

Modeling in Environmental Economics

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Eccorev Modeling Seminar Oct 7-8, 2014



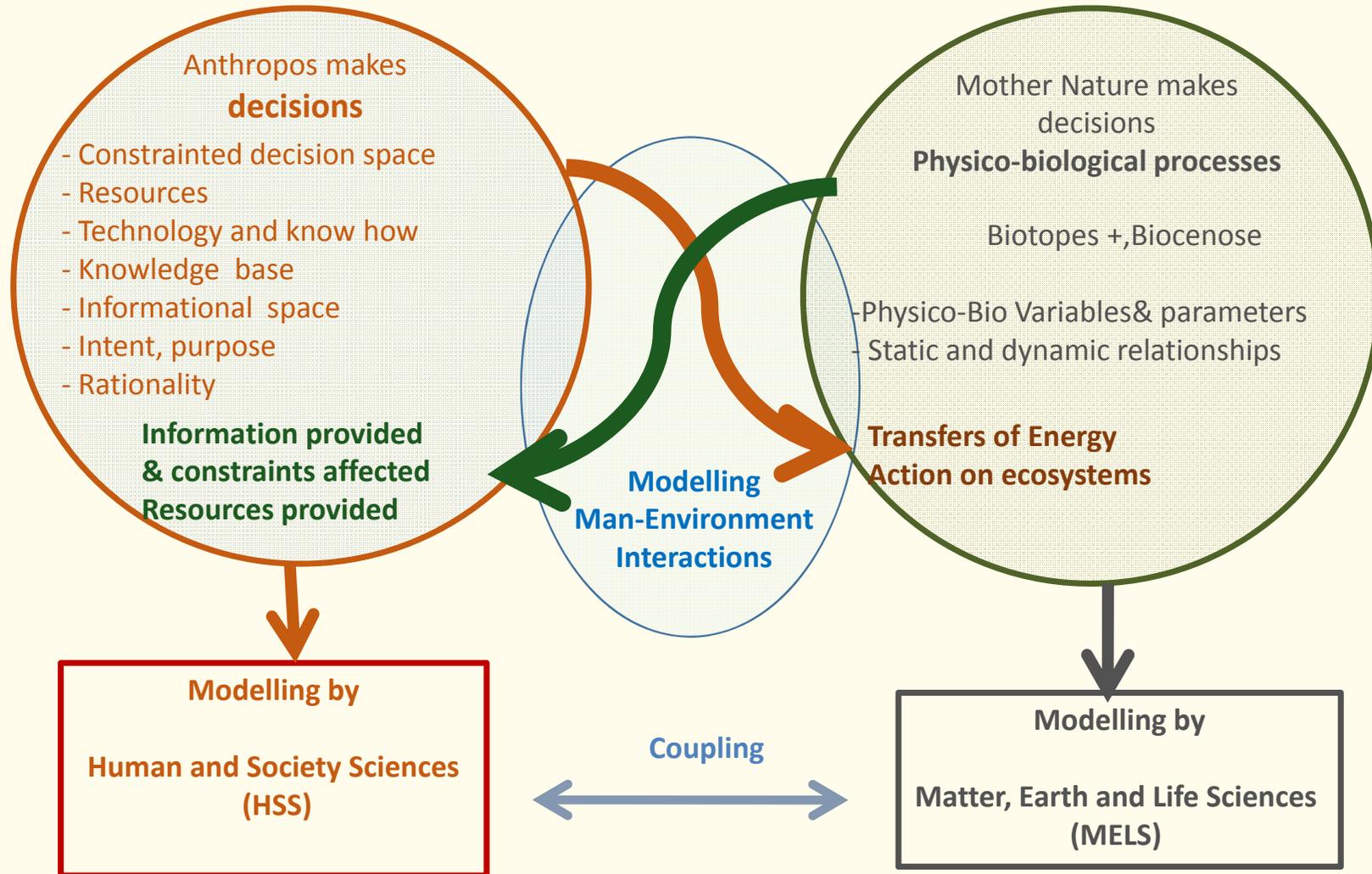
Agenda

- Brief survey of the evolution of economic thinking with respect to Nature
- Origins of the economists' interest for environmental issues
- The structure of economic research questions and the sources of inspiration for modeling
- The quest for happiness: The goods and the bads : which welfare criteria? For whom?
- Markets : valuing goods and bads
- Non-market: regulation, taxation, legislation, redistribution, government allocation, rationing...
- **The toolkit for model building**
- Time
- Uncertainty and risk
- Games

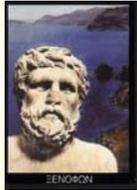
Types of Model in Environmental Economics

- Model = formalizing a theoretical question
 - e.g. is a carbon market an efficient solution to monitor emissions
- Model = best mathematical form to fit with a set of data (e.g. Statistical models)
- Large scale models: simplifying the whole economic system
 - For analytical reason or for predictive purposes
 - e.g. General Equilibrium Models GEM
- Integrated models : large scale or small scale

Integrated models

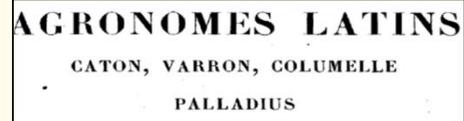


Brief survey of the role of Mother Nature in economic thinking



- **Xenophon (-426 -355)** *ŒKONOMIKOS* (Textbook on rules for good management of a large farm)

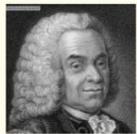
- The latin agronomists:



- Until the physiocrats, **economics = management** (*menasger, menasgement*)

How to discipline and organise nature for satisfying human welfare (food, landscapes, flowers...)

- 16 and 17th century: the rise of merchants in Europe: dignity and wealth through trade and no longer from aristocratic, military, or religious status.



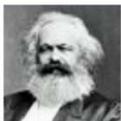
- Around 1750, the physiocrats; The source of wealth dwells in the work of Nature
- the pioneers of the valuation of ecosystem services François Quesnay (médecin) 1694- 1774.
- An integrated model : Nature produces and Man distributes. The doctrine pleases the aristocracy, owner of the land.



- Adam Smith and the theorisation of markets
- The wealth arises with trade The doctrine pleases the merchants and the entrepreneurs

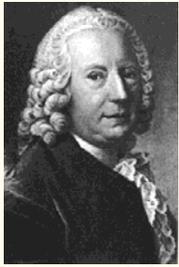


- Malthus the relationship Nature ability to produce and Man ability to reproduce itself



- XIX century Ricardo and Marx : The wealth dwells in human labor

Some contributors to Mathematical modeling in Economics



D. Bernouilli
1700-1782



A.A. Cournot
1801-1877



J. Dupuit
1804 - 1866



René Roy
1894-1977

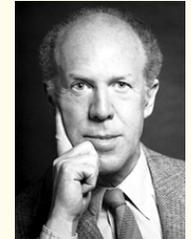
Providing the tools for the neo-classical approach and its extensions



P.A. Samuelson
1915-2009



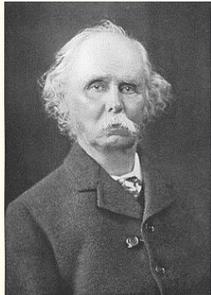
K. Arrow
1921-



G. Debreu
1921-2004



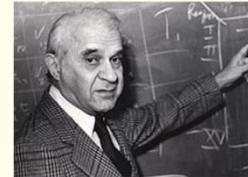
L. Walras
1834-1910



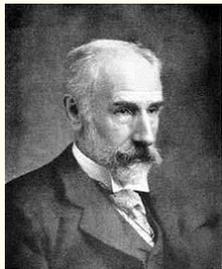
Marschal
1842-1924



V. Pareto
1848-1923



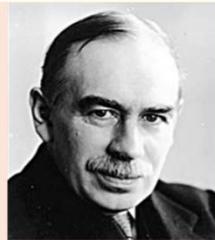
W. Léontieff
1906-1999



F. Edgeworth
1845, 1926



J. Bertrand
1822 -1900



J.M. Keynes
1883-1946

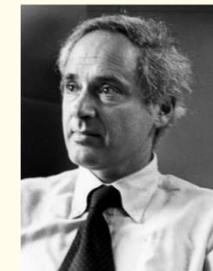


Joan Robinson
1903-1983



Maurice Allais
1911-2012

Some important 20th C deviants



H. Scarf
1930-



E. Malinvaud
1923 -

Modelisation in Environmental Economics: some origins

- Early interest of modern economists for environmental issues:
Fisher, Kurtilla & Cicchetti (1972), K. Arrow (1974) C.Henry (1974).
- Economic models of externalities as « anomalies »: in discussion for 300 years.
- Theory of public goods
- Old tradition in agricultural economics: interaction food-nature (Henry Charles Taylor 1873 –1969 at Madison university, Wisconsin)
- Economists and Biologists approaches in population dynamics : Malthus, Lotka-Voltera (predator-prey models 1925) , Hardin (tragedy of commons 1968),
- Global resource depletion models : J. W. Forrester, D. Meadows (1972)
- Tradition of economic geographers in spatial modeling

W. Brown, A. Singh, and E. Castle, "Net Economic Value of the Oregon Salmon-Steelhead Sport Fishery," *J. Wildlife Manage.*, Apr. 1965, 29, 66-79.

A. Fisher, J. Krutilla, and C. Cicchetti, "The Economics of Environmental Preservation: A Theoretical and Empirical Analysis," *Amer. Econ. Rev.*, Sept. 1972, 62, 605-19.
——— and ———, "Valuing Long-Run Ecological Consequences and Irreversibilities," paper presented at the Environmental Protection Agency Symposium on Cost-Benefit Analysis and Water Pollution Policy, Annapolis, Sept. 1973.

Sources of inspiration for model(l)ing (US: I UK: II)

- Neoclassical streams : (« mainstream » economics »)

Micro and Macro levels. Emphasis on prices and values

- Keynesian and post-Keynesian streams (Flow –Stock Consistent Models)

Mainly Macro. Emphasis on volumes more than values

- Very large scale integrated models : Stern report

Macro level. Integration of economic and ressource models

Economics and biophysical externalities (CO²)

- Behavioral model :

Micro level. Values granted to environment and Nature

Contingent analysis : How much are you willing to pay?

- Agent-Based Models (ABM)

Micro and macro : simulation

- Long term population-resources models (similarity with ecology : Lotka-Voltera etc...)

Diversity of economic models

Classical distinctions in economics

	Micro	Macro
Short term	Markets Firms' decisions Consumer's decisions Price formation	Conjunctural issues Inflation-recession, Public budget-deficit
Long term	Future markets Financial economics Financial markets	Structural issues Welfare system- pensions Dynamics of ressources Dynamics of population Overlapping generations

Postures in the economic models

Anthropocentric posture: Man only does matter

Utility and happiness of human beings of present and future generations

(N.B. happiness can include concerns for the happiness of any other species!)

as opposed to:

Biocentric or ecocentric posture : Man is only one dimension

- *Any type of life experiences happiness and dismay*
- *Nature has to be considered per se*
- *Religious or ethical motives*

The Goods and the Bads

A good (resp. a bad) increases(respectively decreases) happiness when received.

However, this would mean that happiness moves always in the same direction for all human beings.

In what follows good = physical production, service, nuisance (génative good)

-Examples

Classification of goods

	Subtractability through usage		
	<i>Low</i>	<i>High</i>	
Difficulty of excluding potential beneficiaries	<i>Low</i>	Toll goods	Private goods
	<i>High</i>	Public goods	Common pool resources



From E. Ostrom (2005) p.24

Exclusion: Is it possible to keep **free riders**¹ at bay ?

e.g. « *Les Catalans* » is a beach for the « *Marseillais* » funded by local taxes.
Can one exclude the free-riders, in particular if they are « *Parisiens* »?

Subtractability: Does my consumption « *subtract* » to your consumption?

e.g. Halieutic resources, irrigation canals, pastures, commons.

e.g. *Marine Parc des Calanques*. The potential beneficiaries of the sea as a public good are:
swimmers, divers, fishers, industrialists, scientists, army, jetskiers, sailors, etc.

Solution : common pool resources

¹ In French : « *passager clandestin* »

Rationality in Economic Models

How are decisions made by rational economic agents?

The classical answer:

the central character of any economic romance is named **Max U**

Maximize Utility

***Individual Utility** for final consumers*

***Profit** for firms (actually *maximize shareholder utility*)*

***Collective Utility** for government*

Max U is always acting within a set of constraints

So, the basic tool for modeling is Maximisation Theory

There are many qualifications to Max U hypothesis

For a large survey, read: D. Kahneman, *Thinking Fast and Slow*, Pearson, 2011.

Hypotheses on Consumption: Utility Functions

« **Monotony** » : more of a good can never harm, less of a nuisance can never harm!

« **Convexity** » : preference for diversity

« **Continuity** » : slight changes in a « basket » of good produces slight changes in happiness.

NB : actually, the general mathematical framework is more abstract:

One supposes that each individual has simply a complete preference pre-order over the set of all possible bundles of goods she may receive



A rich uncle who has collected luxury cars wants to make you a gift of TWO cars.
Which do you prefer?

$U(\mathbf{x})$ = level of utility when consumer endowed with a vector \mathbf{x} of goods

$$\mathbf{x} = (x_1, x_2, \dots, x_i, \dots, x_n)$$

*N.B.: $U(\mathbf{x})$ represents **just a ranking**, so any positive transformation of U is feasible*



Typical
Customer plateau

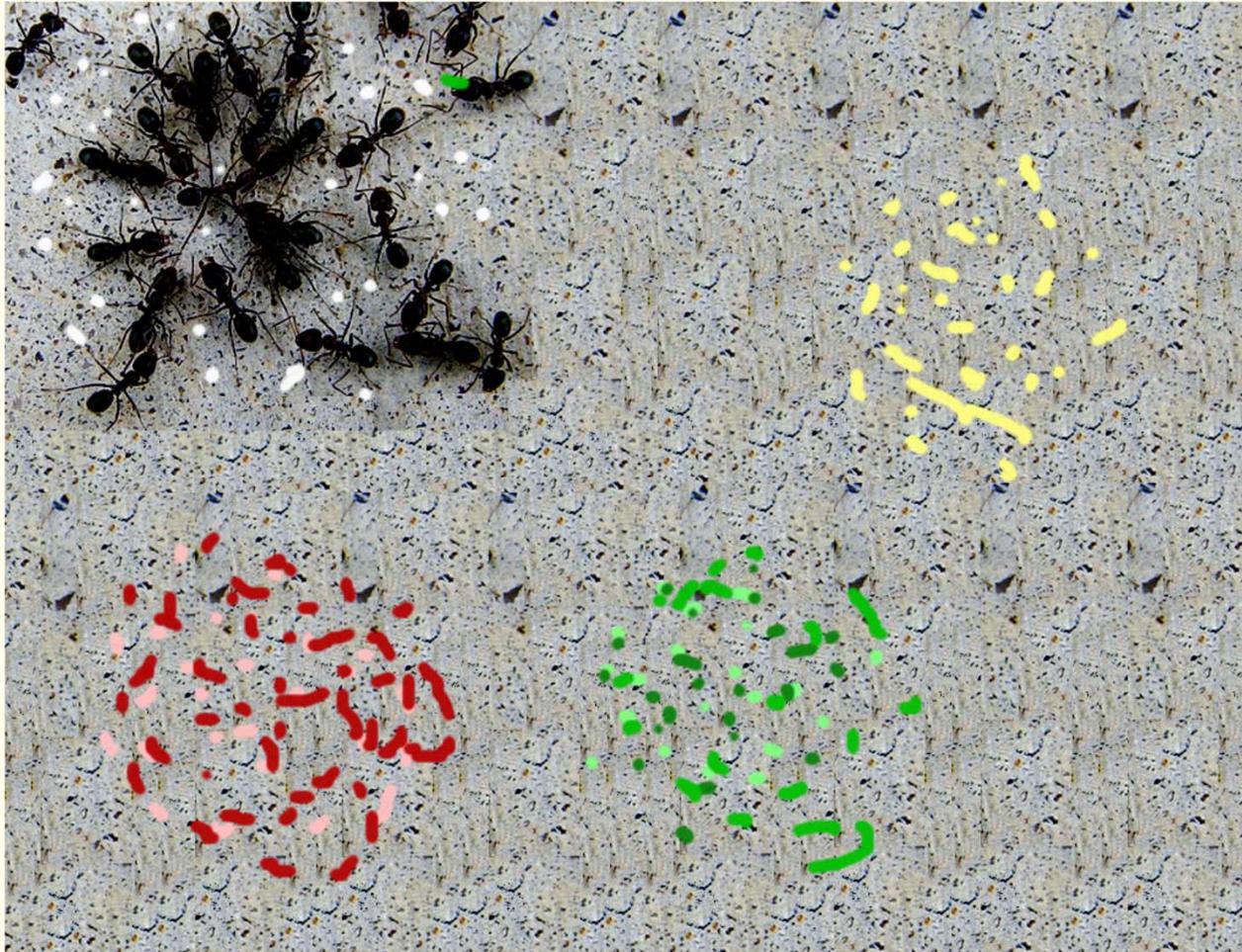
A luxury hotel buffet : a « no-price » area, like the Garden of Eden

Observations of Mrs LAMBDA :

- 1) The size of her predation is always limited (saturation effects)
- 2) Her selected breakfast is diversified



Quite rare
customer plateau



Lexicographic preferences for Eric Provost 's ants ?

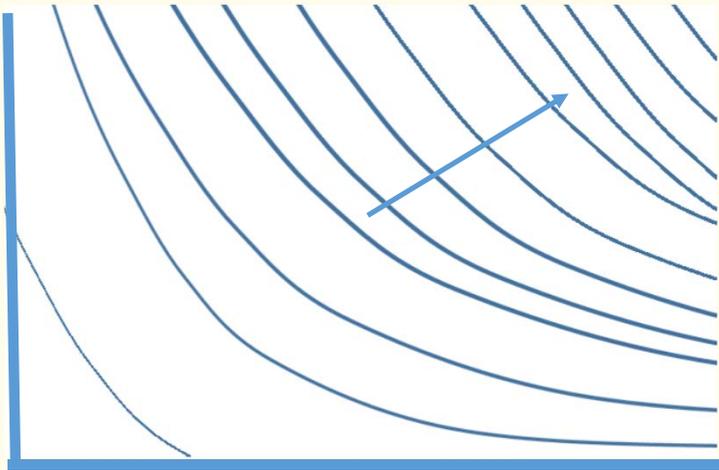
Several heaps of fine grains
of different foods eaten by
the ants have been
proposed to the choice

Expected result as shown

**Excluded for human beings
in models!**

Convexity of preferences

Index of environmental quality



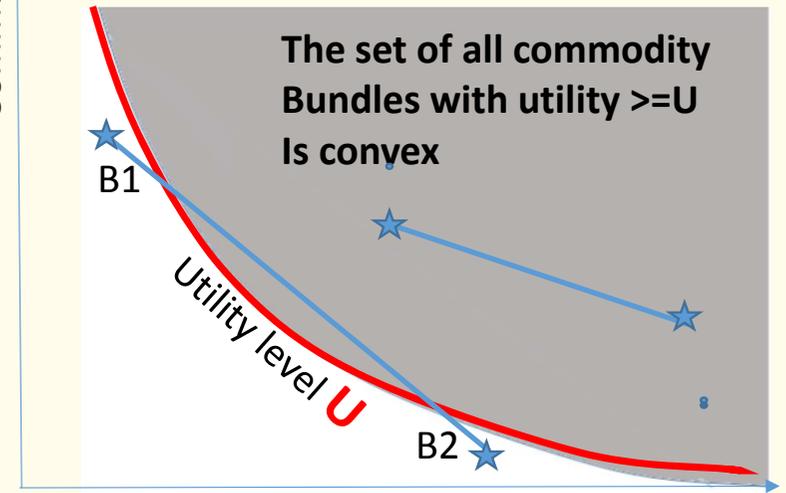
Square meters to live



Environment quality

House space (m²)

Commodity 2



The set of all commodity Bundles with utility $\geq U$ is convex

Commodity 1

Given a level of utility U , it is possible to combine two baskets $B1$ and $B2$ which are under U to get a basket above U

A « basket » of goods which is a **linear convex combination** of any two baskets above U is always itself above U

A classical utility function (Cobb Douglas)

Typical utility function used in modeling with two goods (or more)

$$U(x_1, x_2) = x_1^a \cdot x_2^b \quad a \text{ and } b > 0$$

Along a constant utility curve the total differential is null:

$$dU = 0 = \frac{\partial U(x_1)}{\partial x_1} dx_1 + \frac{\partial U(x_2)}{\partial x_2} dx_2 \Rightarrow (ax_1^{a-1} x_2^b) dx_1 + (bx_1^a x_2^{b-1}) dx_2 = 0$$

$$\Rightarrow a \frac{U}{x_1} dx_1 + b \frac{U}{x_2} dx_2 = 0$$

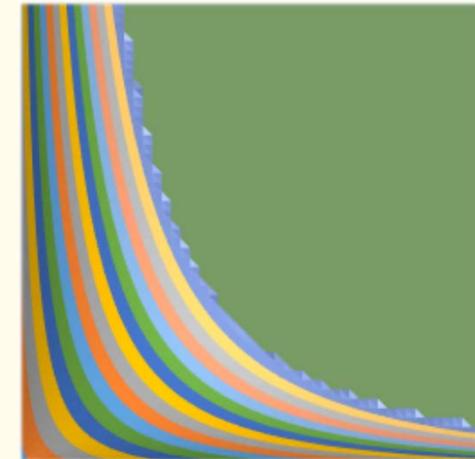
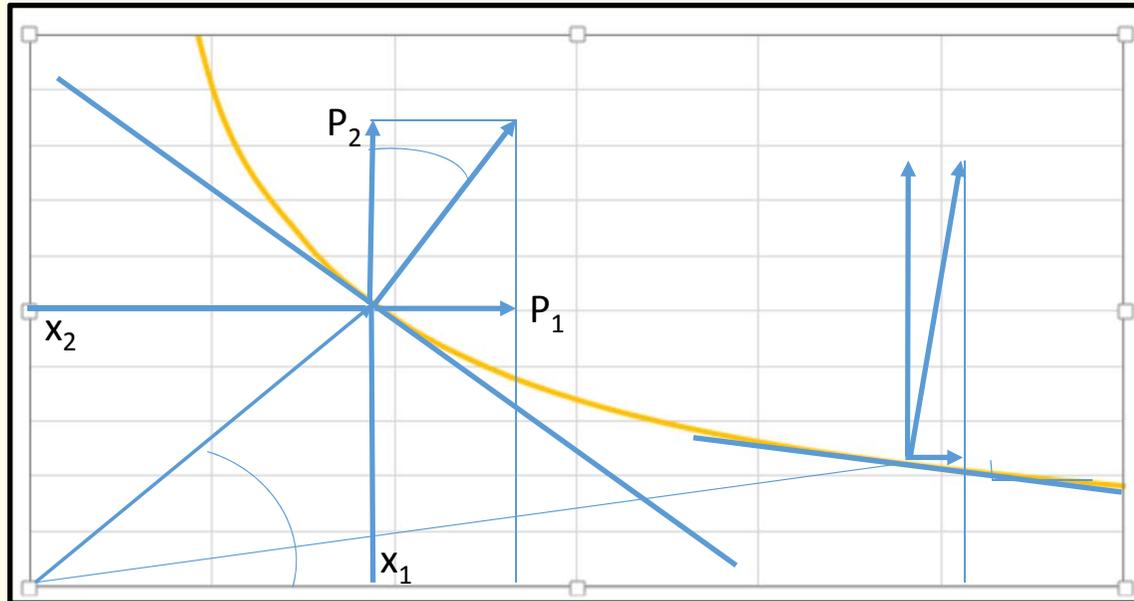
$$\Rightarrow \frac{dx_1}{dx_2} = -\frac{bx_1}{ax_2}$$

$$\text{Elasticity of substitution : } e = \frac{\frac{dx_1}{x_1}}{\frac{dx_2}{x_2}} = \frac{dx_1}{dx_2} \times \frac{x_2}{x_1} = -\frac{bx_1}{ax_2} \times \frac{x_2}{x_1} = -\frac{b}{a}$$

$$e_{1-2} = -\frac{b}{a}$$

$$e_{2-1} = -\frac{a}{b}$$

Properties of CD utility function



$$\frac{P_1}{P_2} = - \frac{a x_2}{b x_1} = e_{2-1} \frac{x_2}{x_1}$$

Le ratio relatif des deux biens est égal au ratio des « prix » pondérés par l'élasticité de substitution constante

Consumption models: Modeled through Utility Functions

Quasi concave Utility : $U(x_1, x_2, \dots, x_i, \dots, x_k)$

simple case to show how it works

Standard assumptions on **U**

Never decreasing in X_1, X_2 (abundance does not harm)

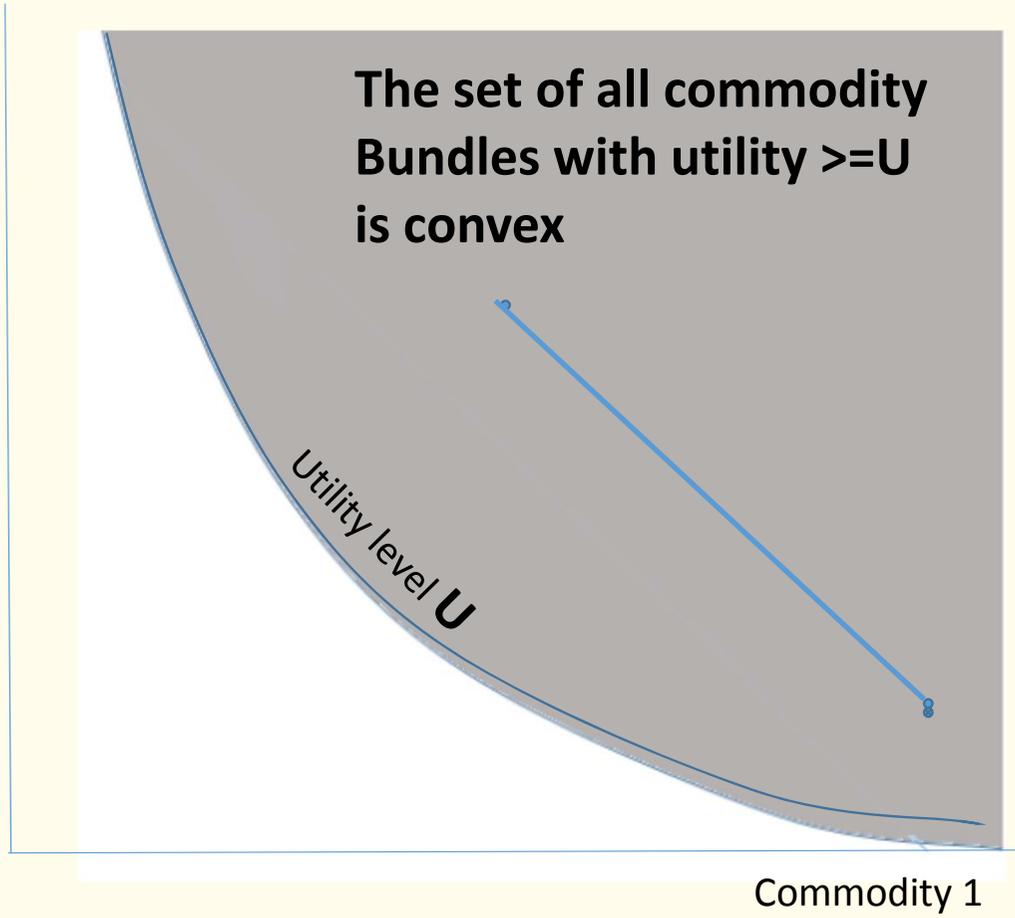
Marginaly decreasing in X_1, X_2 (nearing saturation)

Quasi concave (preference for diversity !)

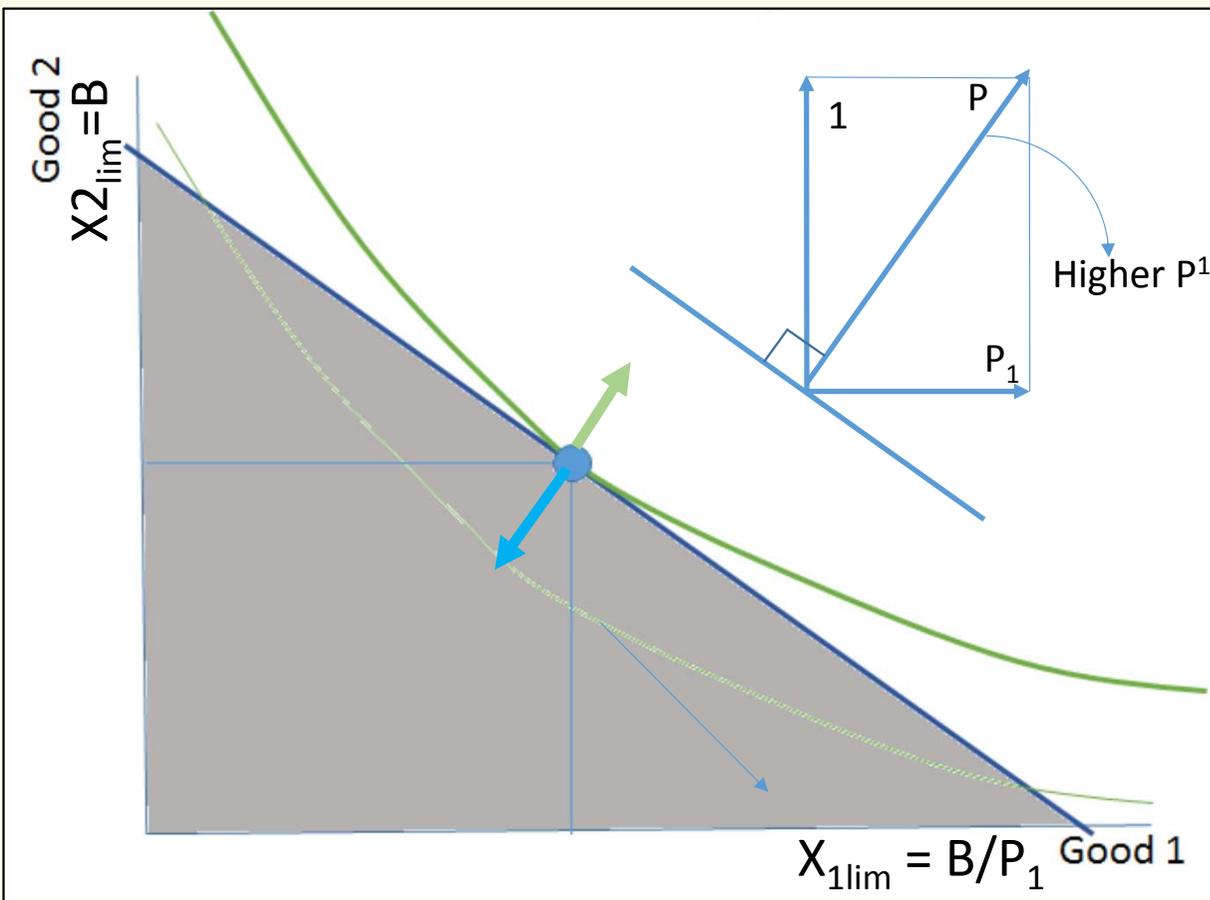
$$\text{Max } U(x_1, x_2)$$

$$p_1 \cdot x_1 + p_2 \cdot x_2 \leq \text{Budget}$$

Commodity 2



Utility maximisation under budget constraint



$$\text{Max } U(x_1, x_2)$$

s.t.

$$P_1 \cdot X_1 + P_2 \cdot X_2 \leq B$$

Prices are « relative » so take $P_2=1$,
i.e. good 2 is the « numéraire »

$$P_1 \cdot X_1 + X_2 \leq B$$

$$\text{If } x_1=0, x_{2\text{lim}} = B$$

$$\text{If } x_2=0 \text{ } X_{1\text{lim}} = B/P_1$$

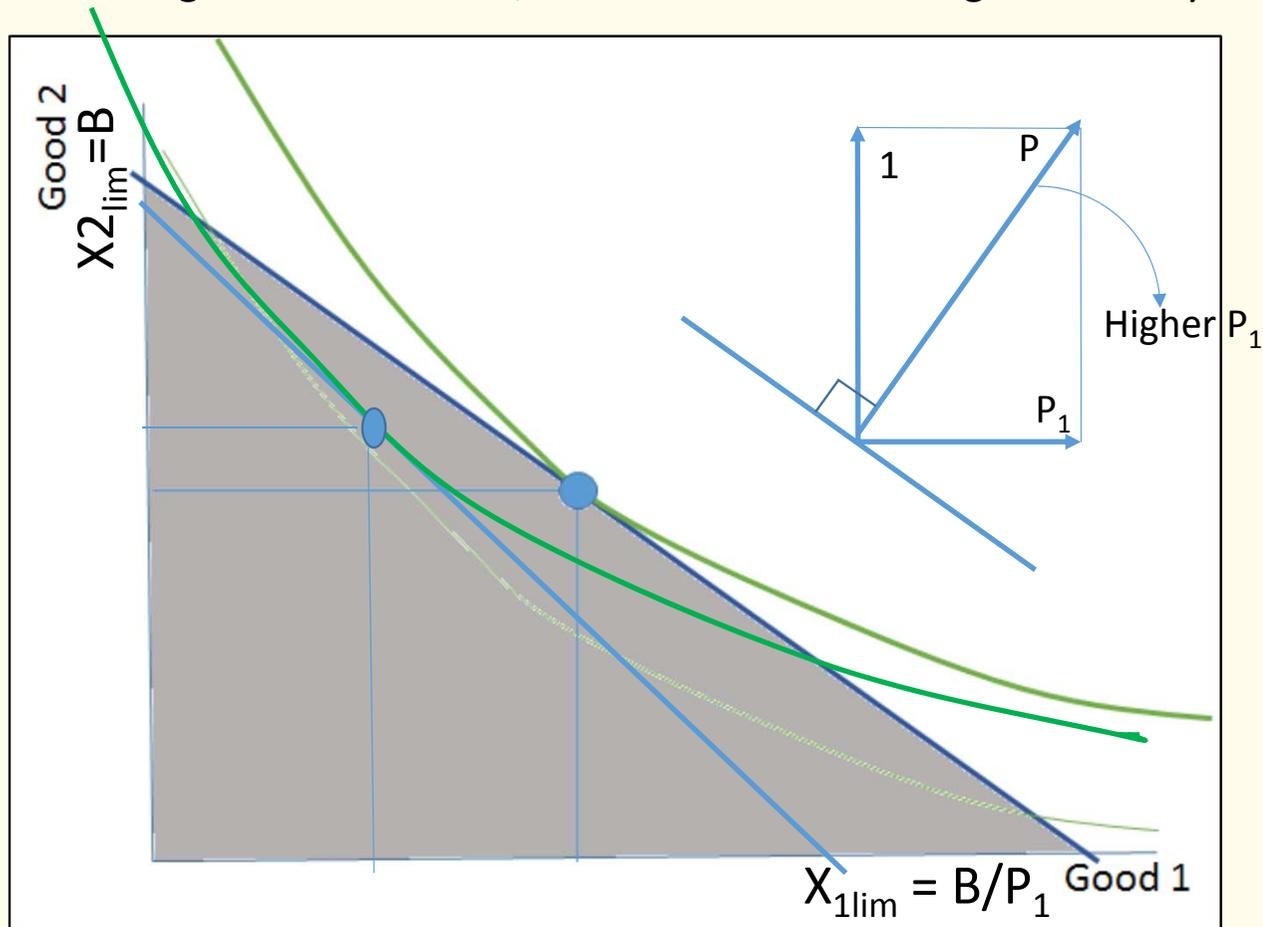
Solutions of this inequation : green area

Utility maximizing bundle in blue

From a mathematical standpoint : optimality implies equality of the gradient of U and the gradient of Budget

Effect of change in price: substitution effect

When P_1 increases, the selected bundle is B^{**} which includes less of good 1 (which has become more expensive) and more of good 2 (relatively cheaper). This is a normal case of « substitution » of good 2 for good 1. However, the consumer is losing in « variety »



Examples of substitution effect

1) divisible goods

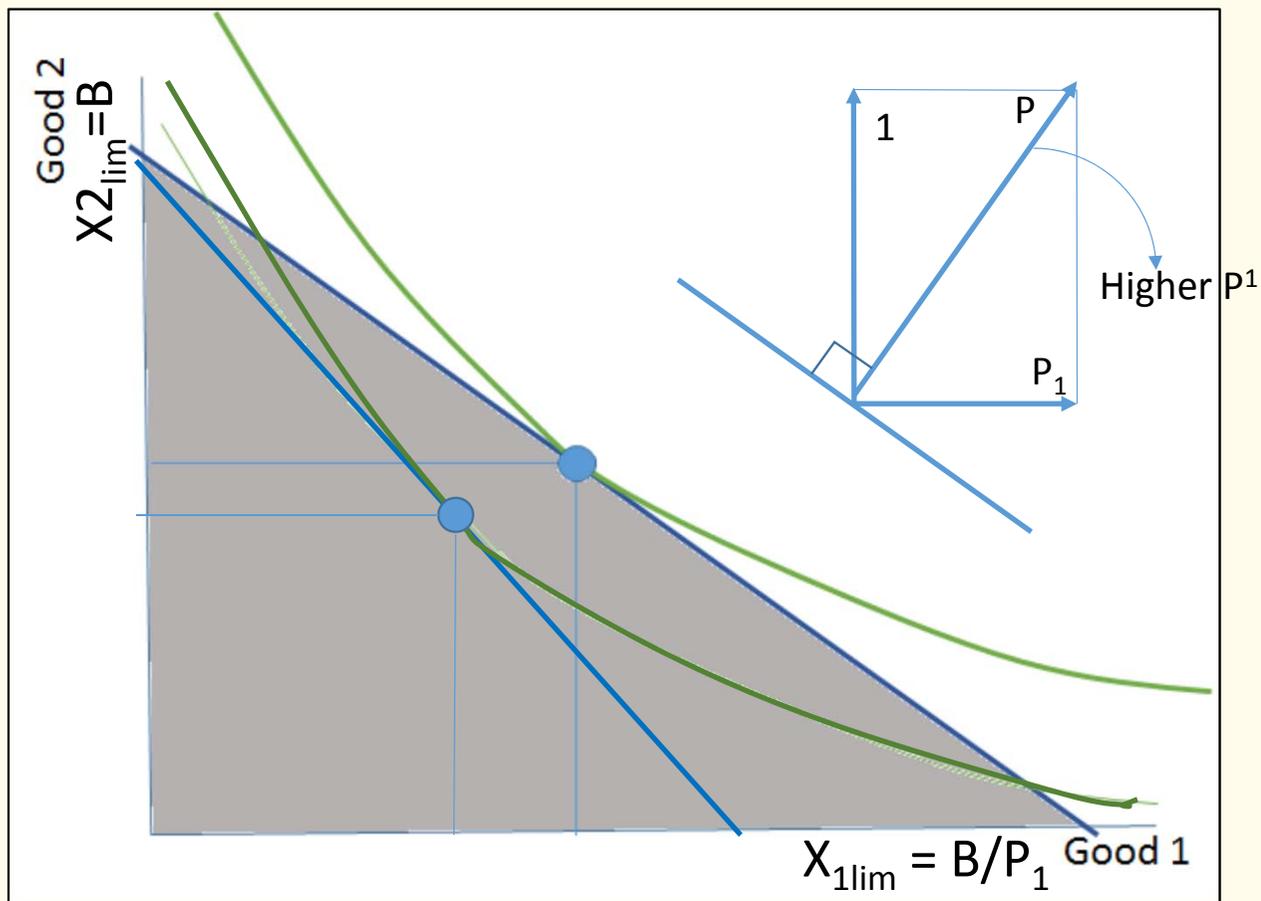
- Meat against fish
- Cane sugar against aspartam
- Yogourt against cheese
- ...

2) less divisible goods

- Home swimming pool against size of the house (m²)
- Garden against travels

Effect of price change 2

In this case, both goods are decreased due to the new budget constraint. This is due to a strong « income effect » : the consumer is « poorer » after the new price and has to reduce his/her consumption on both goods. However the consumer maintain roughly the poportion of the two goods



“There are however some exceptions. (*to downward sloping demand*) For instance, as Sir R. Giffen has pointed out, a rise in the price of bread makes so large a drain on the resources of the poorer labouring families and raises so much the marginal utility of money to them, that they are forced to curtail their consumption of meat and the more expensive farinaceous foods: and, bread being still the cheapest food which they can get and will take, they consume more, and not less of it. But such cases are rare; when they are met with, each must be treated on its own merits.” [\[i\]](#)

Alfred Marshall « *principles of economics* » 1890

See also :

« Housing in New Zealand : a Giffen Good » by Keith Rankin)

and also :

« Are tortillas a **Giffen Good** in Mexico? »

By David Mckenzie Department of Economics,

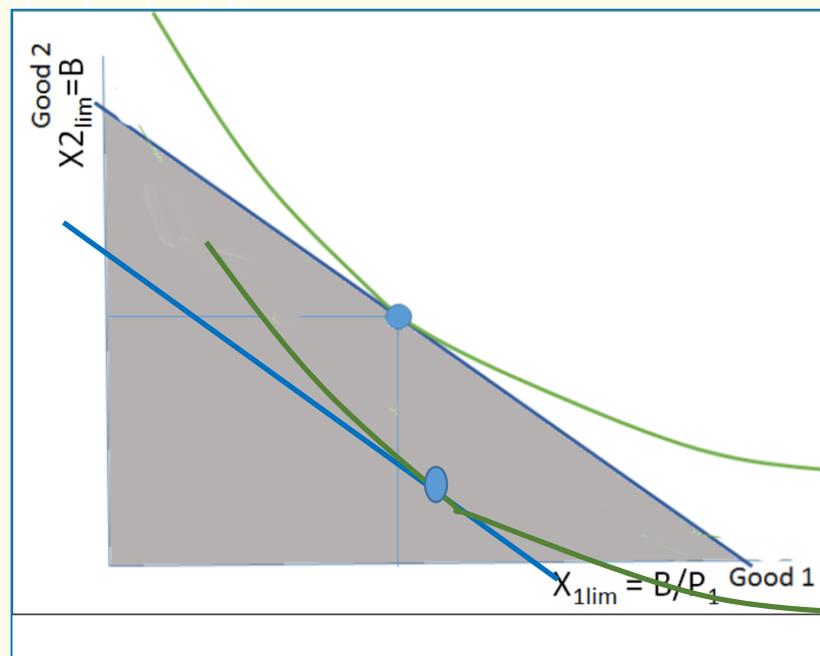
Stanford university

www.economicbulletin.uiuc.edu/2002/volume15/EB-01O10003A.pdf

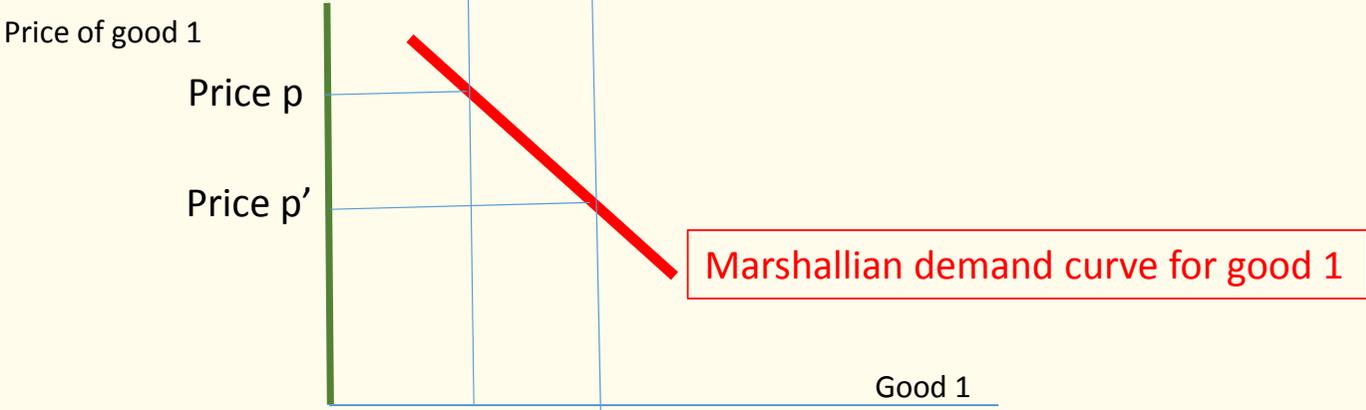
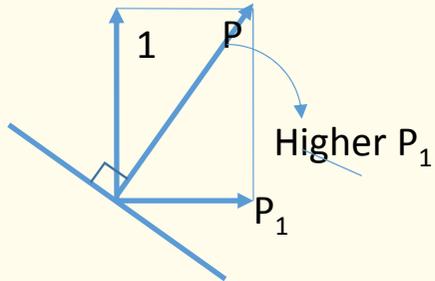
Effect of Budget Change

Relative prices could stay alike or just be slightly affected, while important budget changes might result from income tax, VA taxes, subsidies ... windfall profits, inflation etc...

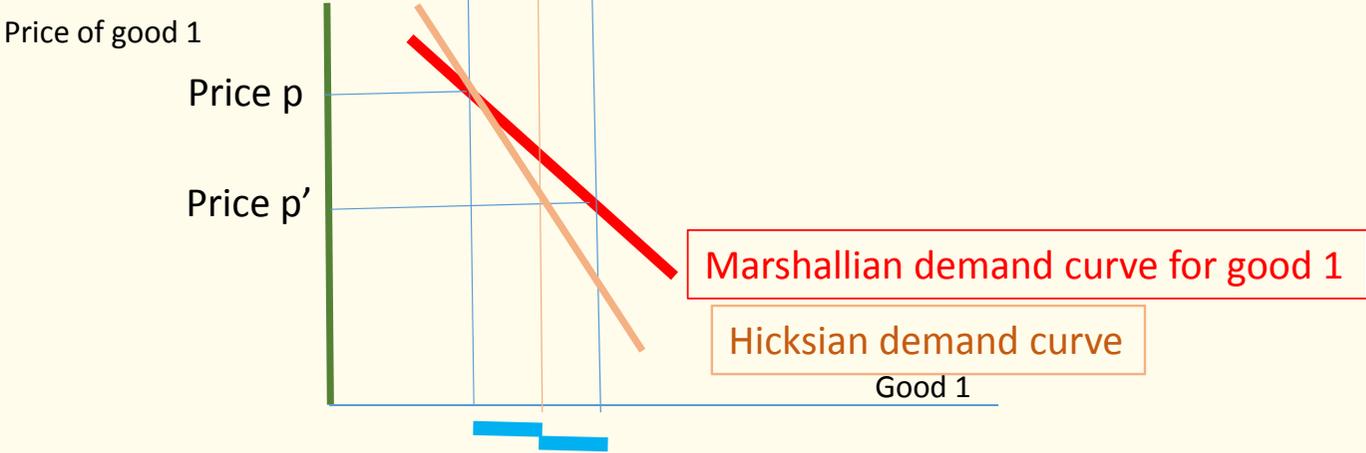
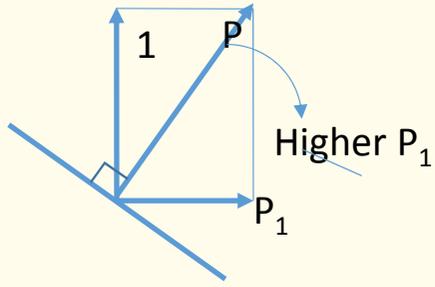
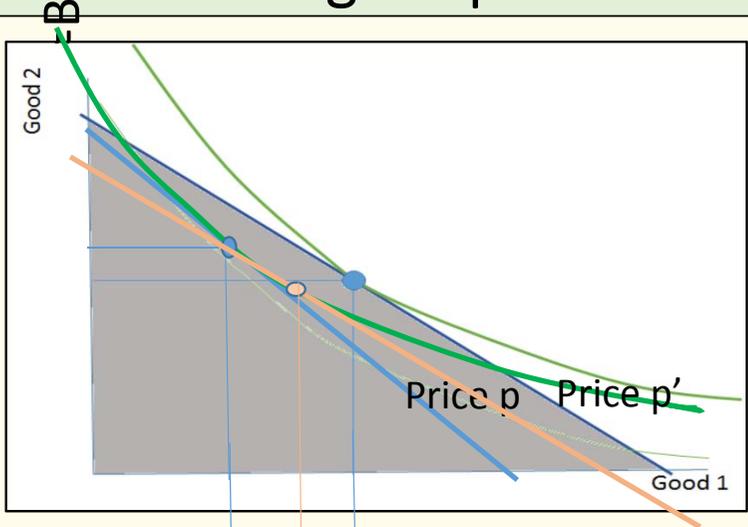
Relative Prices do not change:
same slope of



Effect of change in price: decomposition



Effect of change in price: decomposition 2

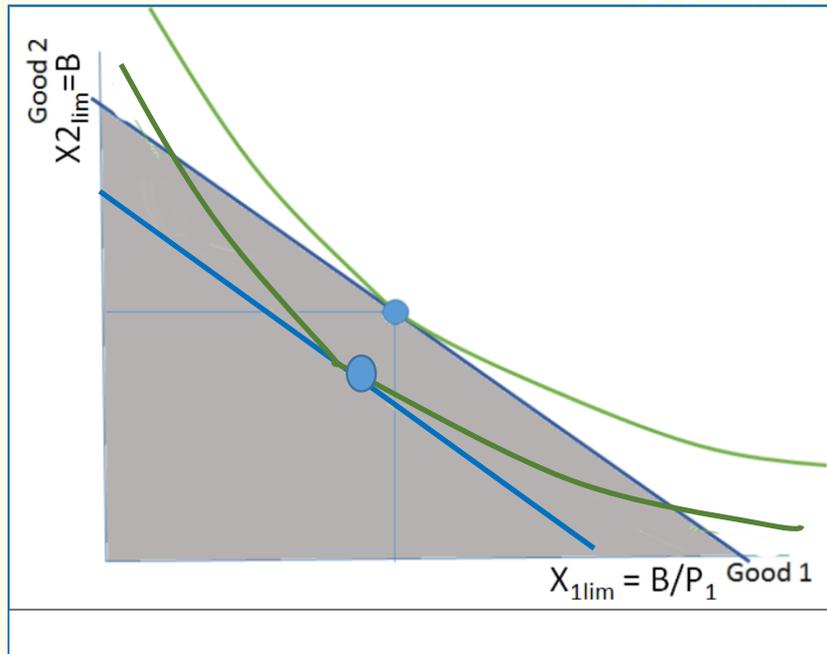


Substitution effect + income effect

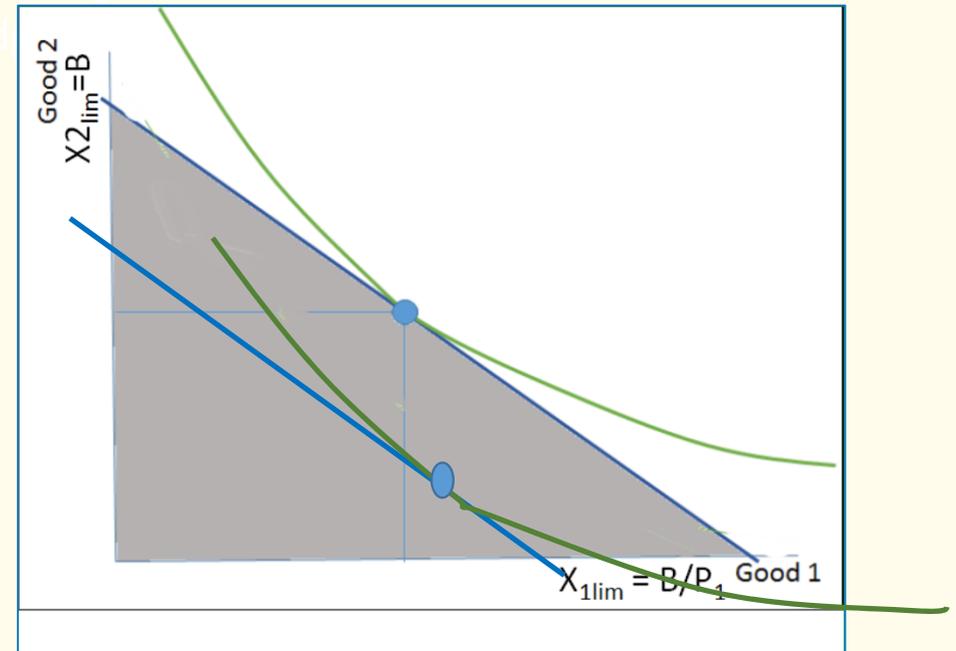
Effect of Budget Change

Relative prices could stay alike or just be slightly affected while important budget changes might result from income tax, VA taxes, subsidies, windfall profits, inflation...

Relative Prices do not change:
of the bud



Normal goods



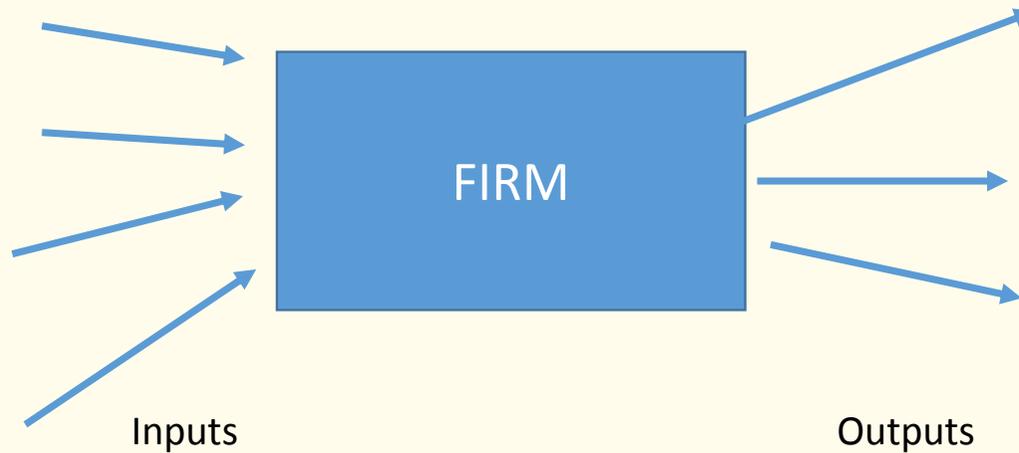
Good 1 is « inferior » good 2 is « luxury »

Demand Curve in the one-price regime

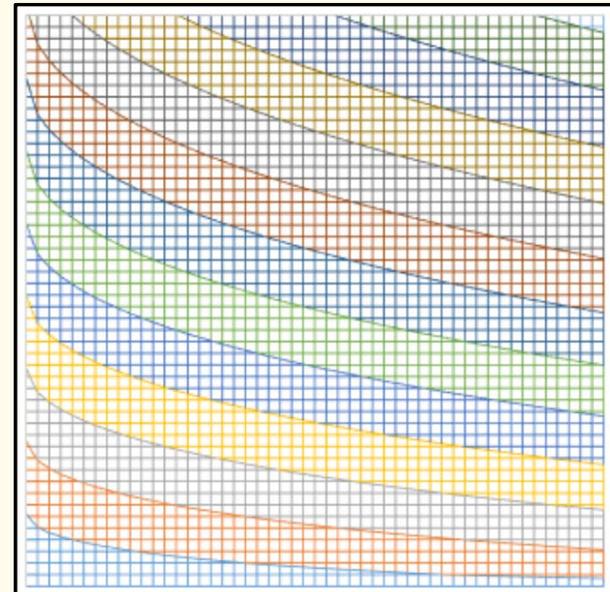
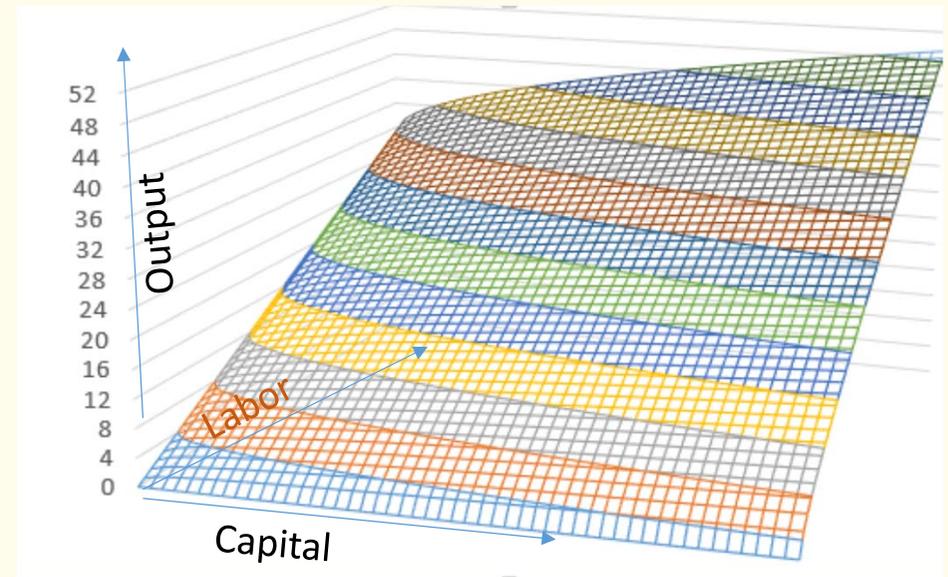
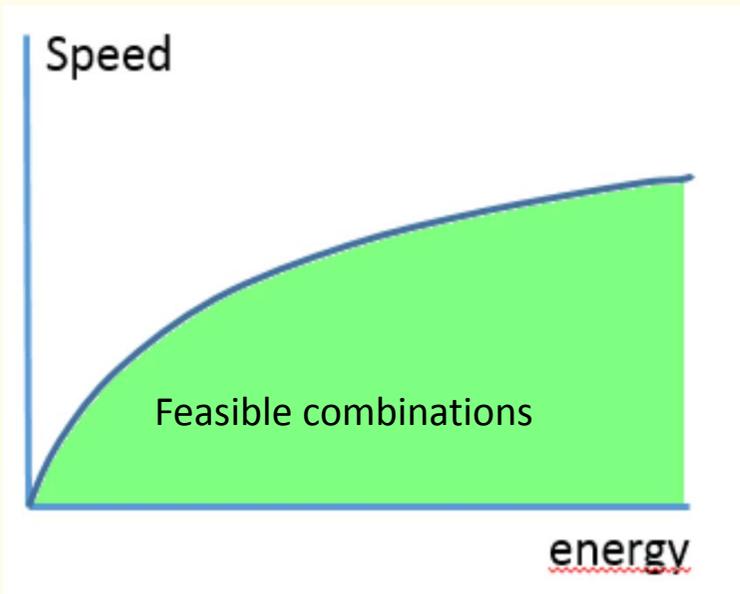
Hypothesis on Production : Theory of the Firm

The « firm » is a technological know-how transforming inputs into outputs

There is one decision maker whose utility function is PROFIT

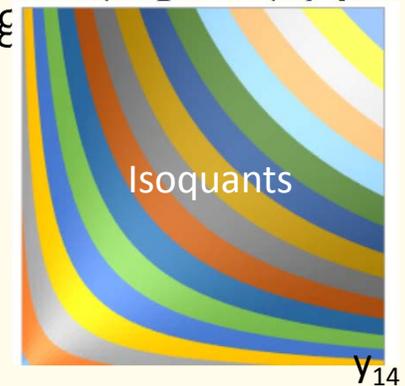


Convexity of technologies



Models of the firm example

Firm j produces y_3 units of good 3 by using y_9 and y_{14} units of goods 9 and 14.
Prices p_3 , p_9 and p_{14} are set by the markets.



$$\text{Max } p_3 y_3 - p_9 y_9 - p_{14} y_{14}$$

$$y_3 \leq S \cdot y_9^r \cdot y_{14}^{(1-r)}$$

$$y_{3, 9, 14} \geq 0$$

S : scaling factor (depends on the units)

$r > 0$ represents the technological process (here « Cobb-Douglas »)

Classical tool for static maximization

Find $x^ = \operatorname{argmax} F(x, p)$*

$x \in R^n$ (numerical variables)

$G(x, p) \leq \mathbf{0}$ (set of inequality constraints: e.g. limited resources)

$K(x, p) = \mathbf{0}$ (set of equality constraints :e.g. conservation)

Lagrange method

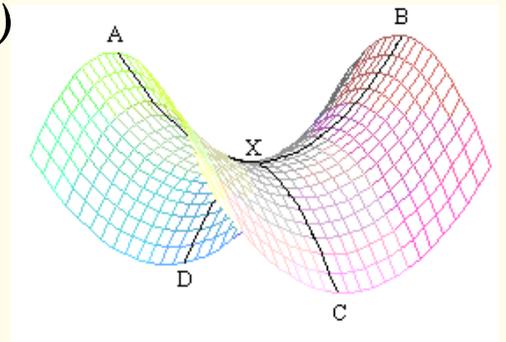
The problem above is equivalent to:

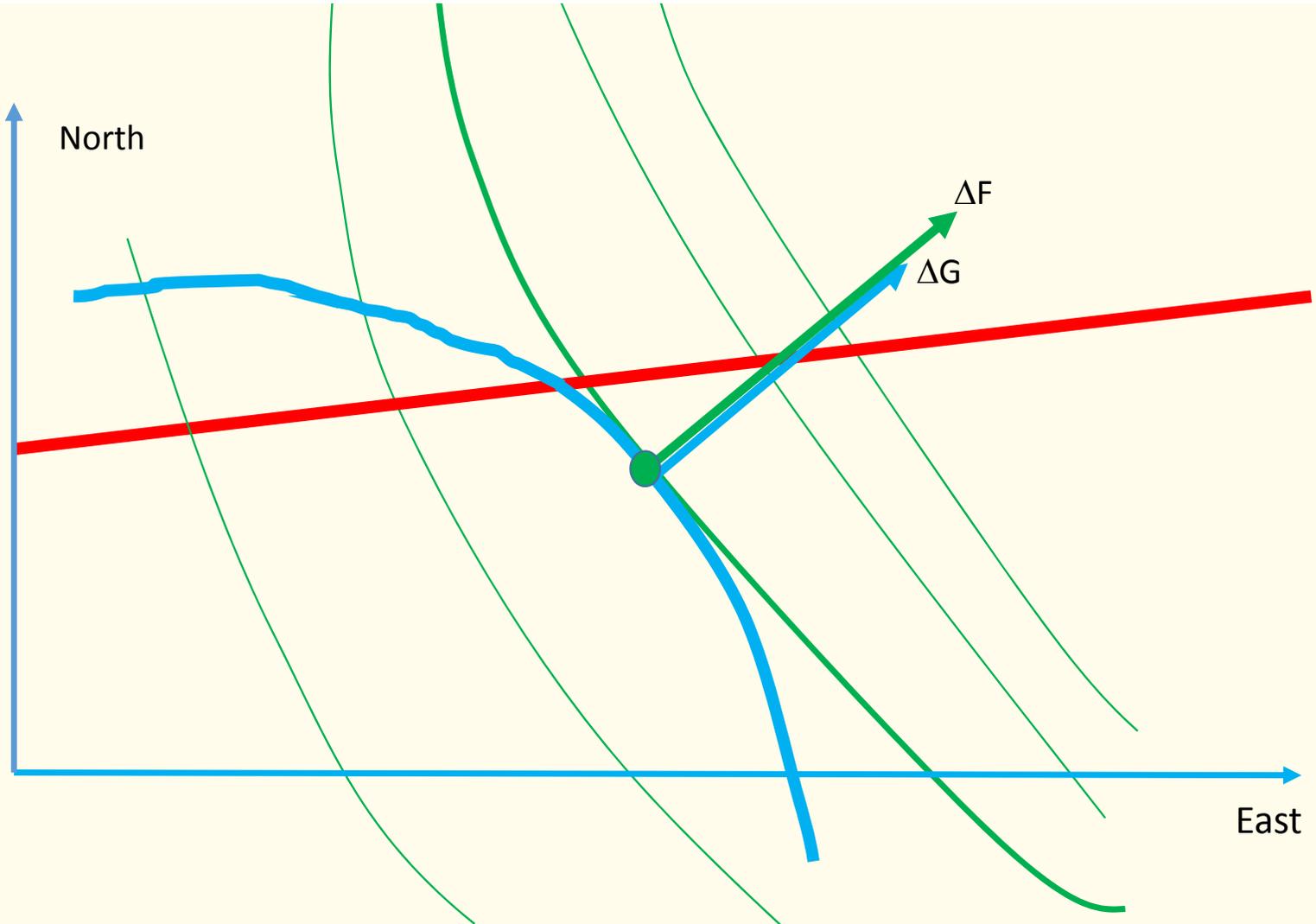
Find $x^ = \operatorname{argmax}$ and $\lambda^*, \mu^* = \operatorname{argmin}$ of*

$L(x, \lambda, \mu, p) = F(x, p) + \lambda G(x, p) + \mu K(x, p)$

Conditions on λ and μ (>0 or $=0$)

(Find a “saddle point”)





North

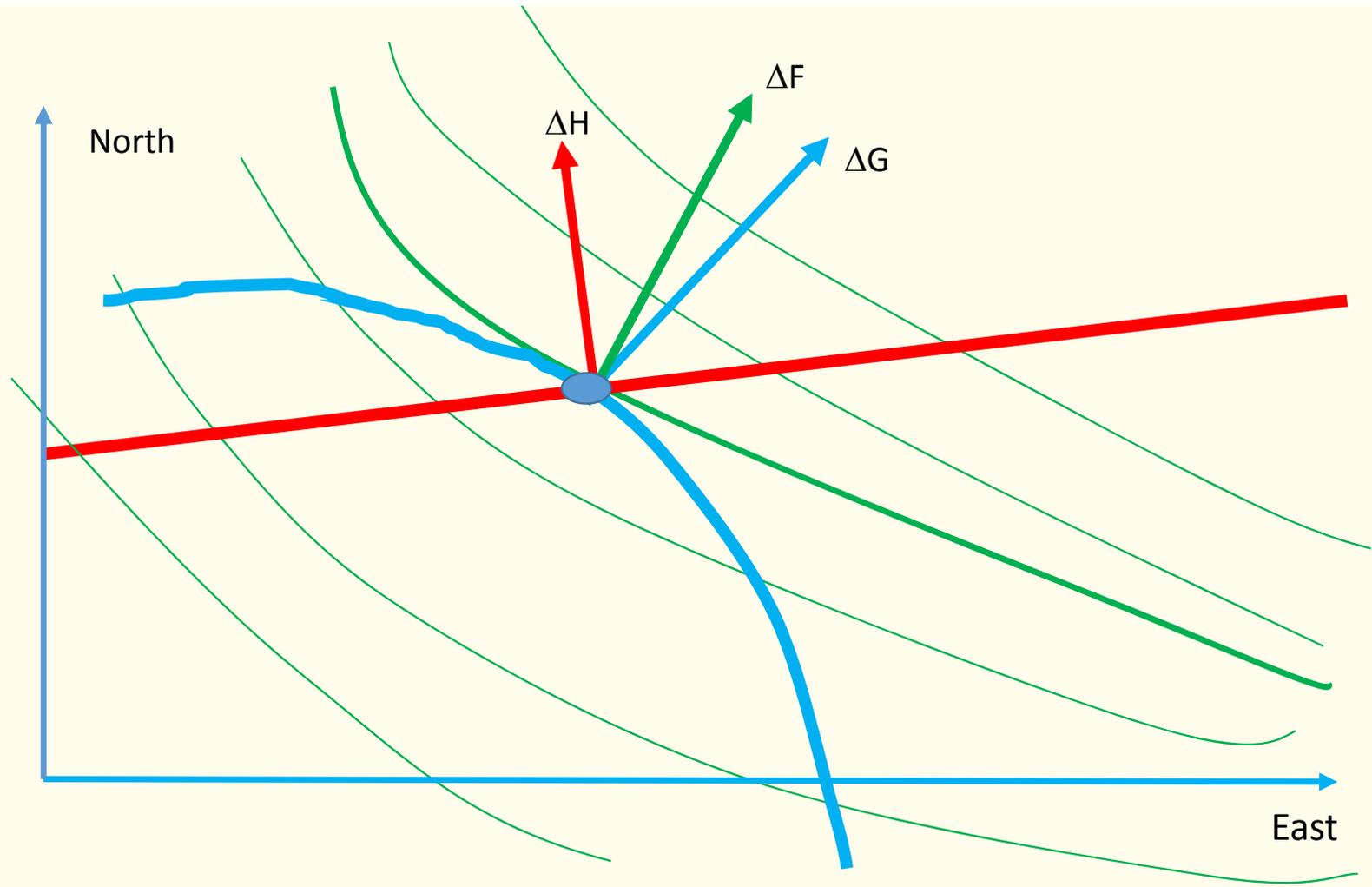
ΔF

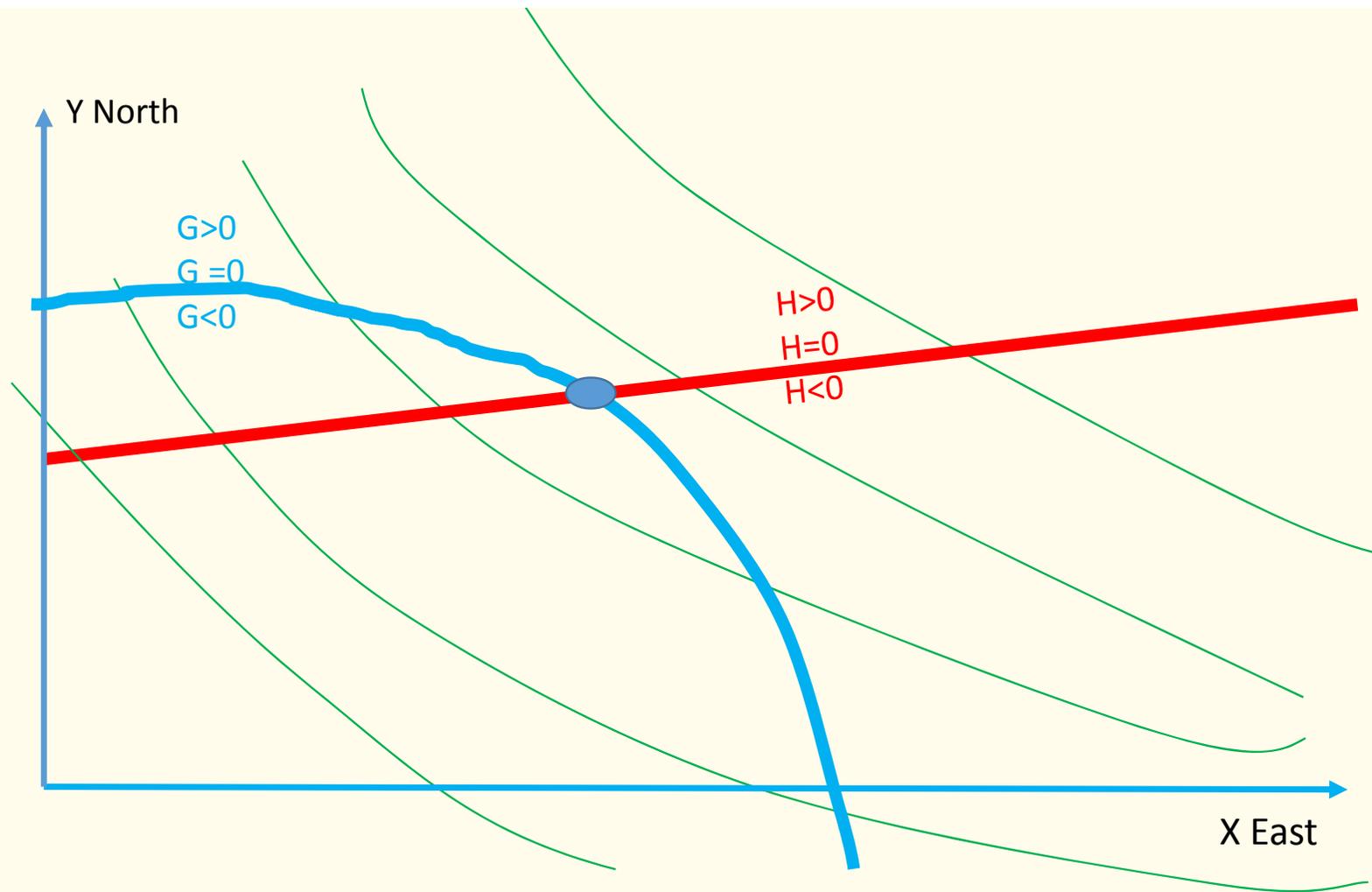
ΔG

East

F =







Example

$$\text{Max}_{x,y} F(x,y)$$

$$G(x,y) \leq 0$$

$$H(x,y) \leq 0$$

$$x \geq 0 \quad y \geq 0$$

$$\text{Max}_{x,y} \text{Min}_{\lambda,\mu} L(x,y,\lambda,\mu) = F(x,y) + \lambda.G(x,y) + \mu.H(x,y)$$

$$x \geq 0 \quad y \geq 0 \quad \lambda \geq 0 \quad \mu \geq 0$$

Compute partial derivatives in x and y and set to 0

$$\Delta F + \lambda.\Delta G + \mu.\Delta H = 0 \text{ or else}$$

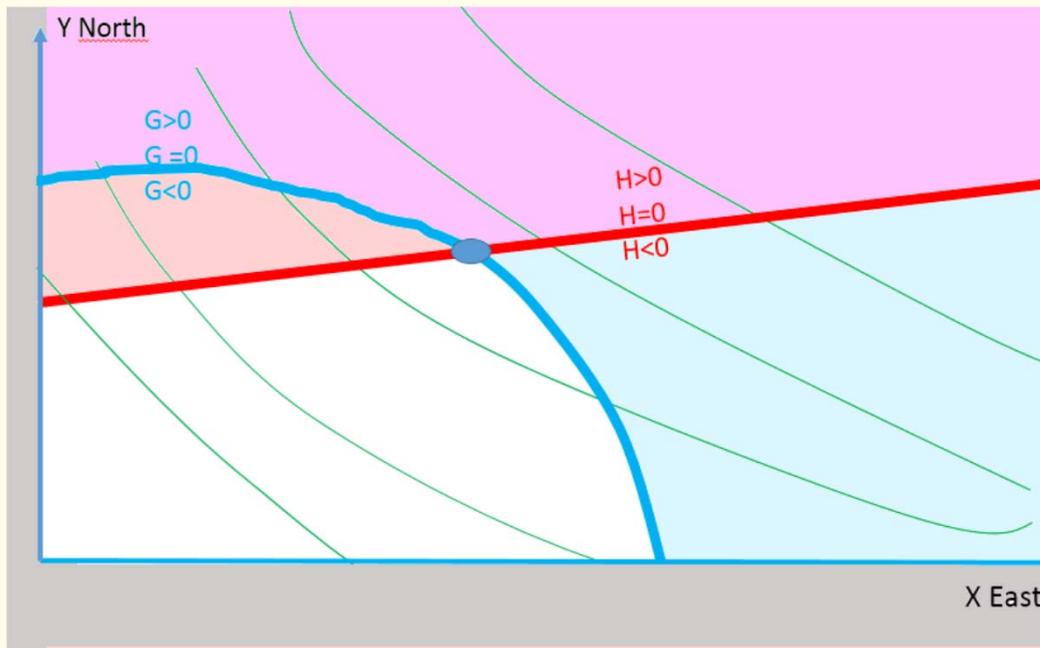
$$-\Delta F = \lambda.\Delta G + \mu.\Delta H \text{ condition 1}$$

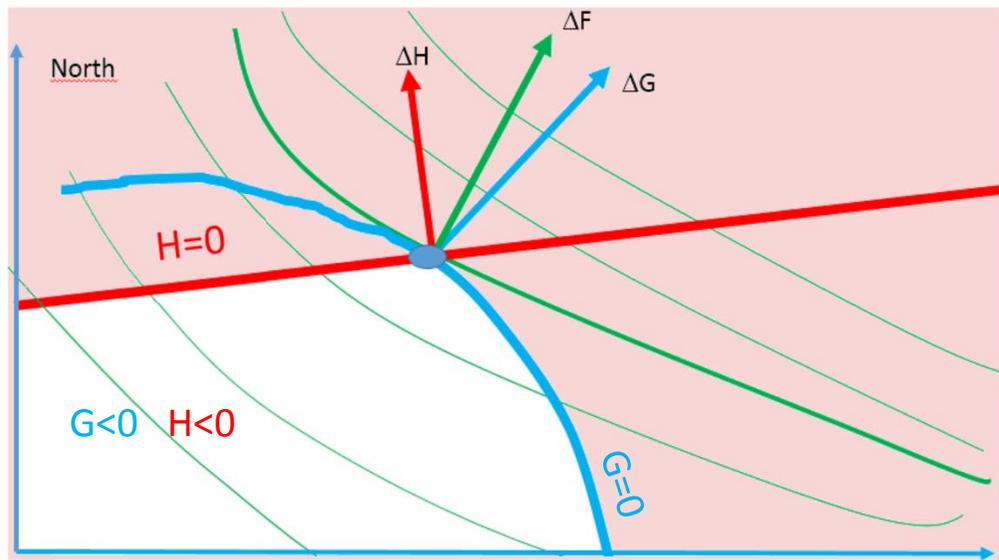
Compute partial derivatives in λ and μ and set to 0

$$\begin{aligned} \lambda > 0 &\Rightarrow G = 0 \\ \lambda = 0 &\Rightarrow G \geq 0 \text{ condition 2} \end{aligned}$$

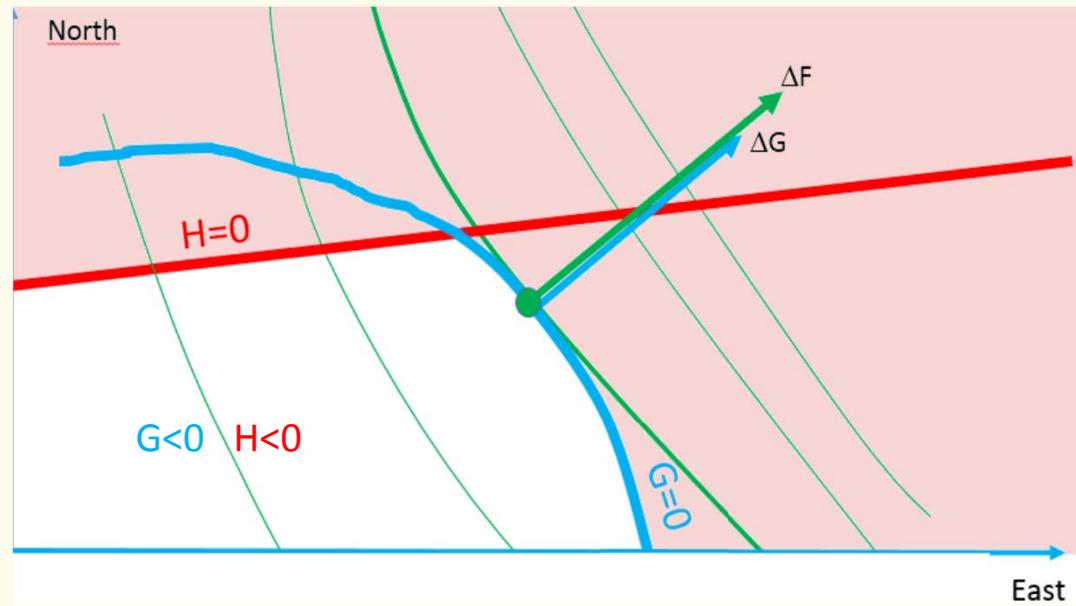
$$\begin{aligned} \mu > 0 &\Rightarrow H = 0 \\ \mu = 0 &\Rightarrow H \geq 0 \text{ condition 3} \end{aligned}$$

In particular when λ and μ are strictly positive $H = G = 0$ i.e. both constraints are binding
Condition 1 says that the opposite of the gradient of F is a positive linear combination of the gradients of G and H





$$\lambda > 0 \quad \mu > 0$$



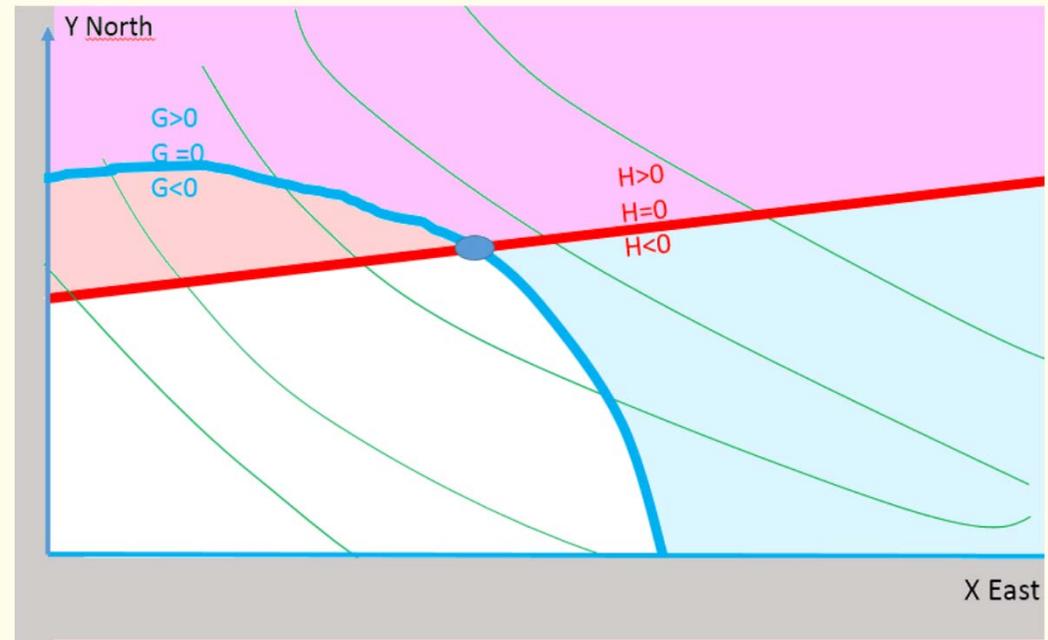
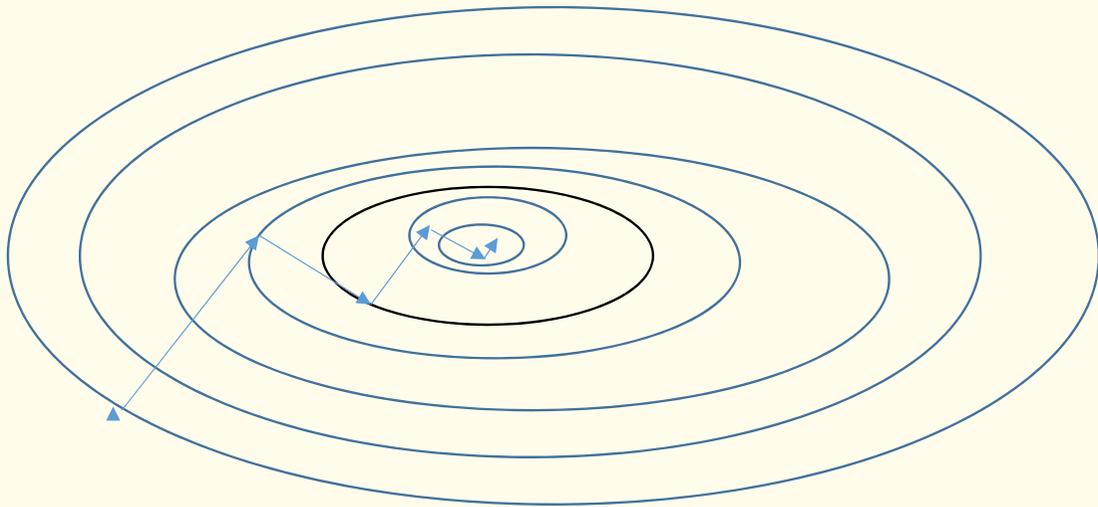
$$\lambda > 0 \quad \mu = 0$$

$$\Delta F = \lambda \cdot \Delta G + \mu \cdot \Delta H$$

Analytical versus numerical methods

Solving a set of inequations : possible in case of nice models and an a priori partial knowledge of the solution properties

Numerical resolution. Example Newton principle



Introduction of time : Optimal control

$$\text{Max}_{u(t)} F[x(t), u(t), p(t)]$$

$u(t)$ control variable to determine

$x(t)$ state variable: endogenous

$P(t)$ environment variable: exogenous

$$\frac{dx(t)}{dt} = G[x(t), u(t), p(t)]$$

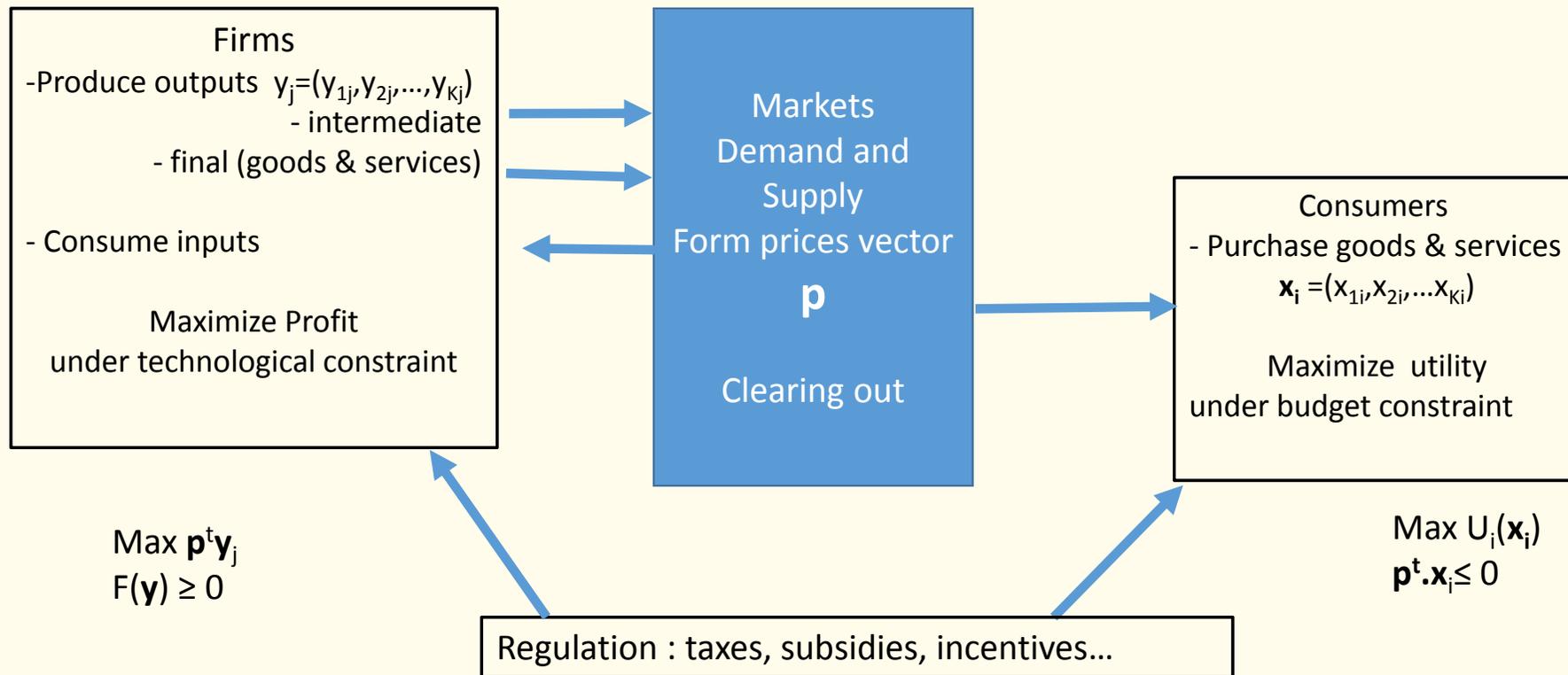
$$u(t) \in \text{domain}[h(x(t), p(t), u(t))]$$

To add to complexity introduce uncertainty

Stochastic parameter: $dp(t) = r(p(t), t) + s(p(t), t) * dW$
 W is a brownian motion

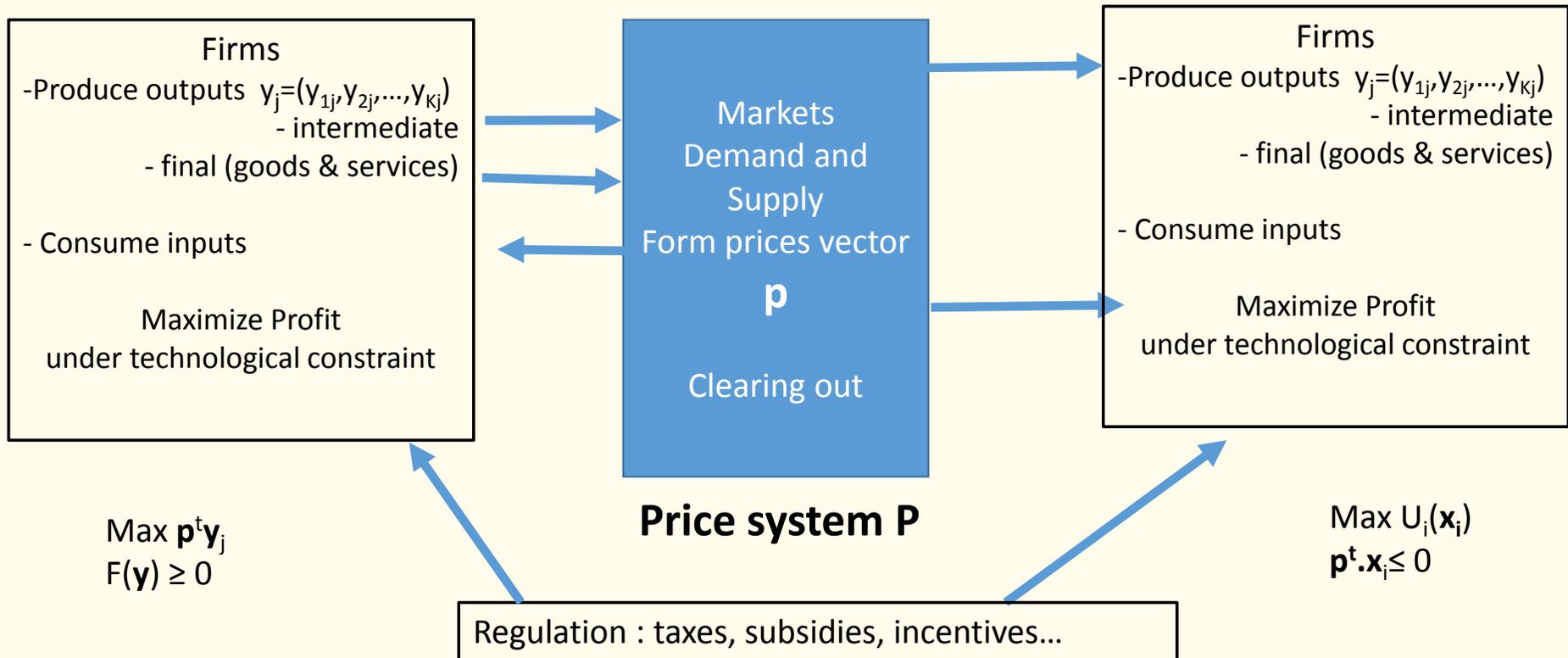
Structure of Equilibrium Models B to C Firm to Consumers

K goods and services indexed 1, 2, ..., k, ..., K



Structure of Equilibrium models B to B

K goods and services indexed 1, 2, ..., k, ..., K



Matrix input-output à la Leontieff

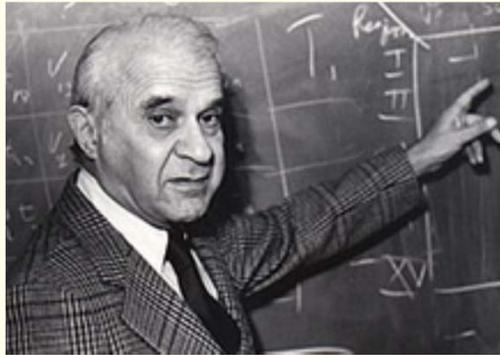
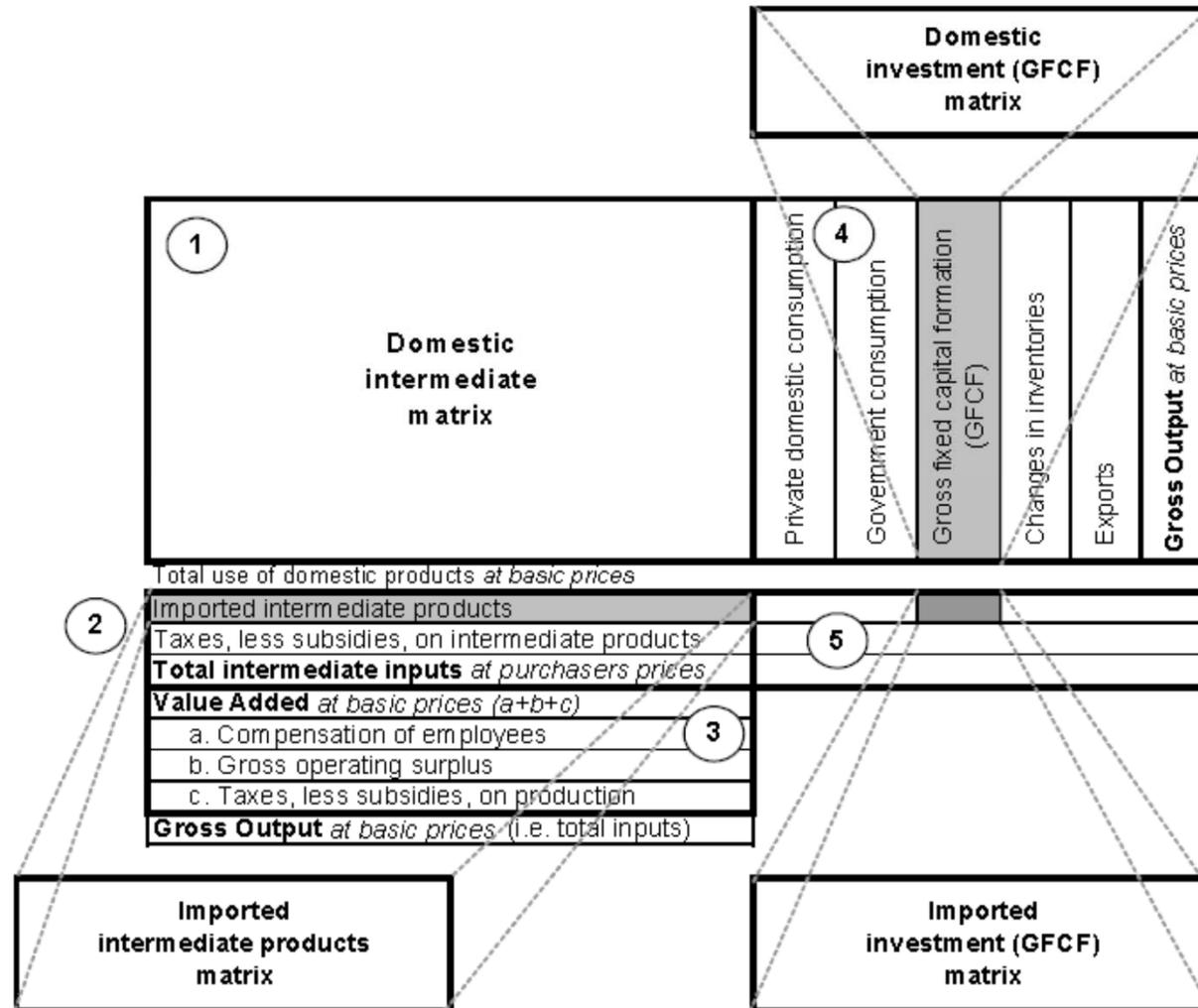


Figure 1. The basic structure of an input-output table



The good conditions for nice properties

The case of competitive markets

Consumers maximize utility Firm maximize profit *Markets make prices*

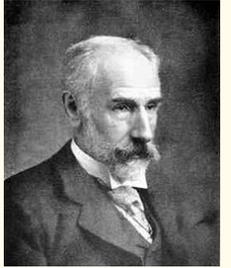
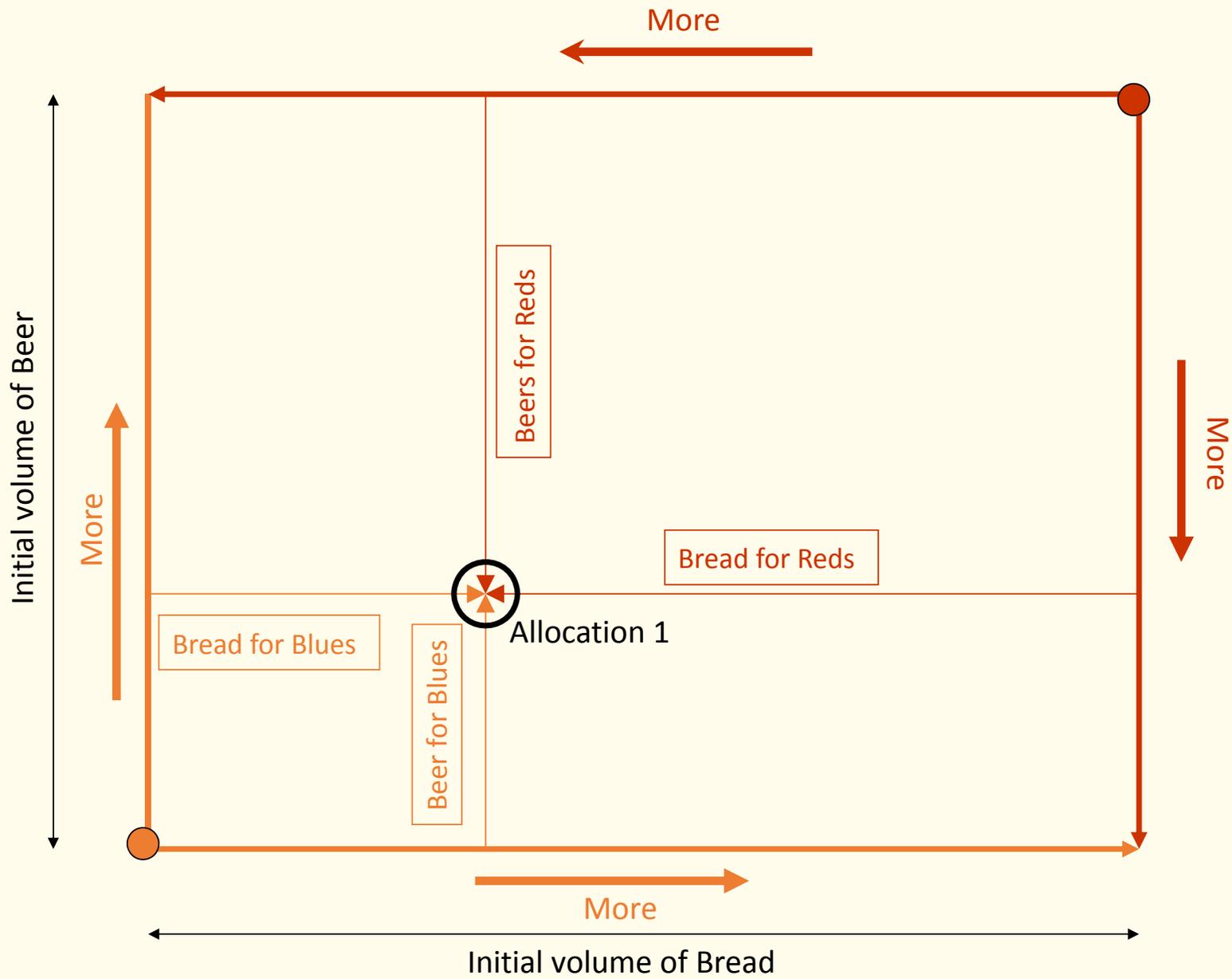
(prices cannot be manipulated by consumers or producers)

Consumers' utility functions are quasi concave

Producers' technologies are quasi-concave (non increasing returns to scale)

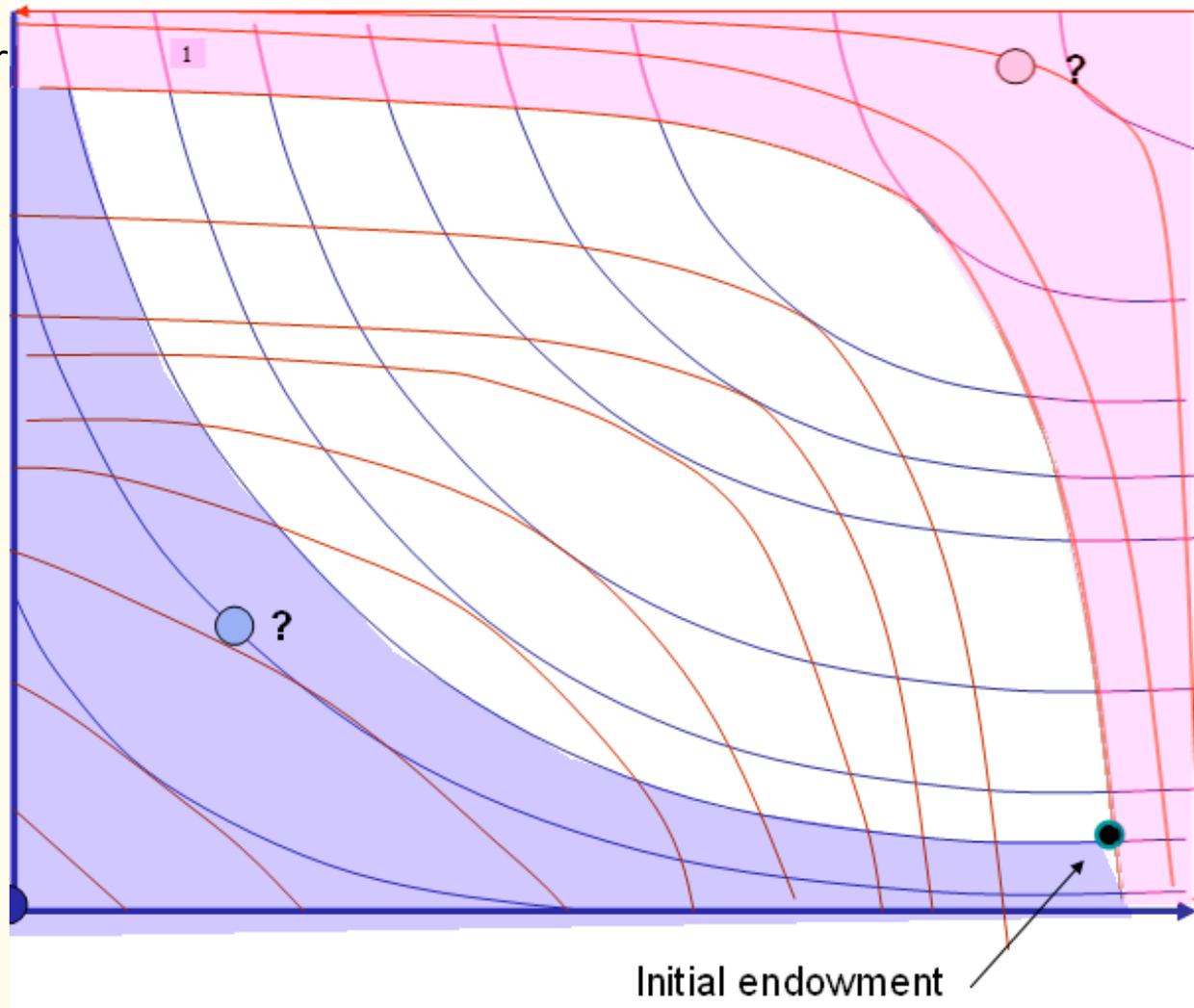
There are no externalities

ARE SUFFICIENT CONDITIONS FOR OPTIMALITY OF EQUILIBRIUM

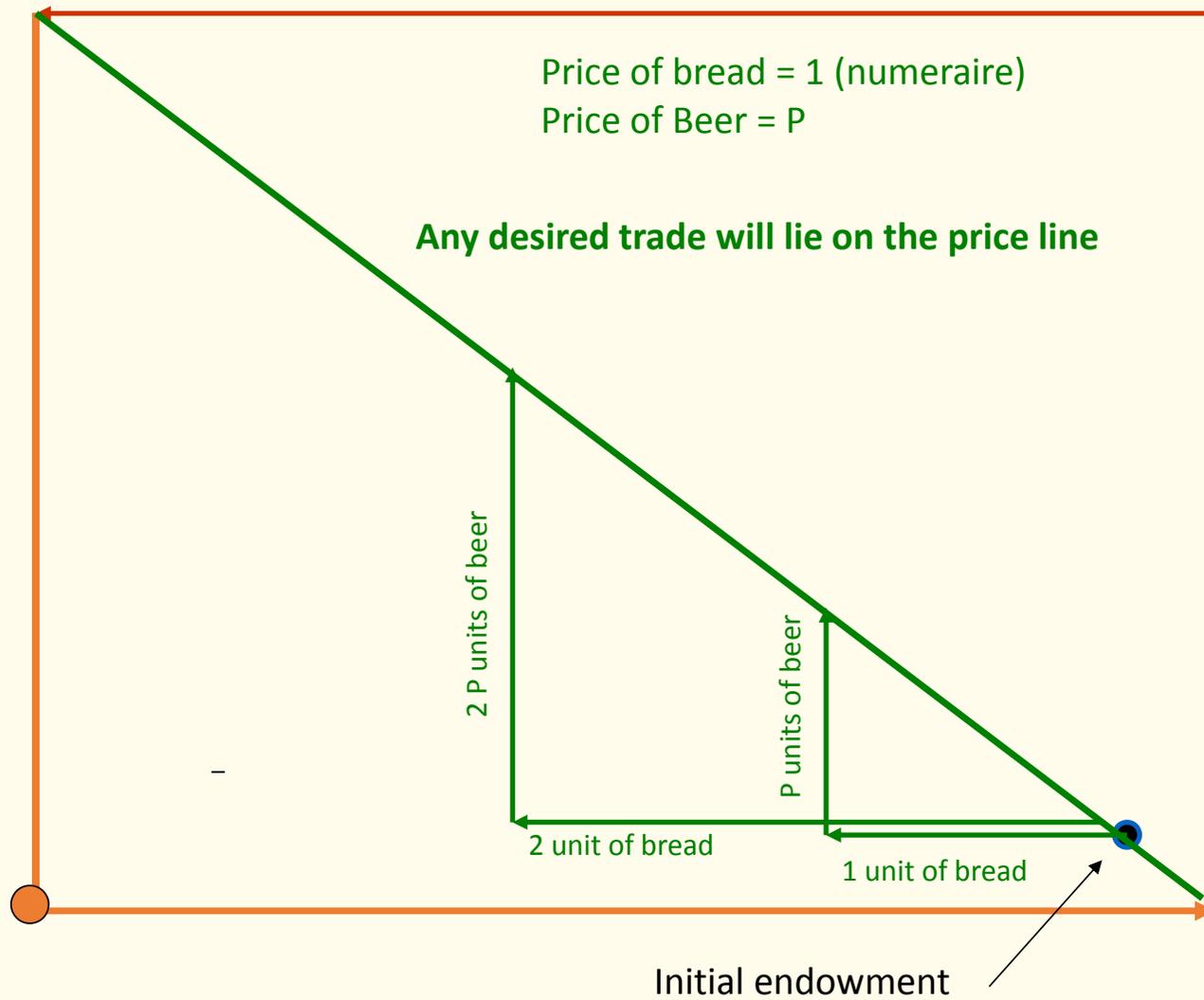


Edgeworth's Box

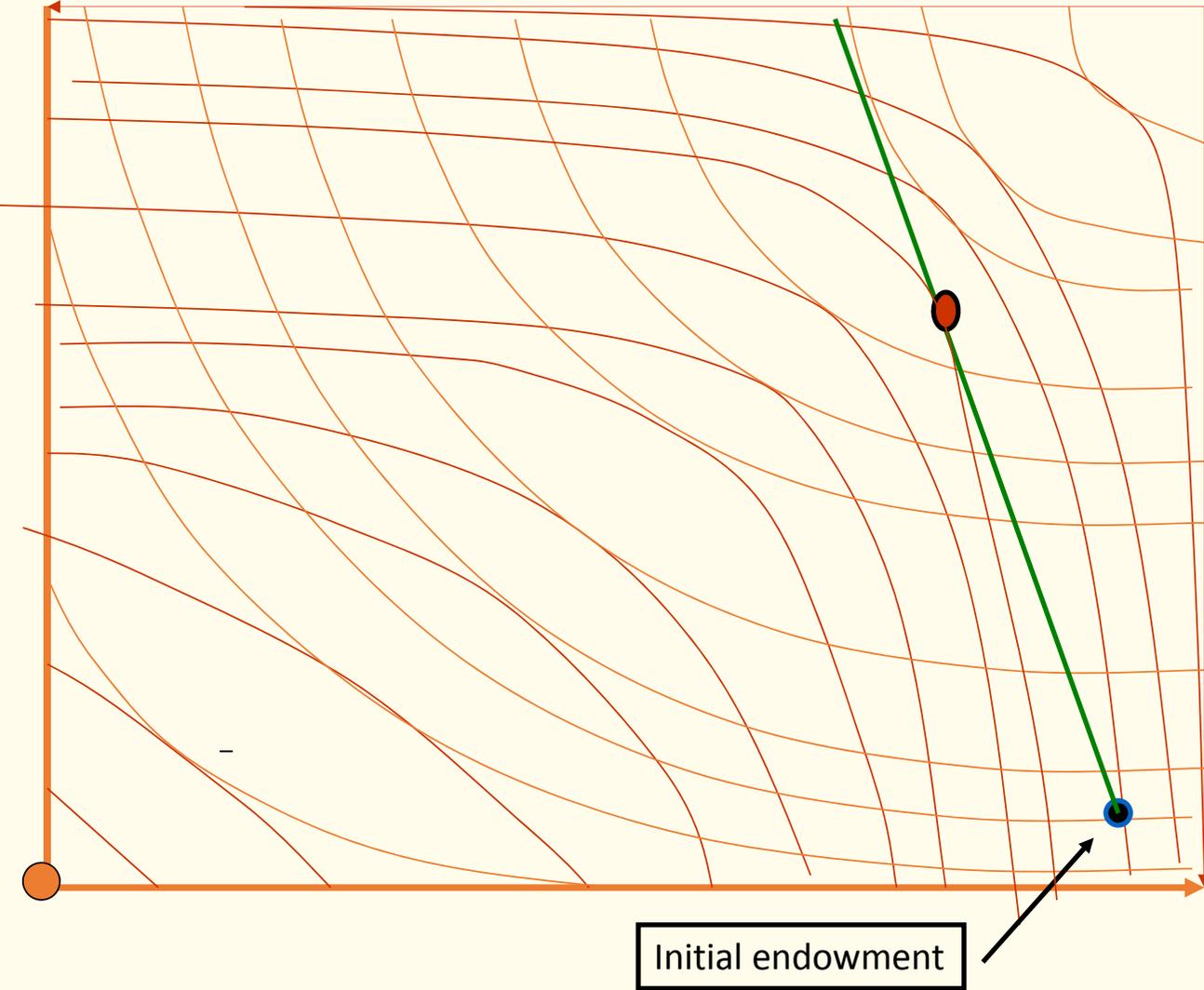
Unilaterally r



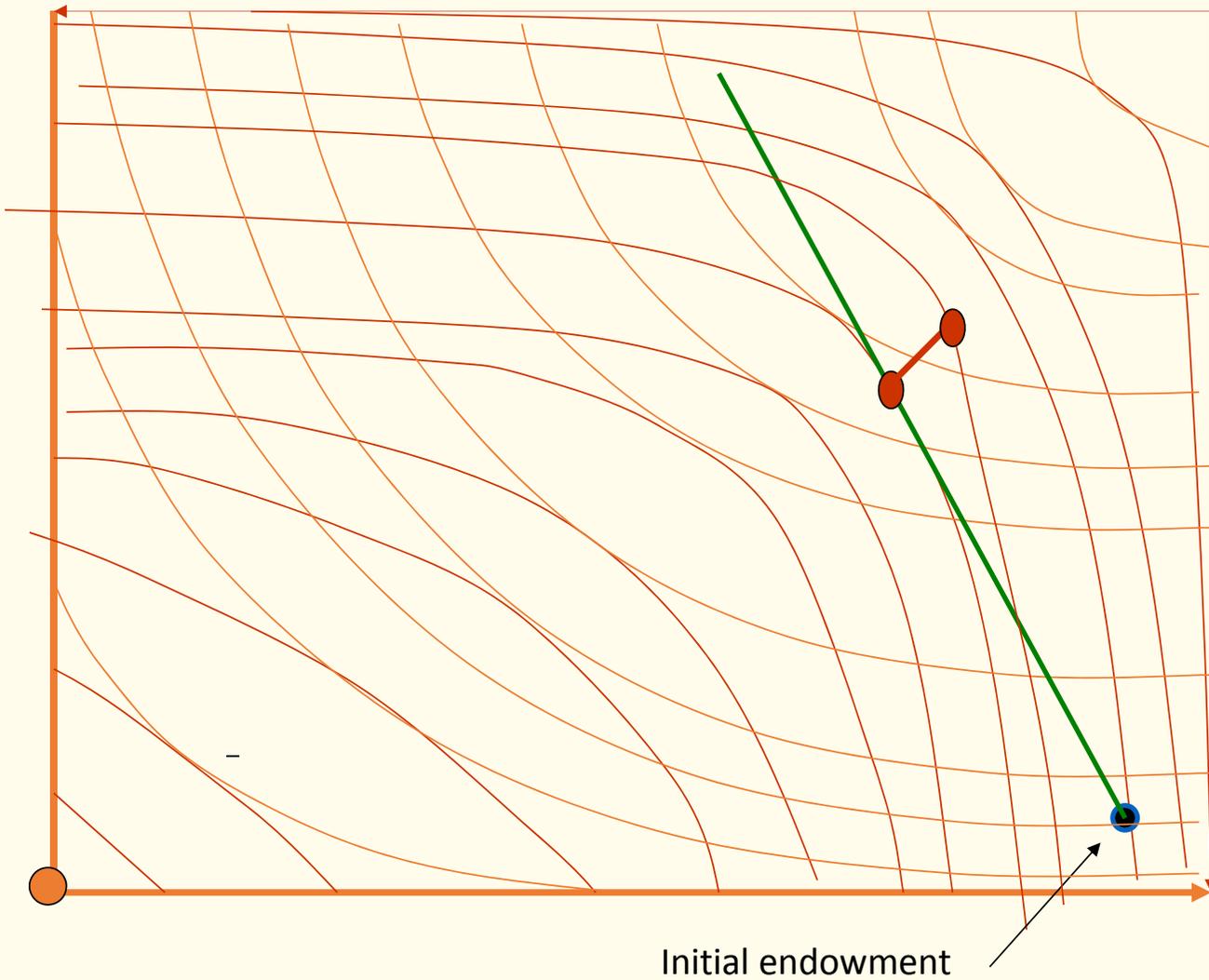
Trading via a price set by an external referee (commissaire priseur)



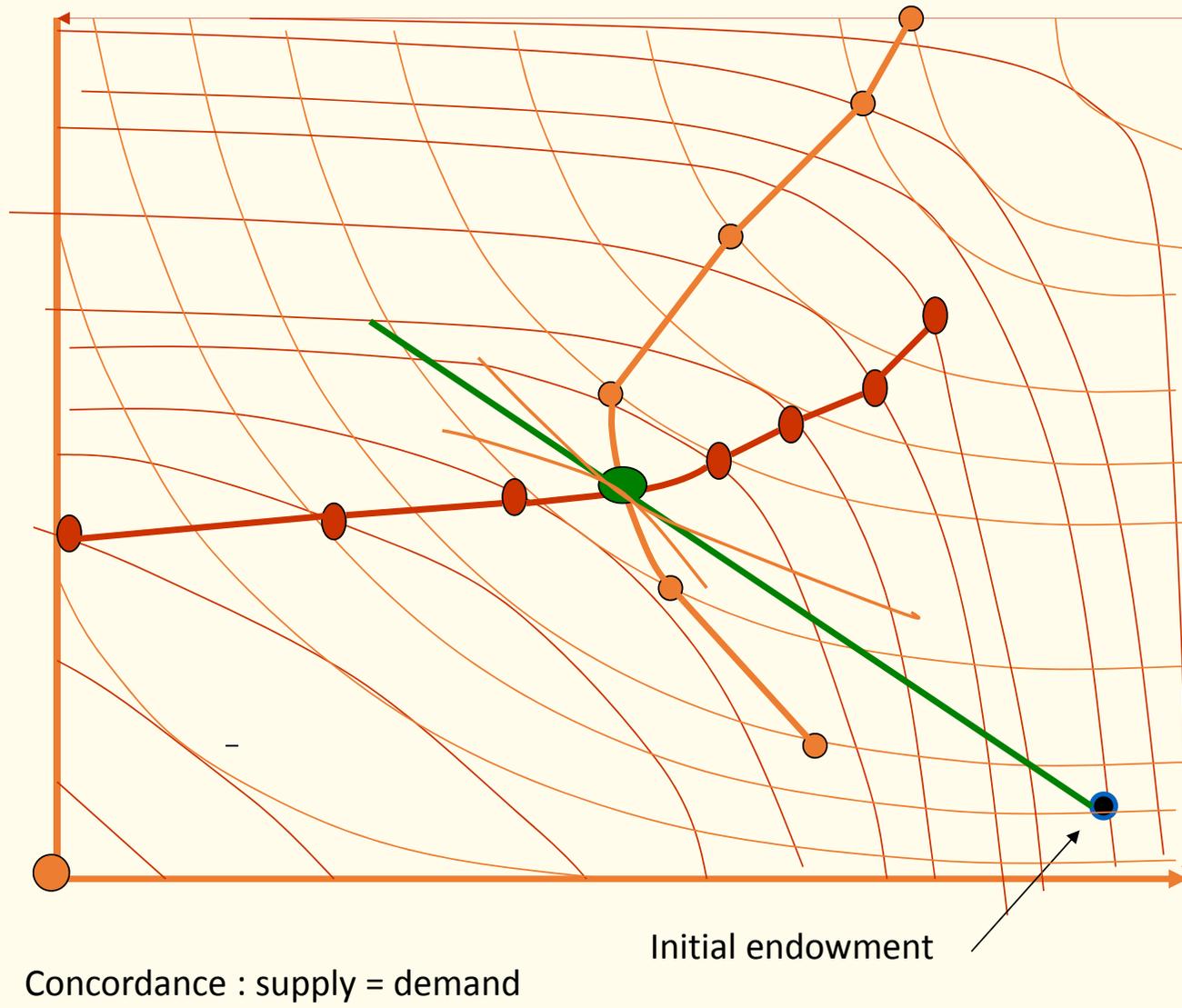
Supply-demand curve for the Reds

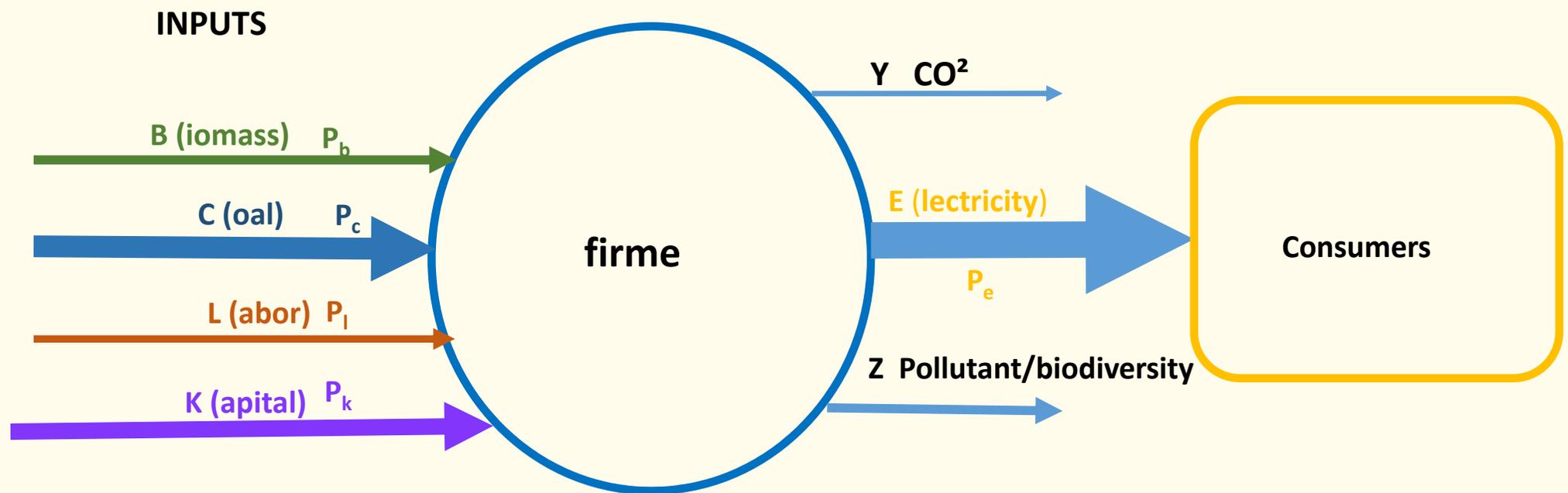


Supply-demand curve for the Reds



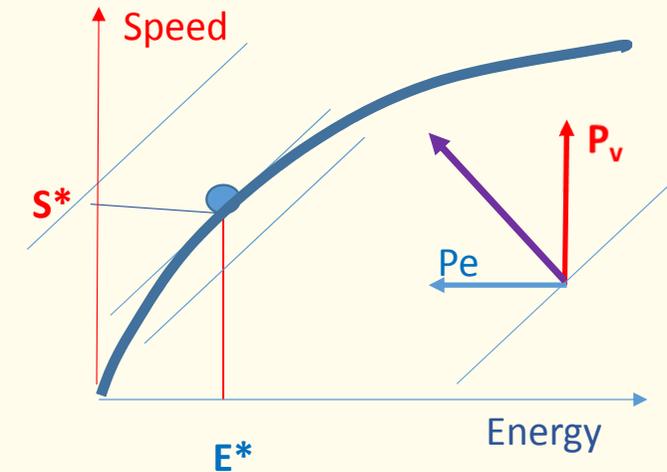
Concordance of the desired allocations by competitive price two-trader model





Max Profit $\Pi = P_e E + P_z Z + P_y Y + P_b B + P_c C + P_l L + P_k K$ **N.B.** *inputs < 0 outputs > 0*

$G(E, B, C, L, K, Y, Z) \leq 0$ *set of technological and process equations*



Max Profit $\Pi = P_v S - P_e E$ (here output and inputs are positive)

s.t. $S^2 \leq E$ (efficiency requires equality)

Introduction Ecotax

Max Profit $\Pi = P_v S - P_e E - P_z \cdot Z$

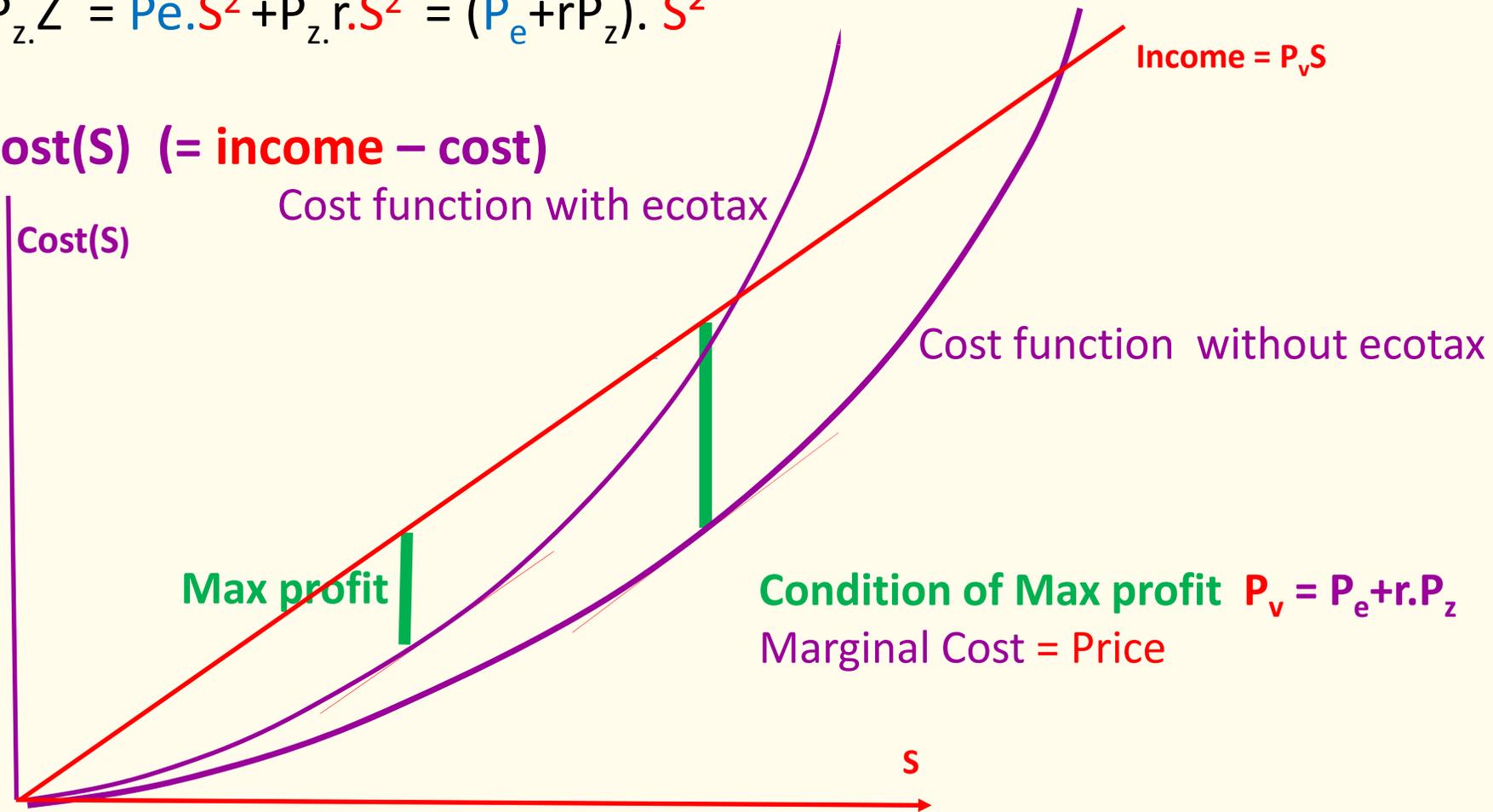
s.t. $S^2 = E$
 $Z = r \cdot E$

How much does it cost to produce S efficiently?

Construct a cost function

$$\text{cost}(S) = P_e \cdot E + P_z \cdot Z = P_e \cdot S^2 + P_z \cdot r \cdot S^2 = (P_e + rP_z) \cdot S^2$$

$$\text{Profit} = P_v \cdot S - \text{cost}(S) \quad (= \text{income} - \text{cost})$$



Environmental markets

Many goods or nuisances that contribute to people 's happiness or dismay cannot be assigned to specific agents.

They create « externalities » (external to markets!)

If there is no price, they tend to be over-consumed (good) or over-produced (nuisance)

- Ex :
- The space of the Calanques (overconsumed)
 - The ozone pollution in Aix-en-Provence (overproduced)

If it is possible to find a « proxy » and « identify » the emitter (for a nuisance) or the beneficiaries (for a good), then one might design a « market of rights » (to consume or to emit) and treat the problem within the classical micro-economic market framework.

Marché du CO₂

Cap and trade System



profit of one more ton of
CO₂ emitted
VH = 15€T

Avantage
15 - 10 = 5€T

Market price : 10€T
through ETS

Buys rights

Sells rights

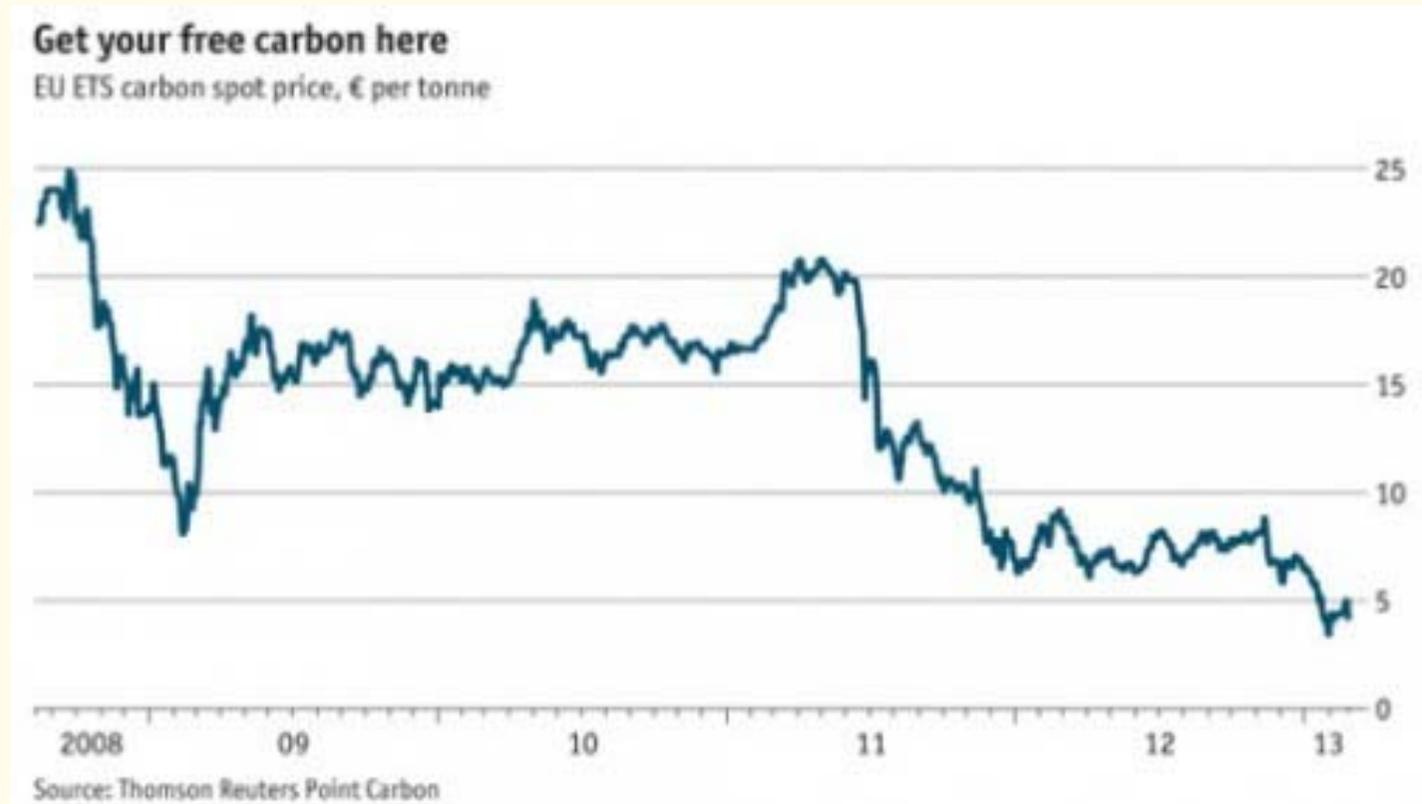


Profit of one more ton of
CO₂ emitted
VL = 6€T

Avantage
10 - 6 = 4€T

The total number of rights issued
is set by the government
e.g. by auction

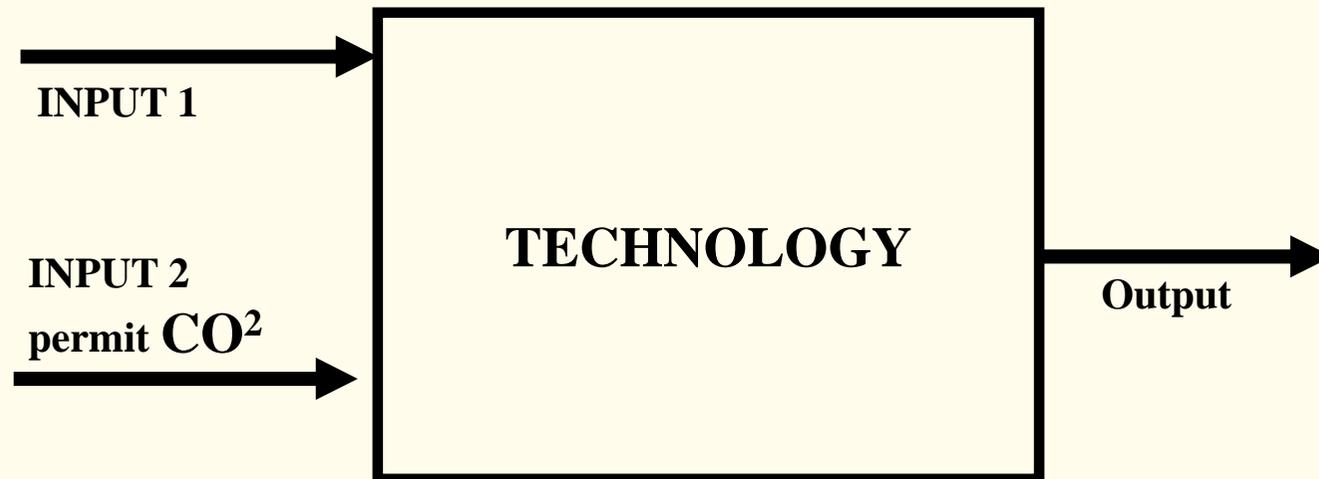
CO₂ market spot price European Trading System



Vers un marché du carbone automobile ?



Limits of carbon markets : only partial equilibrium



The system creates a price for a second input: the emission right . The good was free before. So the firm will be led to modify the combination of inputs to minimize its total cost (and maximize profit) . Input 1 is likely to be used MORE
What if, for instance, input 1 is a dangerous chemical product with effects on the workers's health. This externality is not considered in a « partial » market system

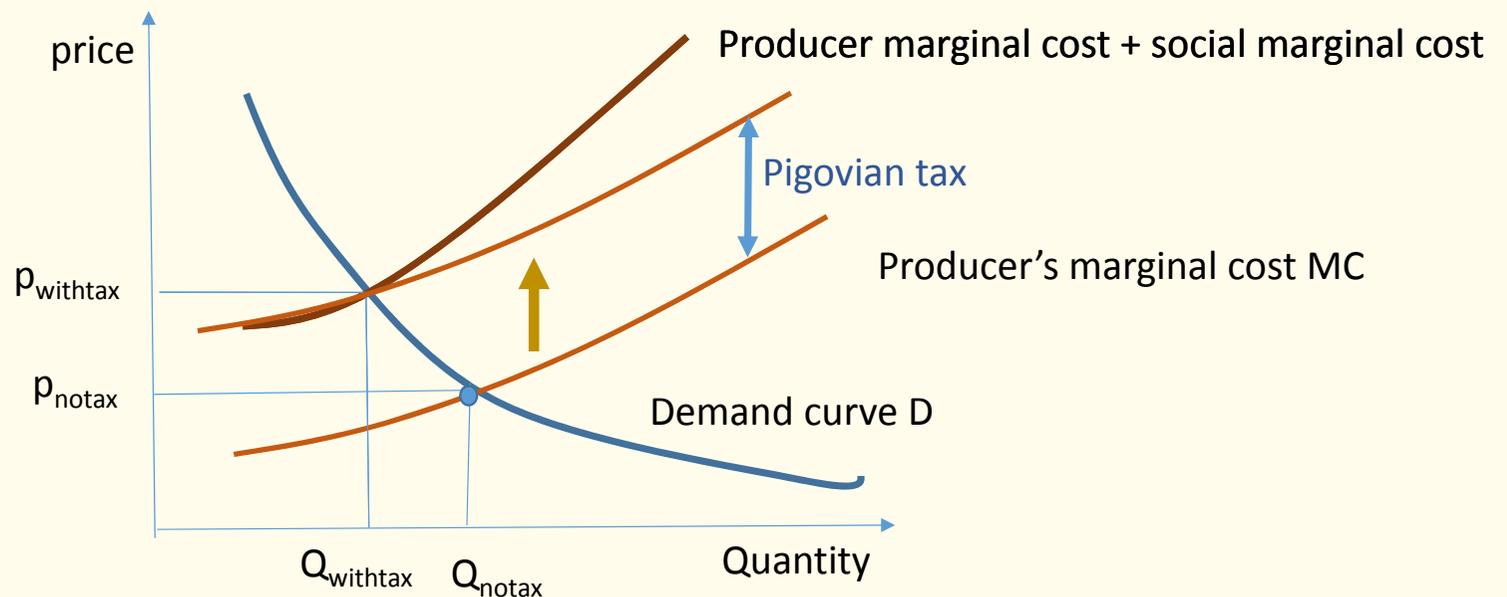
Externalities

- There is an externality each time an economic action between two agents induces a (bad or good) effect on a third party's welfare out of any transaction.

- collective welfare (e.g.) CO₂ or identified individual's welfare

Example: a good produced with marginal cost MC (increasing with quantity) and the demand curve D. However the treatment of the externality entails an additional social marginal cost.

The market solution is M (blue point). A « Pigovian » tax can push the marginal cost upward and produces a solution internalizing the externality



Non-market valuation of public goods and public bads: theory

Formulation of the agent (consumer or household) problem

\mathbf{x} : vector of private goods with market (or administered) prices \mathbf{p}

\mathbf{y}^o : vector of public goods and bads

B : Budget, Utility function $U(\mathbf{x}, \mathbf{y}^o)$ representing preferences in \mathbf{x} and \mathbf{y}

Budget constraint: $\mathbf{p}^t \mathbf{x} = (p_1 x_1 + p_2 x_2 + \dots + p_n x_n) = B$

Derivation of two central tools for studying economic behavior in front of public good

For a given provision of public goods \mathbf{y} , the demand of \mathbf{x} is given by $\text{Max}/_{\mathbf{x}} U(\mathbf{x}, \mathbf{y}) \text{ s.t. } \mathbf{p}^t \mathbf{x} = B$

1 - $V[\mathbf{p}, \mathbf{y}, B] = U(\mathbf{x}^*, \mathbf{y})$ V Indirect utility function for \mathbf{y} when budget is B and prices are \mathbf{p}

2 - $E[\mathbf{p}, \mathbf{y}, \hat{u}] = \text{Min}/_{\mathbf{x}} \mathbf{p}^t \mathbf{x} \text{ s.t. } U(\mathbf{x}, \mathbf{y}) \geq \hat{u}$ for a specified \hat{u} E Expenditure function

$x_i^u(\mathbf{p}, \mathbf{y}, \hat{u}) = \frac{\partial E}{\partial p_i}$ Hicksian utility-constant demand

$x_i(\mathbf{p}, \mathbf{y}, B) = - \frac{\frac{\partial V(\mathbf{p}, \mathbf{y}, B)}{\partial p_i}}{\frac{\partial V(\mathbf{p}, \mathbf{y}, B)}{\partial B}}$ Marshallian demand curve for \mathbf{x}

Willingness To Pay WTP and Willingness To Accept WTA

WTP : **Maximum** amount of your income you are willing to pay for:

- receiving a specified improvement of your welfare
- avoiding a specified decline of you welfare

WTA : **Minimum** amount of your income you are willing to accept for:

- compensating a loss in your welfare
- foregoing a specified improvement in your welfare

	Compensation to pay	Equivalent variation
Increase of welfare	WTP	WTA
Decrease of welfare	WTA	WTP

Formalism

WTP

$V(p, y', B - WTP) = V(p, y, B)$ when more public goods i.e. $y' > y$

i.e. *Maintaining constant the indirect (maximizing) utility with y*

Or $WTP = E[p, y, V(p, y, B)] - E[p, y', V(p, y, B)]$

NB. One can compute similarly a WTP for (private good) price change p' instead of p

WTA

$V(p, y, B + WTA) = V(p, y', B)$ when more public goods i.e. $y' > y$

i.e. *Maintaining constant the indirect (maximizing) utility with y'*

$WTA = E[p, y, V(p, y', B)] - E[p, y', V(p, y', B)]$

For small variations of y , the public good, one should have $WTP \lesssim WTA$

It is not the case empirically : behavioral biases

How to elicit WTP ?

- Example with an indivisible public good which is a nuisance for some and a true good for others
- - State 0 is « no public good (or bad) »
 - no light in my street,
 - no pollution in the Calanques
 - no biomass burning in Gardanne
 - no four lane highway from Arbois to TGV station

One proposes to the agent how he is willing to pay for moving from the present state to state $y = 1$ (light in my street, pollution in Calanques, biomass in Gardanne, highway done)

$$V_i(p, y', B - WTP_i) = V_i(p, y, B_i)$$

If $\sum_{i=1,n} WTP_i >$ then there is case for the public good !

How to elicit « sincere » WTP

No way to do it in general !

Collective welfare optimality

The Pareto criteria : Pareto Optimality or Pareto Efficiency

An « equilibrium » is not optimal whenever it could be possible to increase the welfare one agent without decreasing the welfare of another one. In other words: there is no waste of happiness!

NB : do not confuse Pareto optimality with justice or fairness! It is just an « allocational efficiency »

General claims of microeconomic analysis:

- *Competitive markets equilibrium are pareto optimal under general circumstances*
- *Presence of non-competitive behavior (e.g. monopolies) leads to inefficiency (waste of ressources, waste of happiness etc ...)*

What is collective Welfare in non-market situation ?

General problem

Let S the states of all future possible trajectories of the world (ambitious !)
and $s \in S$ a state

Each agent i is supposed to have a « ranking » R_i (a complete pre-ordering),
i.e. For any pair s, s'

- 1) either s Preferred s' or s' Preferred s or else s' indifferent to s
- 2) If $s P s'$ and $s' P s''$ then $s P s''$ (transitivity)

Can one define a « reasonable » function which derives a collective ranking from the individual ones?

$R_C = F(R_1, R_2, \dots, R_i, \dots, R_n)$ Answer : No! (Arrow' theorem , 1952)

(A mountain of literature on the theorem over more than 50 years)

Effect of time

- Intertemporal preferences
- Form of discount : exponential or hyperbolic?
- Discount factor $1/(1+r)^t$ t = number of periods
where r is the constant periodical interest rate

Suppose I prefer to receive a Renault Twingo today (2014) rather than a Renault Megane one year ahead (2015). Then with exponential discounting, I should prefer a Twingo received in 2024 to a Megane in 2025. Experiments show that it is not the case

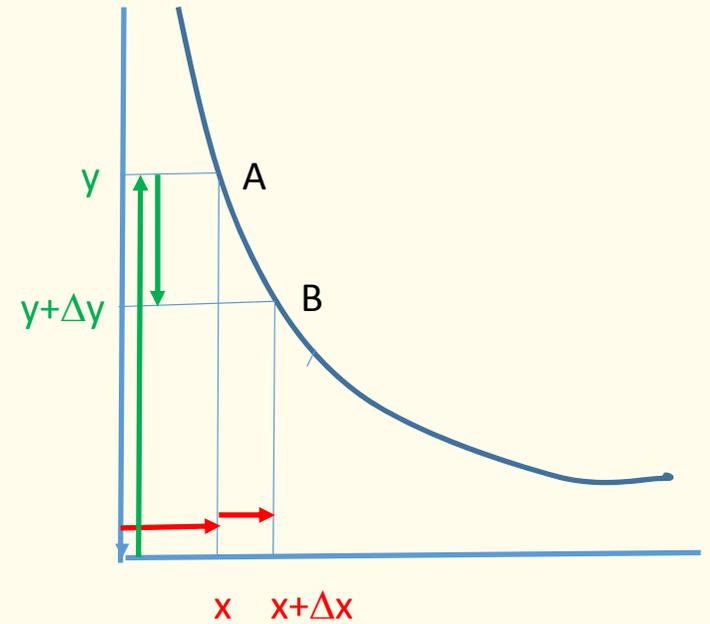
Discount factor $1/(1+rt)^{a/b}$

- Permanent income hypothesis : people tend to smooth their consumption over time.

Elasticity $y = f(x)$

$$e = \frac{\frac{dy}{y}}{\frac{dx}{x}} = \frac{d\ln(y)}{d\ln(x)} \quad e = x \frac{f'(x)}{f(x)}$$

x	y	
100	3000	
103	2730	
3%	-9%	$e = -9/3 = -3$



Technology modelling

Constant Elasticity of Substitution (CES) functions

$$Q = S. [\theta.(a_k.K)^{(e-1)/e} + (1-\theta).(a_L.L)^{(e-1)/e}]^{e/(1-e)}.$$

or , with appropriate units

$$Y = S. [\theta.K^\alpha + (1-\theta).L^\alpha]^{1/\alpha}.$$

Q: amount of output

K: amount of 1st input (e.g. capital)

L: amount of 2nd input (e.g. labor)

S, a_k , a_l : scale coefficients : can be set to 1 with appropriate units

α : substitution coefficient $\alpha \in [-\infty, 1]$

$e = 1/(1-\alpha)$ e = substitution elasticity

$\theta \in [0, 1]$ labor/capital proportions

Représentation of technology : fonctions CES (Constant Elasticity of Substitution)

$$Q = S \cdot \left[\alpha \cdot X_1^{\frac{e-1}{e}} + (1-\alpha) \cdot X_2^{\frac{e-1}{e}} \right]^{\frac{k \cdot e}{e-1}}$$

Q: amount of output

X_1 : amount of 1st input (e.g. capital)

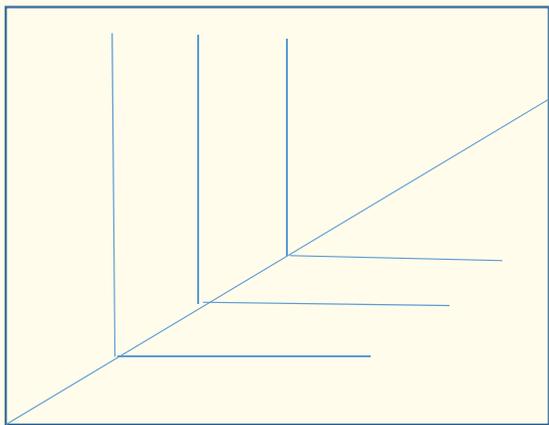
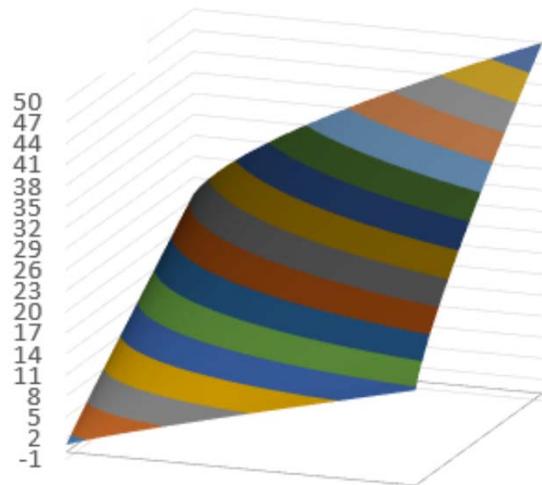
X_2 : amount of 2nd input (e.g. labor)

K : degree of homogeneity. Often $k=1$ linear homogenous function

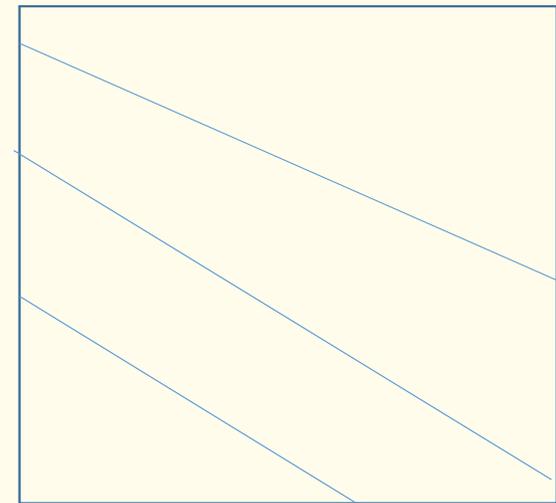
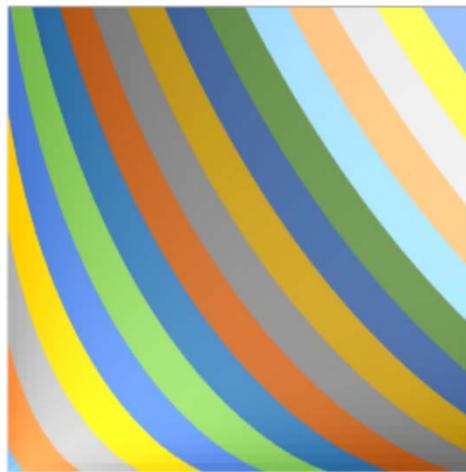
S: can be set to 1 with appropriate unit

e = substitution elasticity $r = (e-1)/e$

$\alpha \in [0,1]$ labor/capital proportions



Technology fixed proportion



Perfect substitutability

Equilibrium and comparative statics

Sensitivity analysis

An equilibrium set of equations can be written as :

$$\mathbf{F}(\mathbf{x}, \mathbf{s}) = \mathbf{0} \quad (\text{more generally } \mathbf{F}(\mathbf{x}, \mathbf{s}) \geq \mathbf{0})$$

\mathbf{x} is the vector of **endogenous** variables

\mathbf{S} is the vector of **exogenous** parameters

Simple case with one endogenous variable : $F(x, a) = s \cdot x^2 - c = 0$

Case with two endogenous variables $F(x, y, s) = 0$

$$\frac{\partial F(x, y, s)}{\partial x} dx + \frac{\partial F(x, y, s)}{\partial y} dy + \frac{\partial F(x, y, s)}{\partial s} ds = 0$$

Market equilibrium

For all firms :

Profit from one more ton = market price

Marginal profit = 0 at Equilibrium

No more incentive to change

Optimality

the market's « invisible hand » directs the rights towards the firms that will use them more efficiently.

The total volume of CO² remains constant since decided on externally.

Large scale models

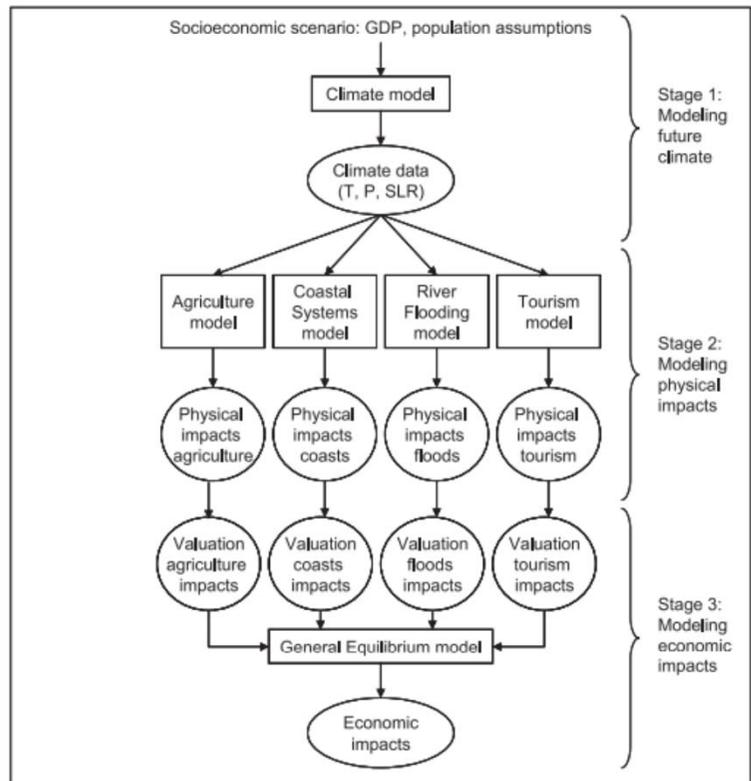
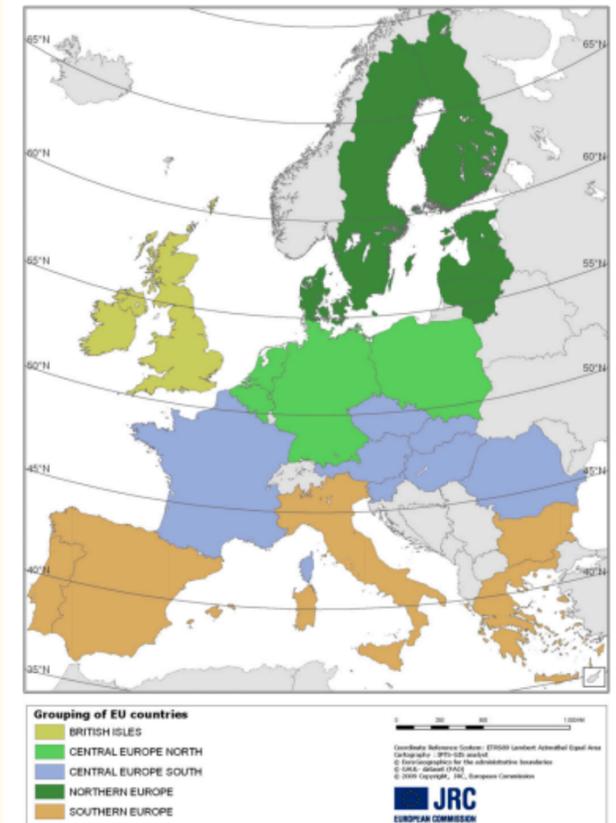


Fig. S2. The PESETA Integrated approach.



Ciscar J.C. *et al.* Physical and economic consequences of climate change in Europe, *PNAS*, vol. 108 no. 7, pp. 2678–2683

The value of time : time premium

A rich parent wants to please you and promises:
I offer you an Audi TTS Coupé 2.0 TFSI quattro BV 6 now or a Ferrari F70 in three years. What would you prefer?



Received on March 2013



Received on March 2016

Ferrari price : 1,000,000 \$, Audi price 70,000 \$

What do you do if there is no financial instrument (no banks, no markets)?

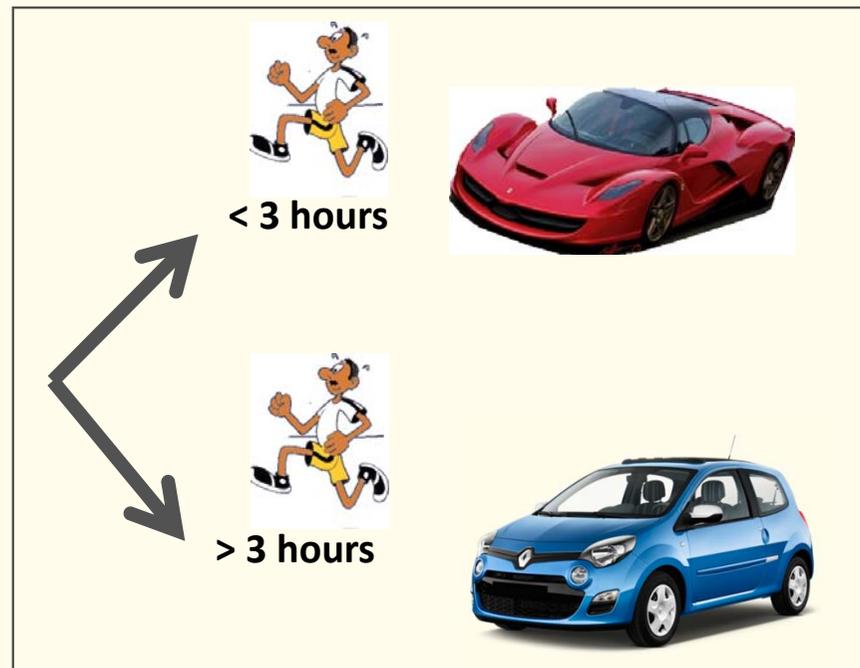
What could you do if there were financial instruments (banks and/or markets)?

The value of risk : risk premium

The same rich parent proposes : receive an **Audi SR3** sportback **now** or run a **marathon** and receive a **2011 Ferrari 458 Italia** if your time < 3 hours or a Renault Twingo II if your time > 3 hours



OR



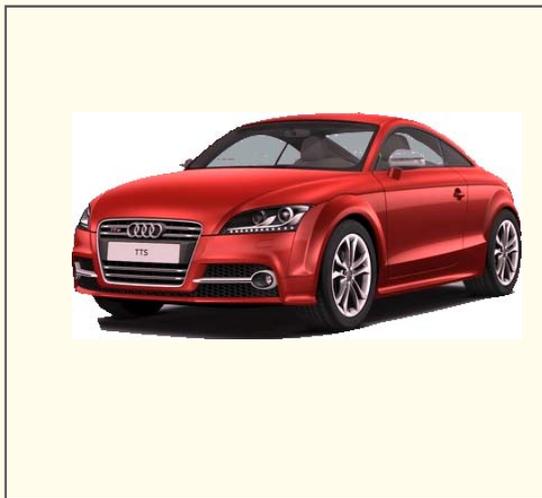
Price of a Ferrari F70 : 1,000,000 \$
Price of a Renault Twingo II 18,000 \$
Price of the Audi : 70,000 \$

What do you do if there is no financial instrument (no banks, no markets)?
What could you do if there were financial instruments (banks and/or markets)?

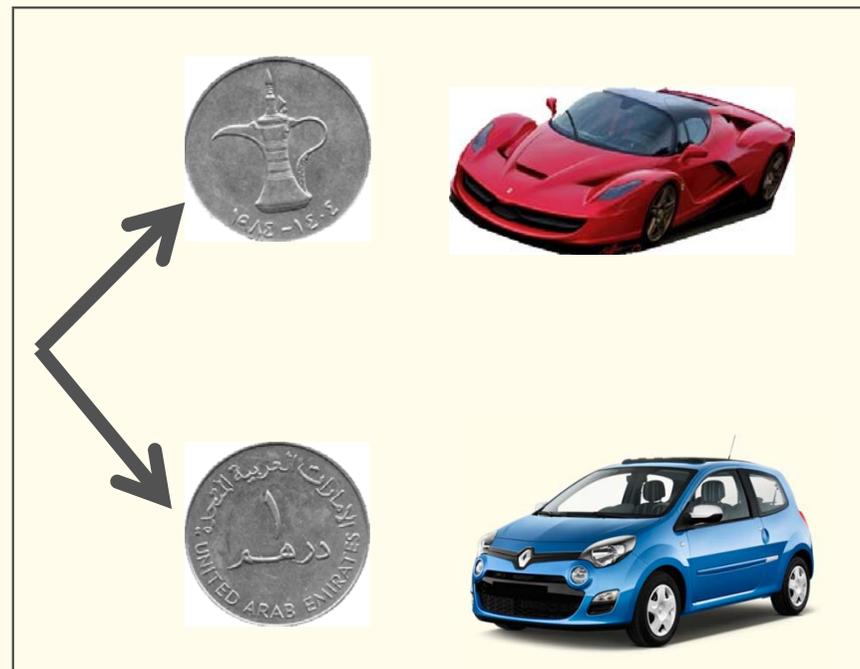
The value of risk : risk premium

The same rich parent proposes

- receive an **Audi SR3** sportback **now** or toss a coin and receive a **2011 Ferrari 458 Italia** if « Heads » or a Renault Twingo II if « Tails »



OR



Price of a Ferrari F70 : 1,000,000 \$
Price of a Renault Twingo II 18,000 \$
Price of the Audi : 70,000 \$

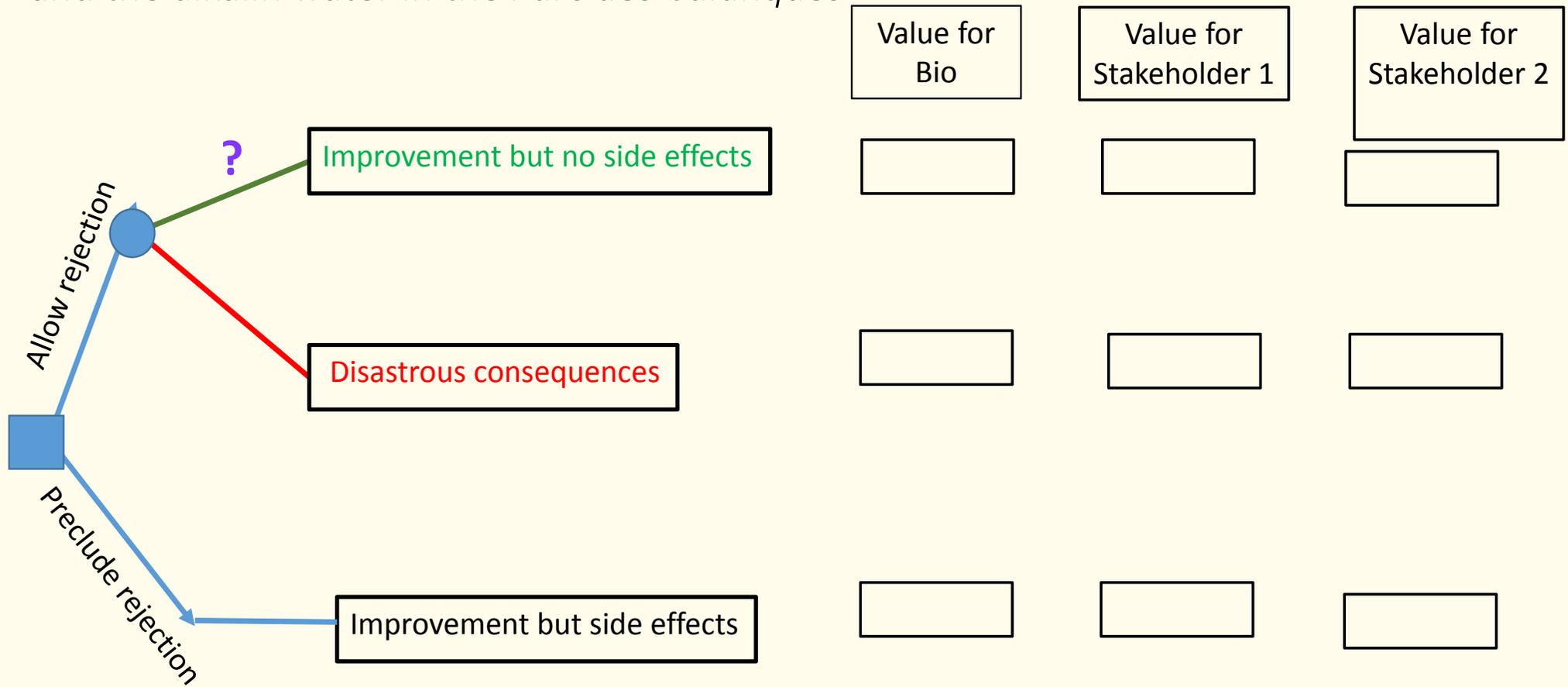
What do you do if there is no financial instrument (no banks, no markets)?

What could you do if there were financial instruments (banks and/or markets)?

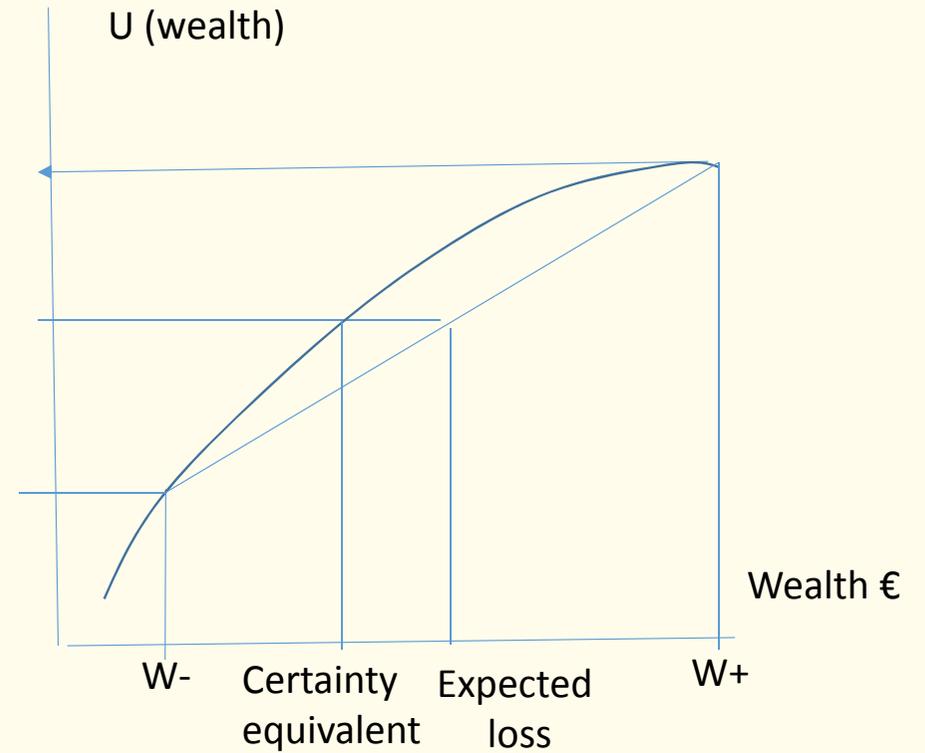
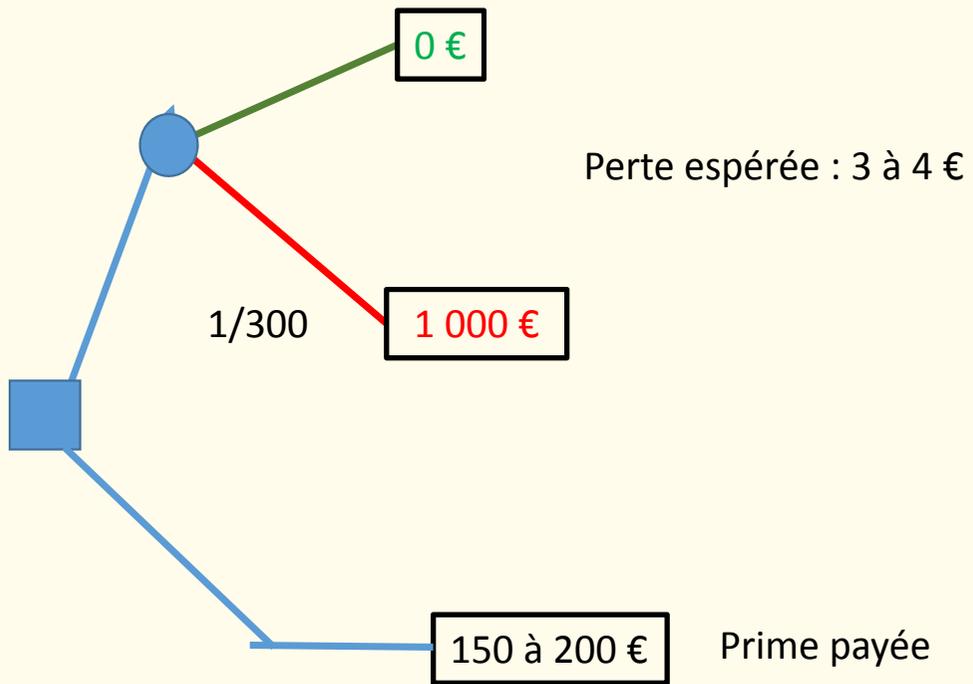
Spatial issues

- Usual difficulties with spatial studies like in ecology and geography
- Explaining clusters
- Explaining concentration of activities in cities and urban areas

Risk and risk aversion the Alteo case and the alkalin water in the *Parc des Calanques*



Risk Aversion : no, no, Bernouilli not dead!



Usual properties of VNM utility functions

$$U(w) \text{ with } U'(w) > 0 \text{ and } U''(w) < 0$$

utility increases with wealth and marginal utility decreases with wealth

$$V(w) = a + b U(w) \text{ linear transformation possible like a temperature scale (} ^\circ\text{C} \rightarrow ^\circ\text{F)}$$

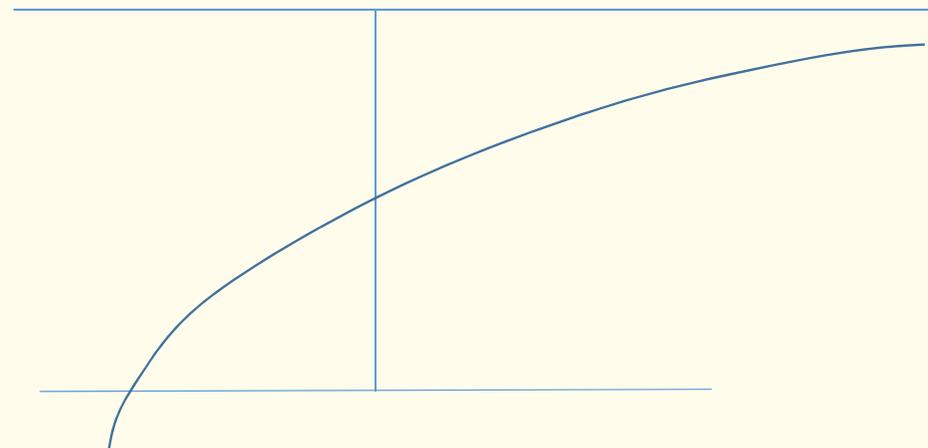
Risk aversion indices

$$\text{Absolute } -U''(w)/U'(w)$$

$$\text{Relative } -w \cdot U''(w)/U'(w)$$

$$\text{If absolute is constant } r : \frac{d^2 U(w)}{dw^2} = r \cdot \frac{dU(w)}{dw}$$

$$\text{implies } U(w) = a - be^{-rw} \quad b > 0$$



Game Theory

Game in normal form

N players

Each player has a strategy set S_i and select strategy $s_i \in S_i$

Utility of i depends on the others' strategy: $U_i(s_{-i}, s_i)$

Many solution concepts, the most often used being the Nash solution

S^ is « Nash » equilibrium iff $U_i(s_{-i}^*, s_i^*) \geq U_i(s_{-i}^*, s_i)$ for all s_i and all i*

- under very general conditions Nash solutions always exist ,

provided « mixed (random) strategies are considered -

Game in extensive form

Description of the sequence of actions (ex : chess)

Well adapted to multiperiod models

Games in extensive form can be turned back to normal form

Some classical games invoked in the environment literature

The celebrated « prisoner's dilemma »

Rule : « Respect Nature » around you

		Alice	
		Comply	Shirk
Bob	Comply	10, 10	5, 11
	Shirk	11, 5	6, 6

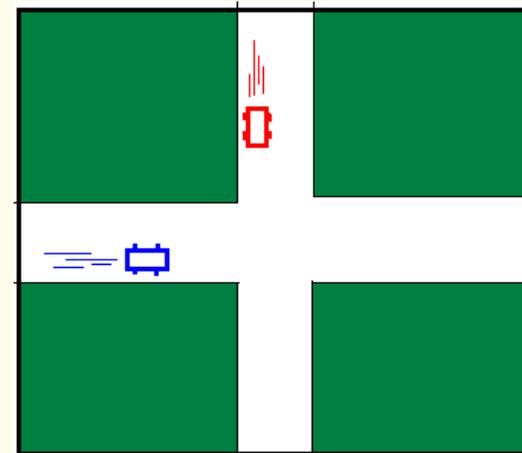
Coordination Game

		Alice	
		Stop	Pass
Bob	Stop	1, 1	1, 0
	Pass	0, 1	-∞, -∞

The role of conventions as coordination instruments for accessing to common resources in lieu of markets

See Ostrom (1994)

Breton M. & Keoula M.Y. A great fish war model with asymmetric players, *Ecological Economics*, 97 (2014) 209–223



Differential games (

Games of pursuit in continuous time

Big scale models

- **Climate Change Mitigation, Technological Innovation and Adaptation**

V. Bosetti, C. Carraro, E. Massetti, M. Tavoni

Model WITCH coupled with MAGICC6

- Recursive dynamic computable general equilibrium model IMACLIM-R

Leading Journals in Economics



Leading Journals in Environment Economics



Others !



Voilà pour le moment

