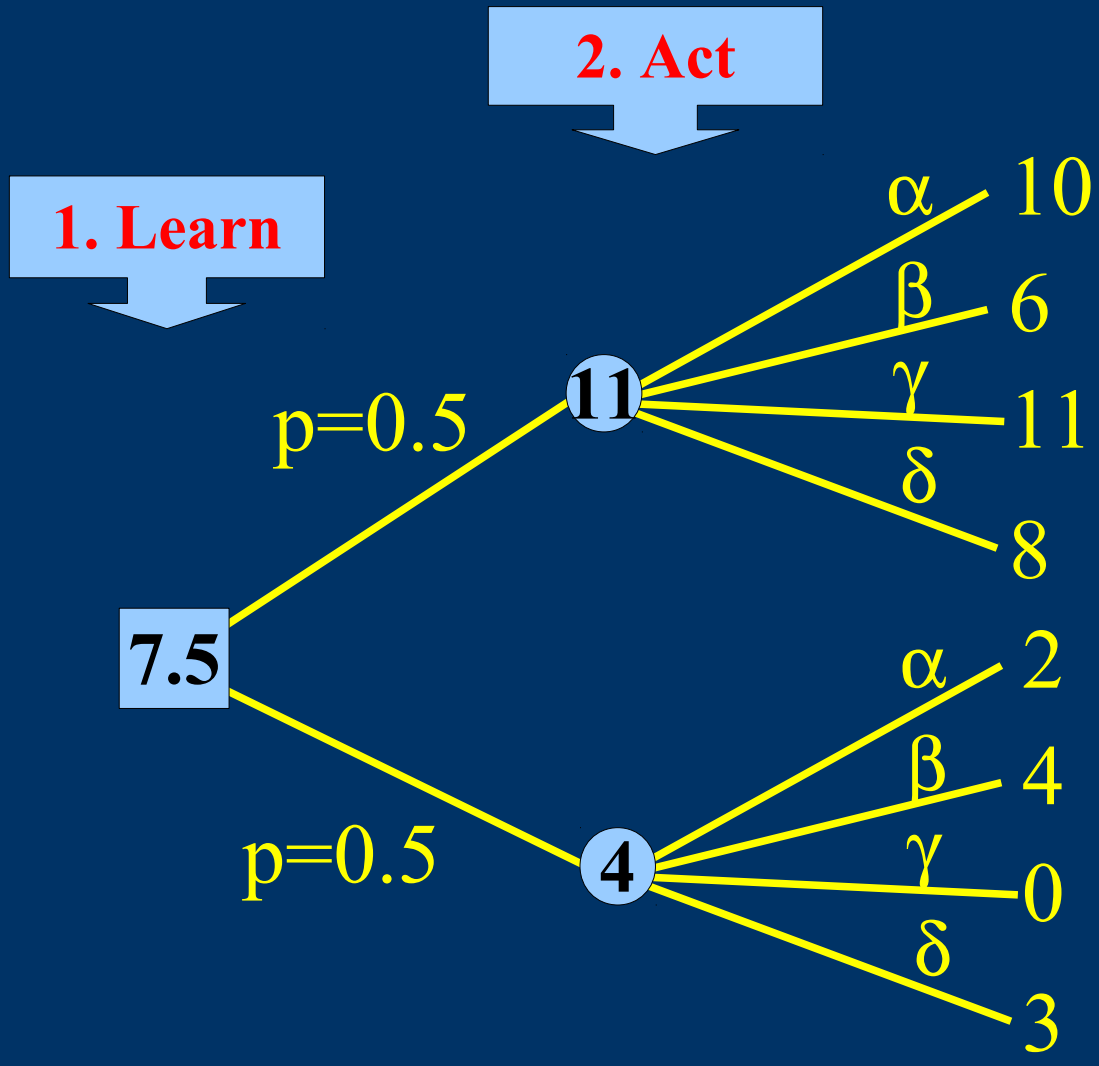


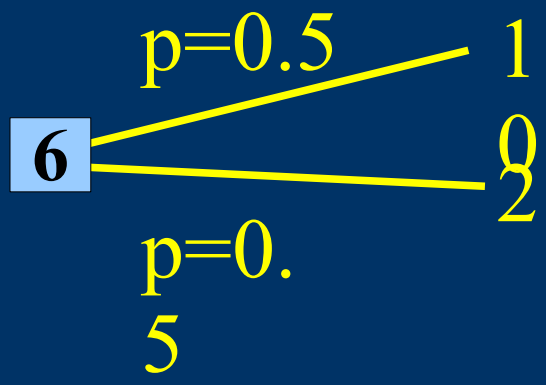


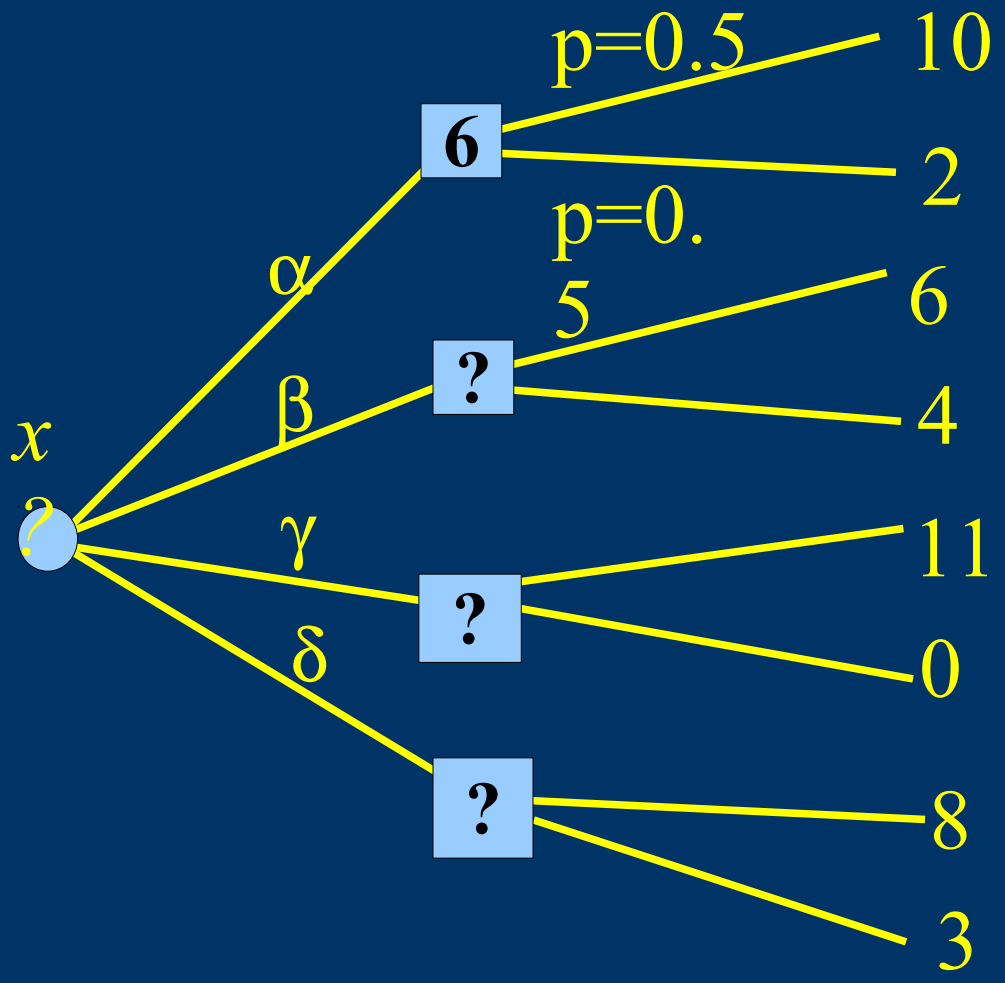
$x^* = \beta$

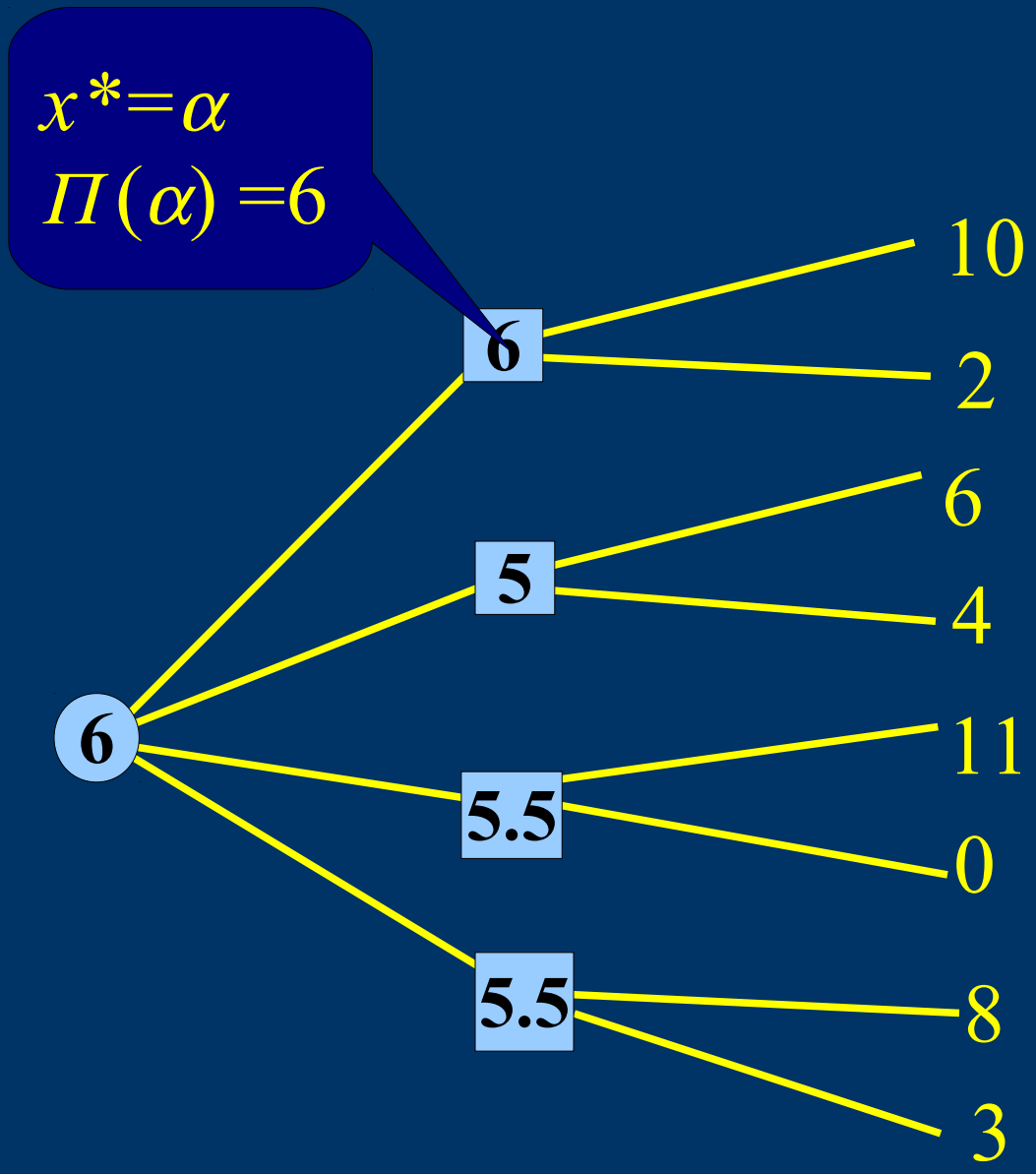
$\Pi(\beta) = 4$

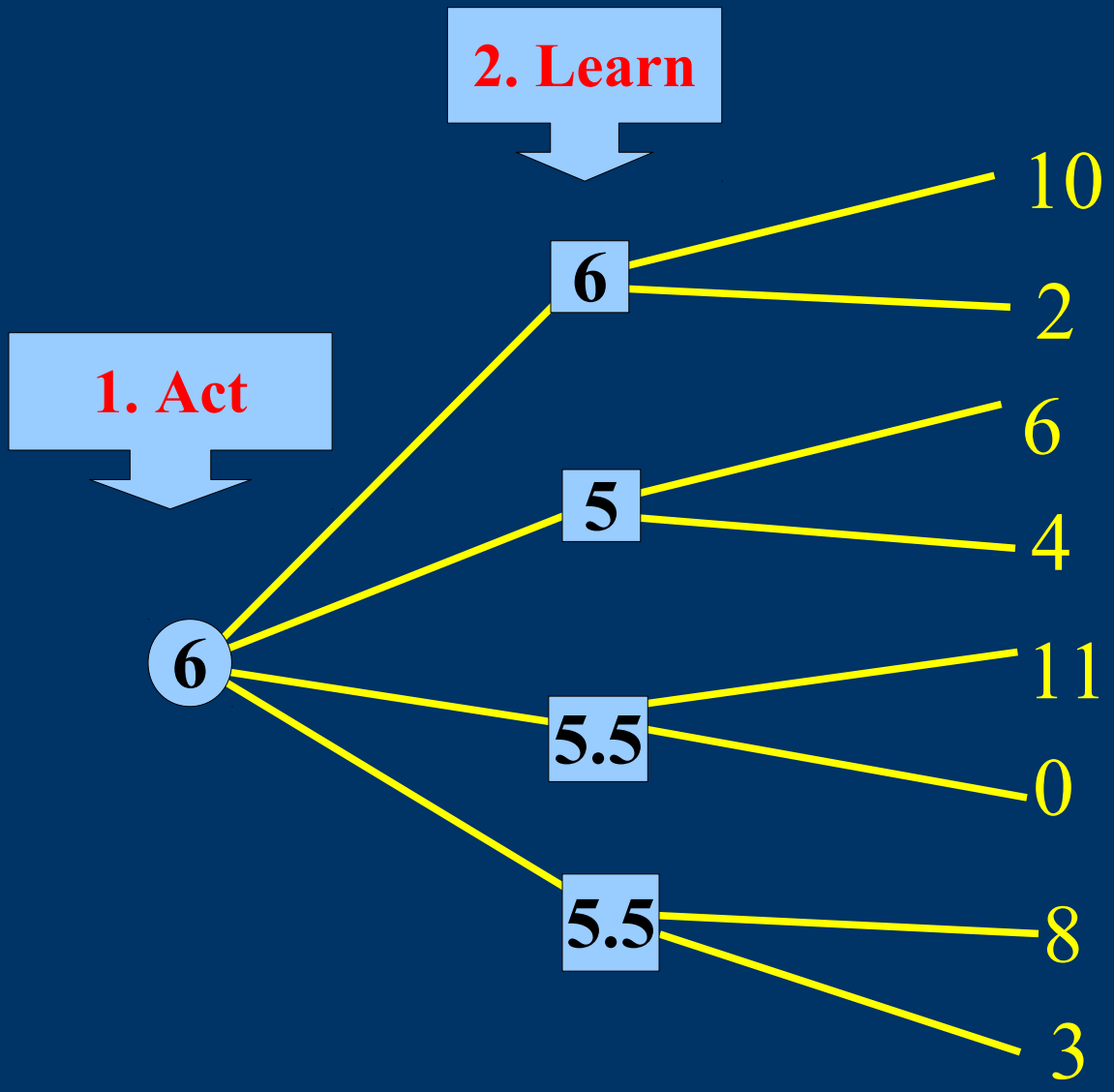

α
10
β
6
γ
11
δ
8
11
11
p=0.5
7.5
p=0.5
4
4
α
2
β
4
γ
0
δ
3


2. Act
1. Learn
α
β
γ
δ
10
6
11
8
p=0.5
11
7.5
α
β
γ
δ
2
4
0
3
p=0.5
4

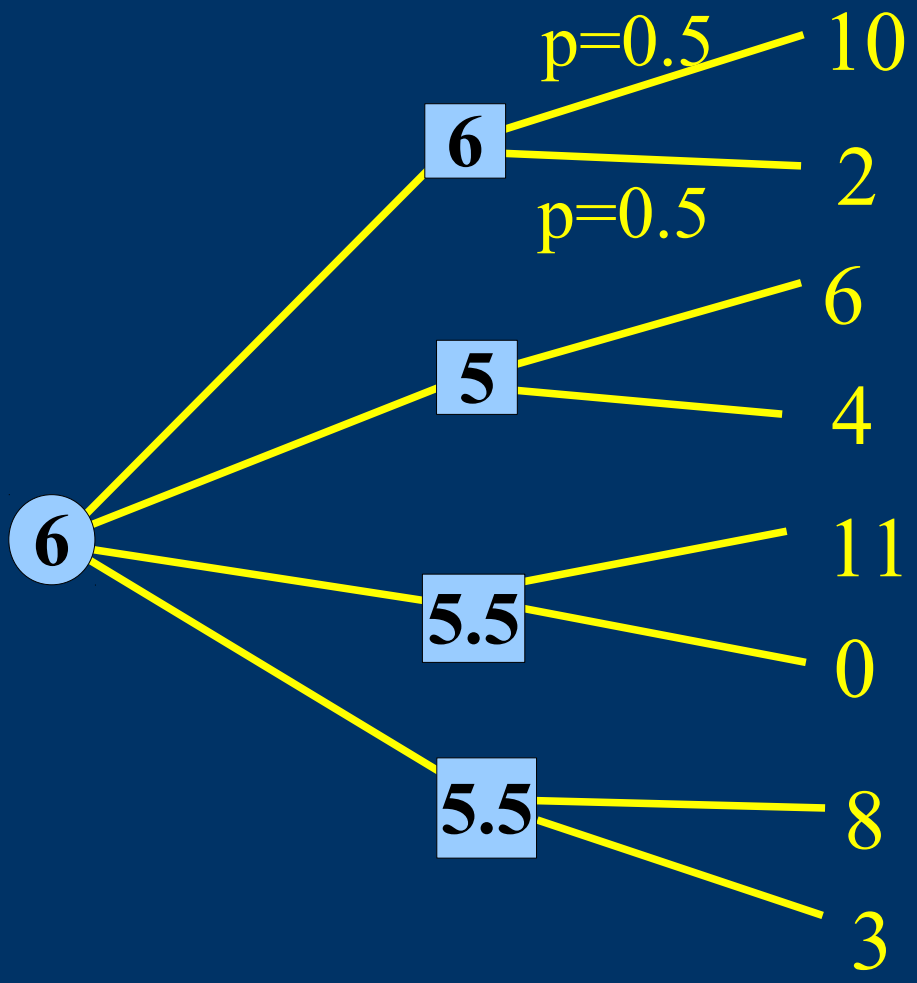

p=0.5
1
0
6
2
p=0.
5


p=0.5
10
6
2
p=0.
5
6
α
?
β
4
x
?
γ
11
?
δ
0
?
8
3

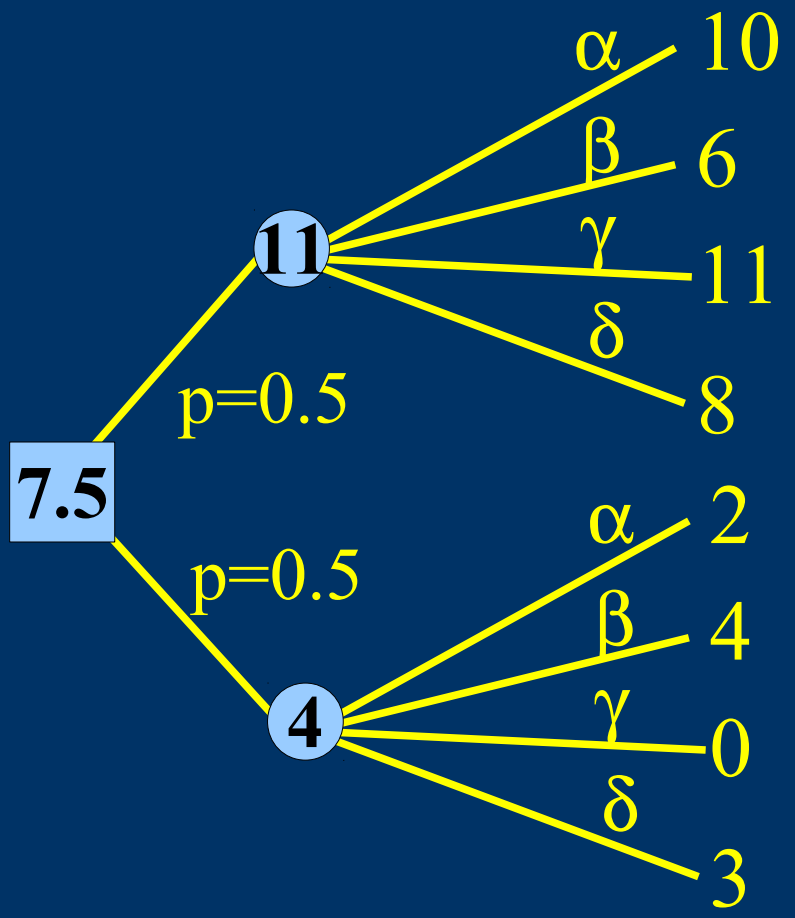

$x^*=\alpha$
$\Pi(\alpha)=6$
6
6
5
5.5
5.5
10
2
6
4
11
0
8
3


2. Learn
1. Act
6
6
5
5.5
5.5
10
2
6
4
11
0
8
3

Act then learn



Learn then act



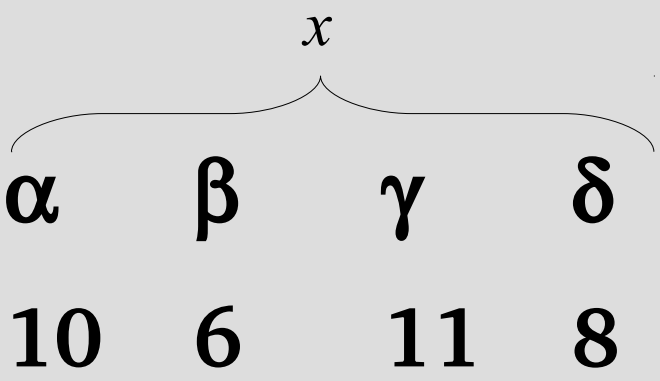
2. Optimization under risk
Maximizing expected “utility”

A short course in decision theory:

1. Decision criteria
2. Utility maximization
3. Information and option
4. Limits of the standard model

2.1 A toy decision problem
The ice cream truck

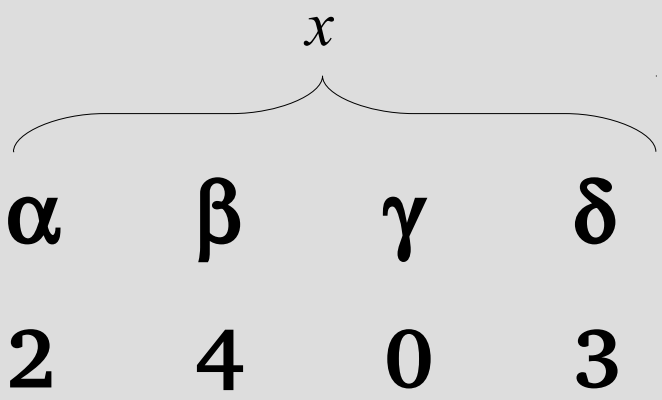
Make a decision x among 4 possible choices $\{\alpha, \beta, \gamma, \delta\}$, given that the profit $\Pi(x)$ is:



Profit $\Pi(s, x)$

2.1 A toy decision problem
The ice cream truck

Another one:



Profit $\Pi(s, x)$

Help !

Decide under uncertainty

Profit $\Pi(s, x)$ depends on the weather,

Weather will be Hot or Cold: s = H, C

	x			
	α	**β**	**γ**	**δ**
s=H	**10**	**6**	**11**	**8**
s=C	**2**	**4**	**0**	**3**

Profit $\Pi(s, x)$

Many behavioral rules

- Maximize expected gain
- Maximin (precaution)
- Maximax

Who decides the criteria?

Is there a criteria general enough to represent any “rational” decision maker ?

The Utility of wealth

Increasing

But at a slower rate as wealth increases

2.2 Standard decision model

- Monetary gain $\pi(s, x)$
- Alternative outcomes s with probability $p(s)$
- Utility function $u(\pi)$

Choose the decision *x* maximizing expected utility

$$\Pi^* = \max_x \sum_s p(s) u(\pi(s, x))$$

Pros and cons of the standard economic model

General enough: changing *u* allows to represent the various criteria.

Rationality garanteed

Separes *u*, *p*, and π.

But:

Observing parameters?

Adaptation and irreversibility?

2.3 Information and option

- Contingent strategy
- Information value
- Option value

The ice cream truck again

Expected gain, if we can adapt to s ?

x

	α	β	γ	δ
s=H	10	6	11	8
s=C	2	4	0	3

Profit $\Pi(s, x)$

Value of information

Expected gain of the contingent strategy:

$$\Pi^{\#} = \sum_{s} p(s) \left(\max_{x} u\left(\pi(s, x)\right) \right)$$

Expected value of information

$$EVPI = \Pi^{\#} - \Pi^{*}$$

The value of flexibility (avoiding irreversibility)

Assuming that information will be

- Perfect
- In time to adapt
- Free

Then we can define an option value

$$OV = \Pi^{\#} - \Pi^{*}$$

2.4 Limits of the standard model

- Long term benefits
- Probability is too simplistic
- Real life decisions are not rational

Discounting in the long term

1€ at future time t is worth

only $1/(1+r)^t$ € today

r discount rate

Future generations weighted shockingly low

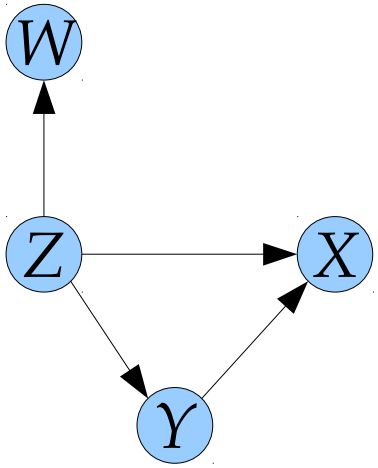
Hyperbolic discounting

Degrees of ignorance

- The probabilistic model starts with an exhaustive partition of the future into mutually exclusive states, and assign each state a specific weight
- Uncertainty: states are known
- Incompleteness: unknown unknowns

Real decision making

- Rationality is a normative assumption, not a descriptive fact: habits, emotions !
- Society is not a single decision maker: confidence and strategic games

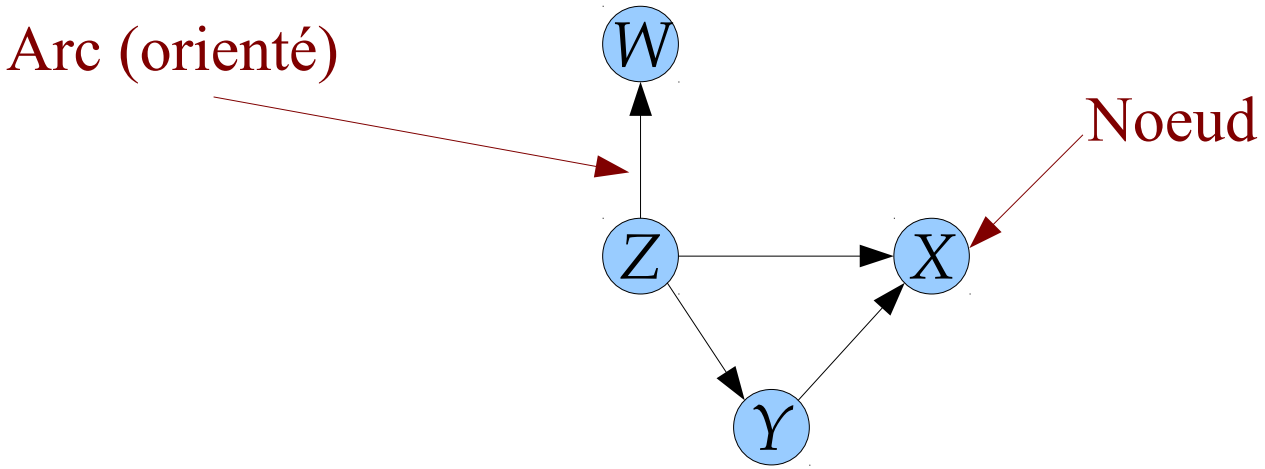


3. Éléments d'analyse des systèmes

Trois usages du diagramme d'influence

1. Aide à la communication
2. Carte cognitive
3. Support de modélisation

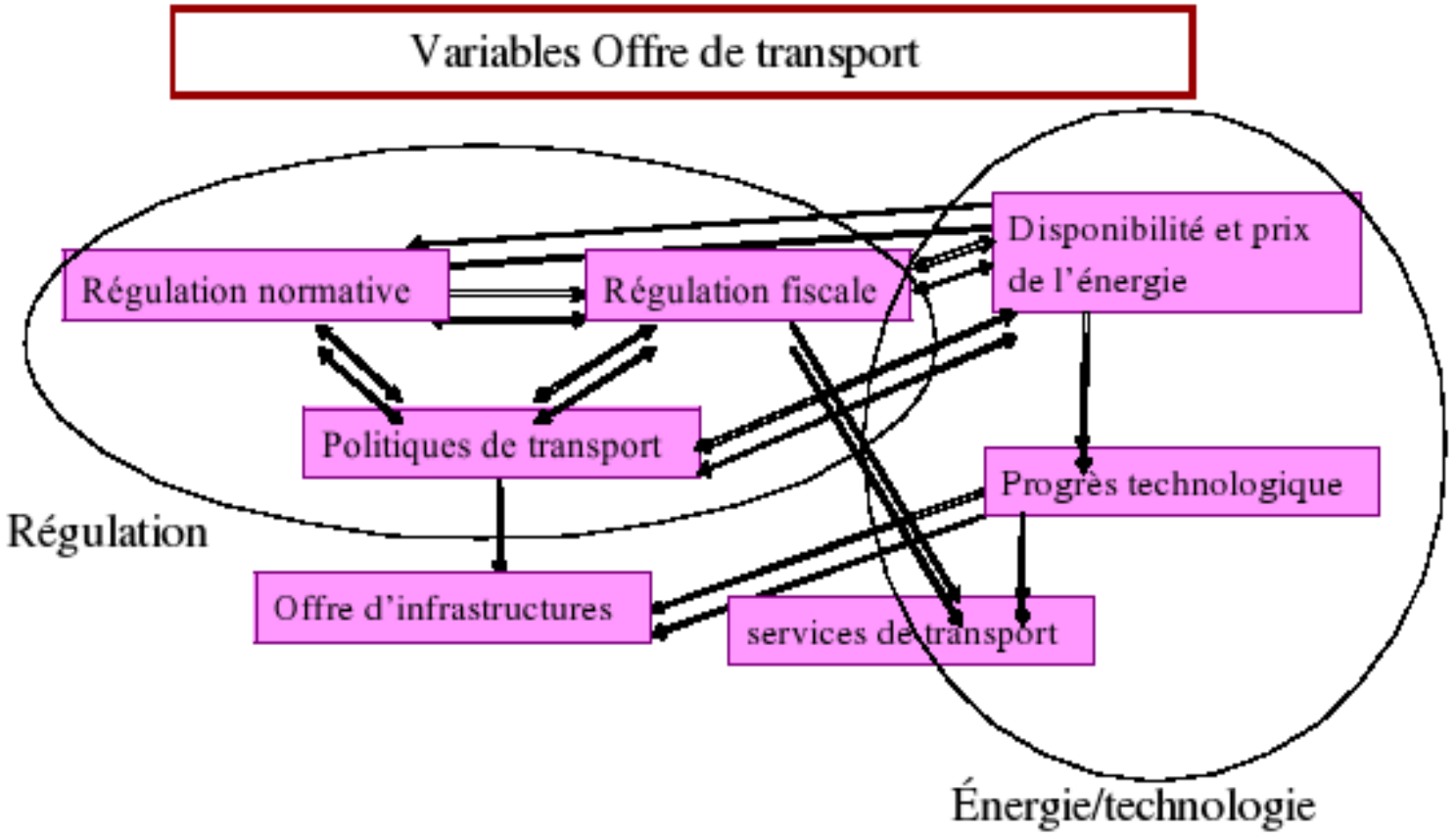
Vocabulaire
Graphe orienté acyclique



Chemin: Z, Y, X

Cycle: chemin fermé

1. Organiser graphiquement des variables

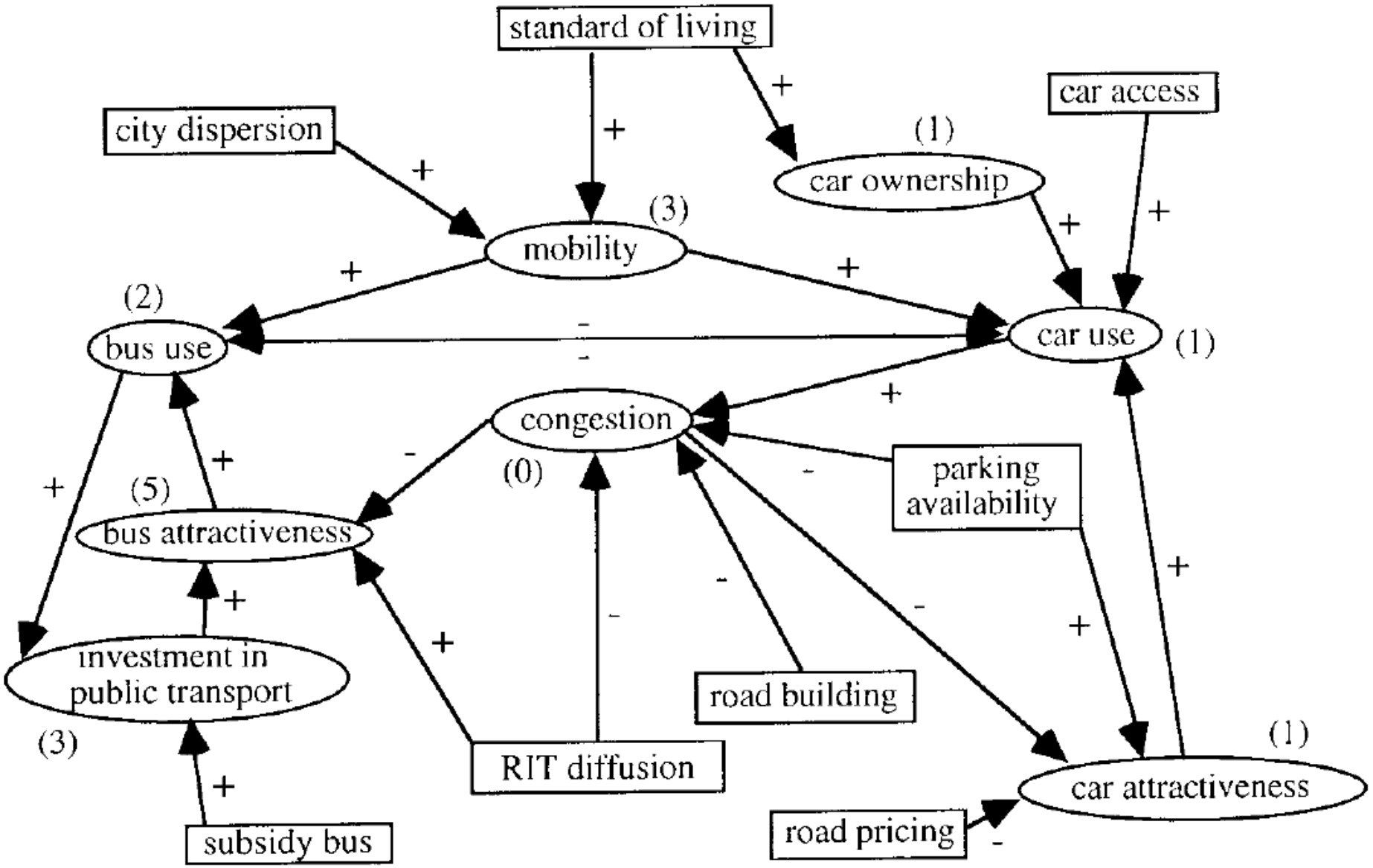


Source: Futuribles (2005) Rapport d'étude prospective pour l'élaboration de scénarios exploratoires sur les transports à horizon 2050

Avantages et inconvénients

- Communication: organiser les variables
- Modélisation: interprétations formelles
- Tout dépend de tout et réciproquement: garder en vue la question posée

2. Carte cognitive

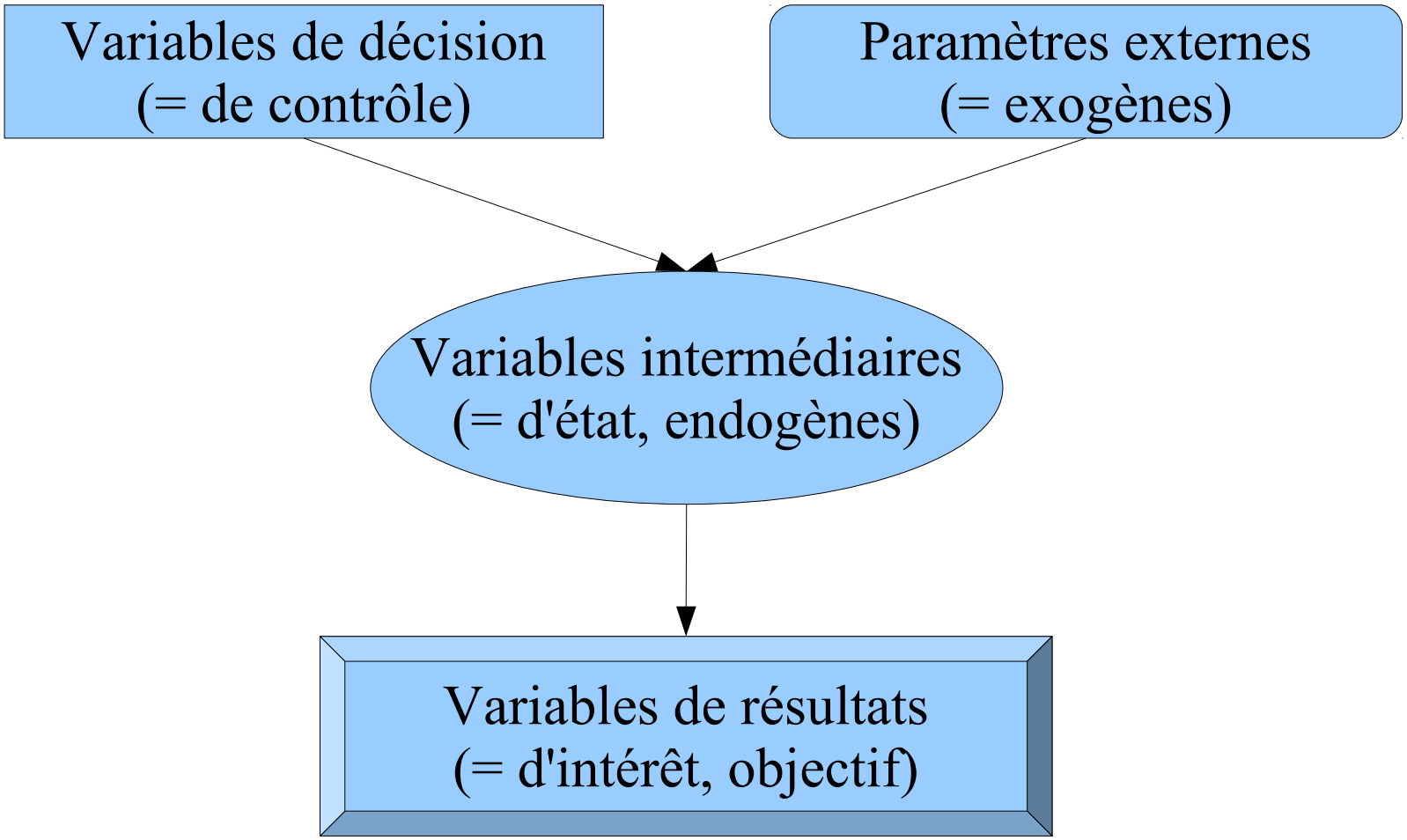


Boucles de rétroaction

Nombre de - dans un cycle :

- Pair: boucle positive, divergence
- Impair: boucle négative, stabilisante

Types de variables

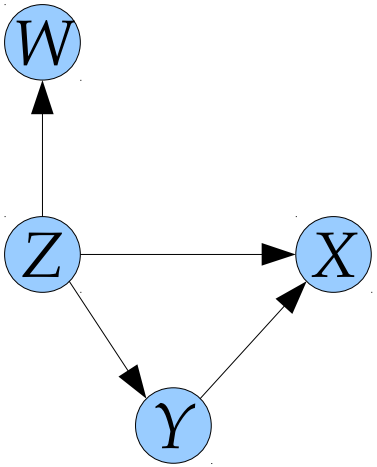


Types de carte mentale

- Carte de dépendances:
  la présence d'une flèche garanti la dépendance
- Carte d'indépendances:
  l'absence d'une flèche garanti l'indépendance
- Carte parfaite (exhaustive): les deux

3 représentations équivalentes

Diagramme d'influence



Equations structurelles

$X = \mathrm{f}(Y,Z)$

$W = g(Z)$

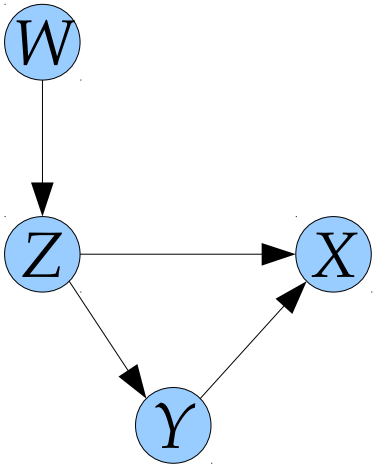
$Y = h(Z)$

Matrice d'incidence

Cause \ Effet	***W***	***X***	***Y***	***Z***
W	***0***	***0***	***0***	***0***
X	***0***	***0***	***0***	***0***
Y	***0***	***1***	***0***	***0***
Z	***1***	***1***	***1***	***0***

Simulation qualitative

- La matrice d'influence décrit l'évolution d'une période sur l'autre
- Coefficients entre -1 et +1
- Simulation par itérations
  - Trajectoires
  - Configurations limite



3. Réseau bayésien

X, Y, ... variables aléatoires discrètes:

X : Vrai ou Faux

Y: Haut, Moyen ou Bas

...

Les flèches décrivent les dépendances :

$$P(W,X,Y,Z) = P(W)\, P(Z|W)\, P(Y|Z)\, P(X|Y,Z)$$

Avantages et inconvénients

- Résoud le problème de la complexité de la distribution de probabilité jointe
- Graphes dirigés acycliques:

  pas de boucle de rétroaction
- Data mining, statistiques avancées, induction et abduction cohérente

À retenir

- Le diagramme d'influence visualise
  une liste de variables interdépendantes
- Variables de contrôle / exogènes / endogènes / objectif
- DI + information qualitative:
  Carte mentale (cognitive map)

4. Decision with scenarios

1. Specifications: what to expect from a scenario exercise ?
2. Execution: how to write them ?
3. Decision: Using scenarios for action

A short history of scenarios

- After the war (1950's) : 2 traditions.
  - Rand, SRI, … Delphi techniques and scenario methods for defense et security
  - «French school » : holistic and philosophic analysis (rapport DATAR).
- Popularized by the first oil shock :
  - Royal Dutch Shell & Pierre Wack.

4.1 Specifications : what to expect?

- Define problem and time horizon
- System analysis: choose key variables
- Actors
- Microscenarios
- Combination into coherent scenarios
- Dynamic modelisation
- Implications for choices

Scenarios ≠ simulation

- Multidisciplinary, system-based (holistic)
- Long time (past, present, futurs).
- Uncertainties, tipping points, signposts

Two kinds of exercises

Exploratory :

- Explore possible futures without limits.
- Look at tendencies, predetermined constants, uncertainties, tipping points, ...

Normative/strategic:

- Focus on choices to be made, the sensitivity of operational results to risks

Number of scenarios ?

- How many:
  - 1 exploratory future alone: uncertainty ??
  - 1 normative scenario is a roadmap
  - More than 4 scenarios is too complicated
- Normative: Wished or feared ?
- BAU/central scenario or not ?
- Plausibility level of the extremes ?

Time horizon

- Horizon: far enough for structural changes
- Backcast time series at 2 x Horizon
- Constraints: time, data, literature available

4.2. Réalisation

- Define problem and time horizon
- System analysis: choose key variables
- Actors
- Microscenarios
- Combination into coherent scenarios
- Dynamic modelisation
- Implications for choices

The key thing to remember

Focus on
the variable of interest !

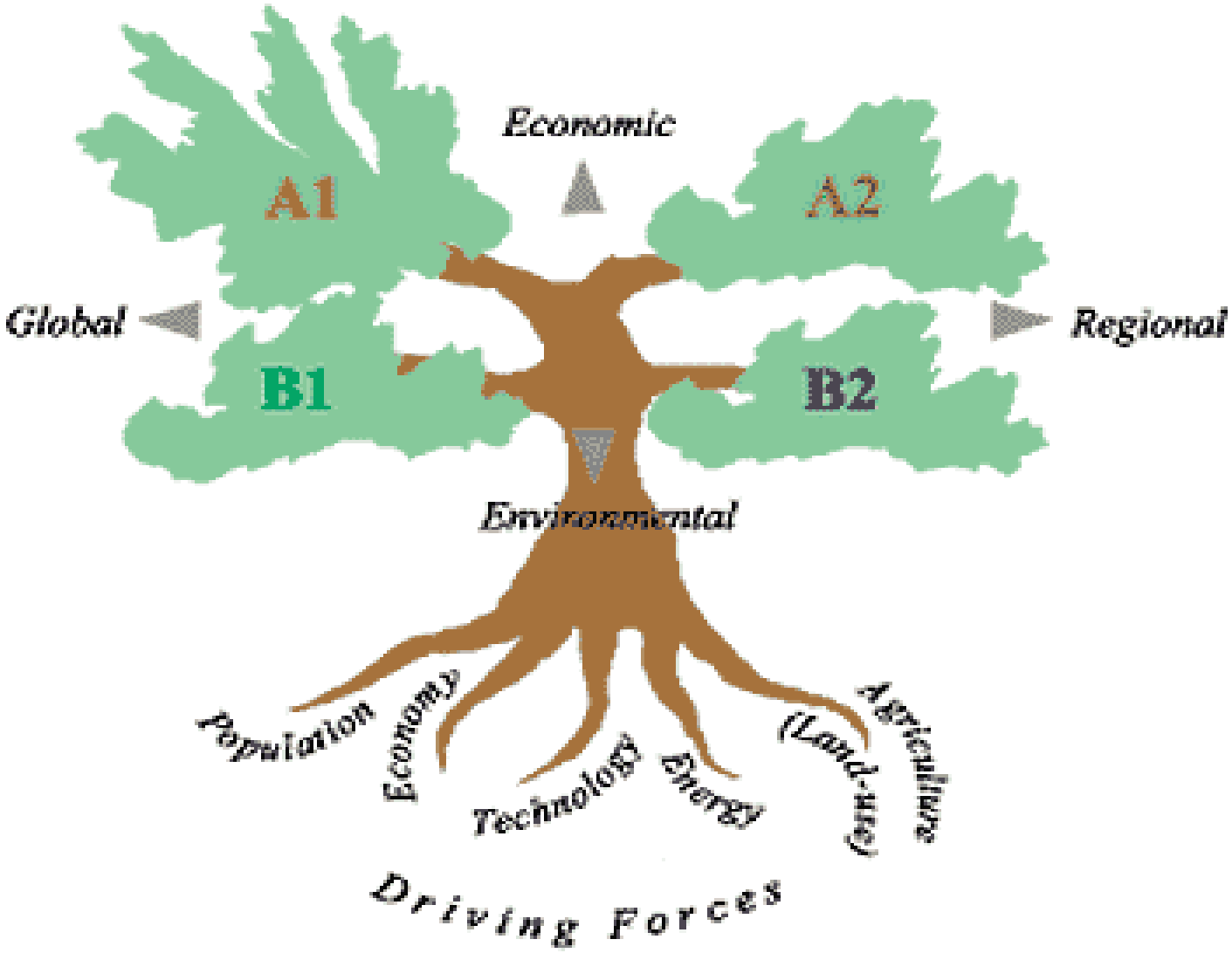
Key variables

- Influence the operational result of interest
- Small number
- Looked at in detail

- Example: Kaya identity

$$CO2 = POP * \frac{PIB}{POP} * \frac{ENE}{PIB} * \frac{CO2}{ENE}$$

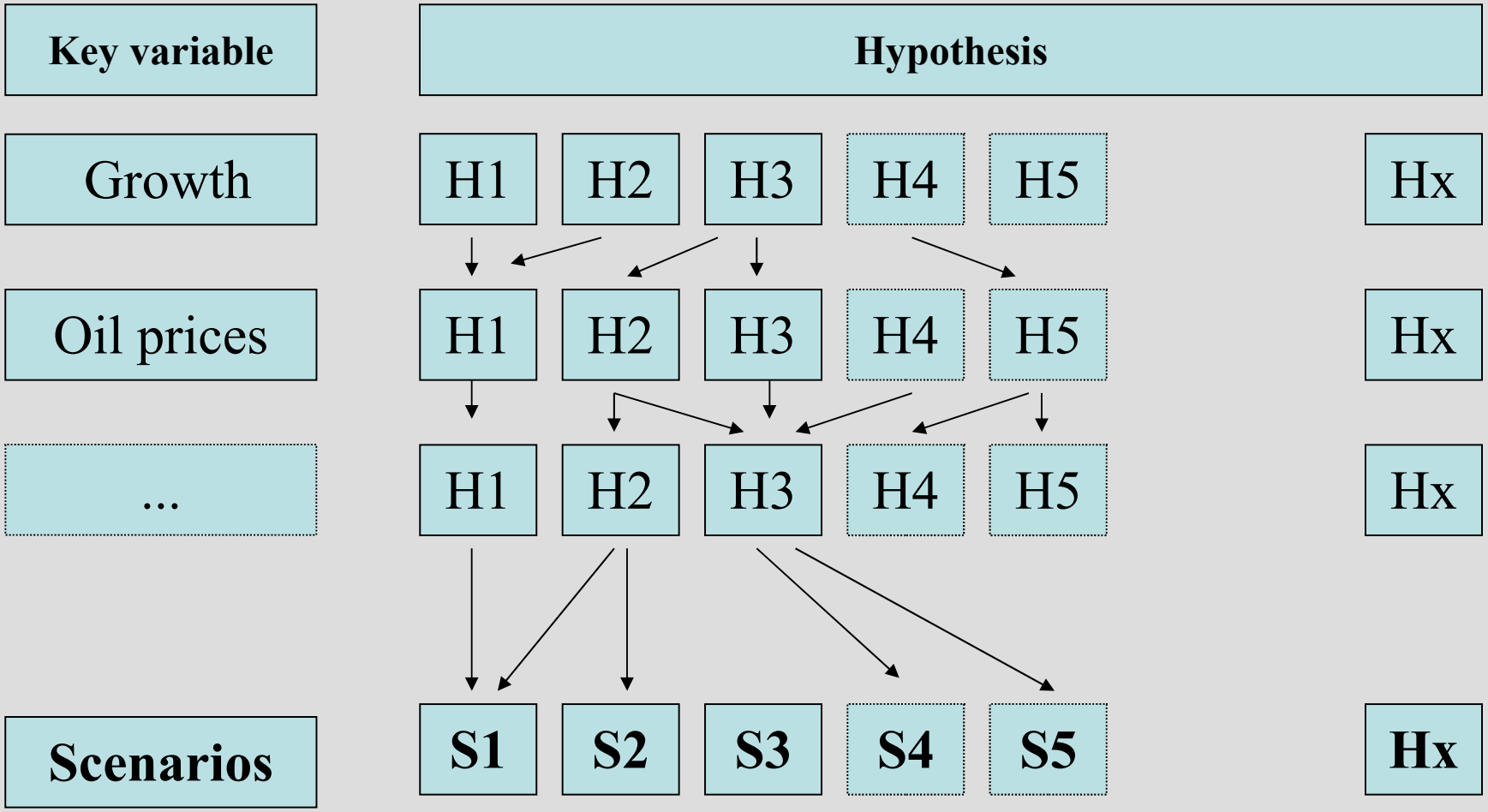
SRES Scenarios



Actors

- Social sciences have a variety of methods
  - Focus groups
  - Interviews
  - Surveys
  - Media analysis ...
- Produce a variety of deliverables such as
  - Mind maps
  - Actors by interest, ability, importance
  - Social subgroups ...

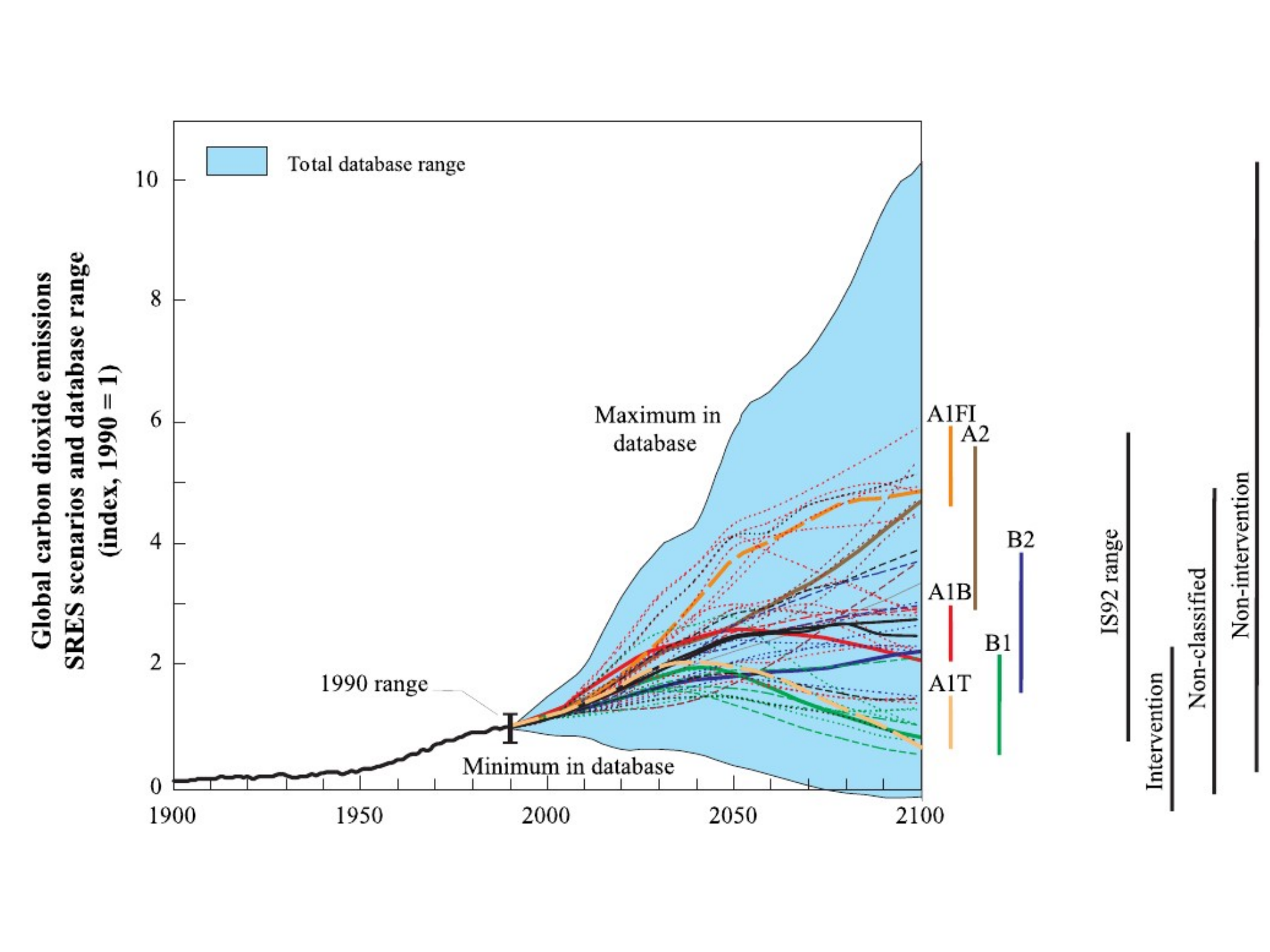
Combine microscenarios seeking coherence and plausibility



Models vs. scenarios

- Models
  - Cartesian division in subsystems
  - Quantitative, (falsely) precise
  - Convincing
  - Must be parametrized

- Scenarios
  - First a narrative
  - More vague (more right ?)
  - Can use models
  - Base + Trajectory + final image


Global carbon dioxide emissions
SRES scenarios and database range
(index, 1990 = 1)
Total database range
Maximum in database
1990 range
Minimum in database
A1FI
A2
B2
A1B
B1
A1T
IS92 range
Intervention
Non-classified
Non-intervention
0
2
4
6
8
10
1900
1950
2000
2050
2100

4.3 Scenarios and decision making

- Analysis tool for strategic decisions
- Provides a common langage
- Warn about possible surprises
- Increase sensitivity to early warnings

Co-construction of the future

- « Ni prophétie ni prévision, la prospective n'a pas pour objet de prédire l'avenir – de nous le dévoiler comme s'il s'agissait d'une chose déjà faite – mais de nous aider à le construire. Elle nous invite donc à le considérer comme à faire, à bâtir, plutôt que comme quelque chose qui serait déjà décidé et dont il conviendrait seulement de percer le mystère ».

  Hugues de Jouvenel, « Invitation à la prospective », Futuribles Perspectives, 2004.

- Nous devons « considérer l'avenir non plus comme une chose déjà décidée et qui, petit à petit, se découvrirait à nous, mais comme une chose à faire ».

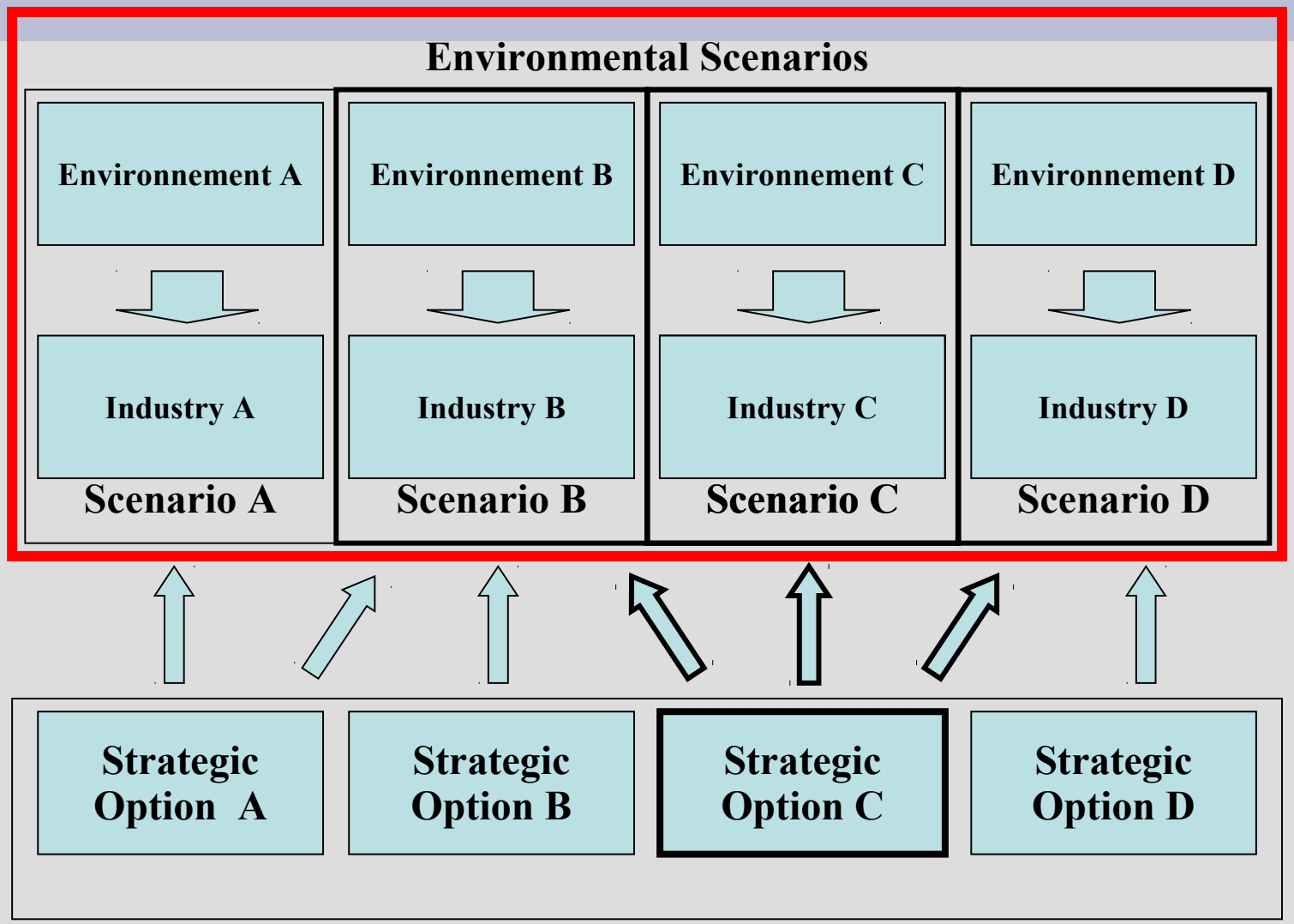
  Gaston Berger, « L'attitude prospective », Prospective, n°1, 1958.

☠ Paralysis by analysis ☠

Necessary balance between:

- Reactivity and anticipation
- Strategic planning and execution

Prospective & Strategy



Conclusion

- « Scenarios are attempts to describe in some details a hypothetical sequence of events that could lead plausibly to the situation envisaged ».

  Herman Kahn.

- « Scénarios are stories about the way the world might turn out tomorrow, stories that can help us recognize and adapt to changing aspects of our present environment ».

  Peter Schwartz.