Economics of Risk and Uncertainty

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Chapters 4, 5 and 6
4. Consumption and Risk

Outline

- A simple two-period model
- The notion of prudence
- How large are precautionary savings?
- Savings and portfolio choices
- Recursive preferences
Consumption vs. Unemployment Rate

Source: Bureau of Economic Analysis, 2004
Consequences of September 11?
Objective

• How does risk affect consumption? What is the part of savings that can be attributed to risk?

• Use the simplest microeconomic framework to examine the effect of risk on consumption and savings

• Will explore basic variant versions of this model
Two-Period Model

\[ U(c_1,c_2) = u(c_1) + \beta v(c_2) \] where \( \beta \) is a discount factor

Assume \( u, v \) strictly increasing and concave and thrice differentiable

\[ y_1, y_2 : \text{income in period 1 and 2} \]

Budget constraint:
\[ \rho y_1 + y_2 = \rho c_1 + c_2 \]
where \( \rho \) is the interest factor (one plus the interest rate)
The Model

Let \( w = \rho y_1 + y_2 \) the future value of total income

The problem is:
1- \( \max_c u(c) + \beta v(w - \rho c) \)

Under a (pure) risk on future income \((y_2 + X)\) the problem becomes :
2- \( \max_c u(c) + \beta \mathbb{E} v(w + X - \rho c) \) where \( \mathbb{E}X = 0 \)

Objective: Compare the two maximization problems
FOC, SOC

Certainty:

FOC: \( u'(c^*) - \beta \rho v'(w - \rho c^*) = 0 \)
SOC: \( u''(c) + \beta \rho^2 v''(w - \rho c) < 0 \)

Uncertainty:

FOC: \( u'(c^{**}) - \beta \rho E v'(w + X - \rho c^{**}) = 0 \)
SOC: \( u''(c) + \beta \rho^2 E v''(w + X - \rho c) < 0 \)

Precautionary savings = \( c^* - c^{**} \) = reduction in current consumption due to a future income risk
(Assume interiority)
Precautionary Savings

Are precautionary savings positive?

Intuitively: Yes, under risk-aversion. Wrong!

Formally: True if for all $\beta$, $\rho$, $w$ and $X$

$$u'(c^*)-\beta\rho Ev'(w+X-\rho c^*) \leq 0 = u'(c^*)-\beta\rho v'(w-\rho c^*)$$

Equivalent to: for all $z$ and $X$, $Ev'(z+X) \geq v'(z+EX)$
Precautionary Savings

For all $X$, $E v'(z+X) \geq v'(z+EX)$

By Jensen $\iff v'$ convex, or $v''''\geq 0$

Not risk-aversion, but aversion to downside risk

This condition, $v'''' \geq 0$, is commonly known as the condition of « prudence » (Kimball, 1990, Etca)

Early literature: Leland (1968, QJE)
Intuition

What matters is not how risk « hurts » utility (risk-aversion) … but how risk « hurts » marginal utility of income (« prudence »)

Prudence: one unit of wealth has more value under uncertainty

⇔ Aversion to a downside risk : uncertainty has more negative impact when less wealthy
Remark: Multiperiod**

Let the indirect utility function:
\[ U(w) = \max_c u(c) + \beta u(w - \rho c). \]

If \( u \) risk-averse (resp. prudent) then \( U \) is risk-averse (resp. prudent) as well.

This suggests that the results can usually be extended to multiperiod.
See Caroll and Kimball (1996, Etca)
Remark: Increase in Risk**

Can be extended to any increase in risk in the sense of Rothschild and Stiglitz (1970).

Depends on whether $f(x) = u'(c) - \beta p v'(w + x - \rho c)$ is concave in $x$ for all the values of the parameters

$\Rightarrow$ prudence
How Large are Precautionary Savings?

• Controversies

• Dynan (1993, JPE) find little evidence for precautionary savings. Relative prudence - i.e., formally $-xv''''(x)/v''(x)$ - is estimated to be equal to $0.3$ $\Rightarrow$ very small and inconsistent with CRRA utility function

• In contrast, Guiso et al. (JME) and Caroll and Samwick (1998, REStat) find significant precautionary savings motive
Exercise

Exercise 1 Let $\max_c u(c) + \beta E_R v(R(y_1-c))$ where $R$ is random (capital) risk.

i) Examine the effect of more capital risk on consumption

ii) Compare the NS condition to that of prudence. Discuss.
Remark: Exhaustible Resource

Controversies about the size of resources. Meadows (1972)'s « Limits to Growth »: out of oil in 1992!

World's Known Oil Reserves
Source: Simon et al. (1996)
Exhaustible Resource Exploitation

• Problem of the optimal exploitation under resource uncertainty

• « How to eat a cake of an unknown size? »

• Similar problem to that analyzed in this chapter (Formally, assume $w+X$ is the size of the resource, and $\rho=1$)
Consumption and Portfolio

Can save in two assets: a risky asset, and a riskless asset

The amount $a$ is invested in the risky asset with a random return of $1+R$; the rest, that is $y_1-c_1-a$, is invested in the riskfree asset with a return $1+r$

$$u(c) + \beta E_R u(y_2 + (y_1-c-a)(1+r)+a(1+R))$$

Basically equivalent to

$$u(c) + \beta E_Z u(w-c+aZ)$$
Consumption and Portfolio (cont’d)

Max_{c,a} u(c) + \beta Eu(w-c+aZ)

FOCs:
EZu’(w-c^*+a^*Z)=0
u’(c^*)-\beta Eu’(w-c^*+a^*Z)=0

SOCs satisfied
Assume interiority

Drèze and Modigliani (1972, JET)
Consumption and Portfolio (cont’d)

**Exercise 2**: Assume u CRRA

Show:
\[ a^* = k^*(w-c) \text{ proportional to current wealth } (w-c) \]
\[ c^* = m^*w \text{ proportional to wealth } w \]

with:
\[ k^* \text{ defined by } EZ(1+k^*Z)^{-\gamma} = 0 \]
\[ m^* \text{ defined by } (m^*)^{-\gamma} - \beta E((1-m^*)(1+k^*Z)^{-\gamma}) = 0 \]
Figure 1: Empirical Income Expansion Paths for Saving Rates (Upper Diagram) and Equity Shares (Lower Diagram)

Source: Binswanger (2005) based on data on 17,670 consumers from PSID, and SCF
Horizon Length and Consumption

• Within a consumption model, we can consider different horizon lengths. So we can examine the effect of age.

• Young have a longer horizon, i.e. more periods to live. => Can compare the risk preferences of « young » people to those of « old » people

• Should the young be less risk averse?
A Simple Model**

An individual has only one period to live (the old). His income in the current period is $y$, and utility $u(y)$.

The young has two periods to live. Income $y$ in each period. He can smooth consumption.

$$v(y) = \max_c u(c) + \beta u(y + \rho(y-c))$$

**Exercise 3:**

i) Show that if $\beta \rho = 1$, the young and the old have the same risk-aversion towards risk on income $y$.

ii) Show that under CRRA utility, they have the same risk-aversion as well.
A Conceptual Caveat

• The intertemporal expected utility models presented in this chapter combine risk preferences and time preferences

• Conceptual (often overlooked) caveat within these common models; also may explain some puzzles

• To see this, simply consider expected utility $u(c_1) + \beta \text{Eu}(C_2)$ where $c_1$ is certain but $C_2$ is random

• Then function $u$ captures two aspects of preferences
A Conceptual Caveat (cont’d)

- $u(c_1) + \beta u(c_2)$: the curvature of $u$ captures the desire to smooth consumption across time (elasticity of substitution) under certainty

- $Eu(C)$: the curvature of $u$ captures risk-aversion, i.e. captures the desire to smooth consumption across states of nature in a static model

$=>$ Not clear why these two different concepts are linked through the same utility function $u(.)$
Recursive Preferences

May want to disentangle the two concepts: Kreps and Porteus (1978, Etca), Selden (1978, Etca), Epstein and Zin (1989, Etca)

=> « Recursive preferences »

Built in two different steps:

1) Let \( f = v^{-1}(\text{Ev}(C_2)) \) the certainty equivalent of uncertain period 2 consumption \( C_2 \): atemporal context

2) Let \( u(c_1) + \beta u(f) \) the intertemporal preferences w/r to the flow of deterministic consumption: certainty context
Recursive Preferences

In the certainty equivalent, i.e.
\[ f = v^{-1}(\text{Ev}(C_2)) \] : the function \( v \) controls risk-aversion

Within the intertemporal preferences \( u(c_1) + \beta u(f) \): the function \( u \) controls the elasticity to substitution

The model thus becomes
\[ u(c_1) + \beta \text{Eu}(v^{-1}(\text{Ev}(C_2))) \]

If \( u(.) = v(.) \) => back to the intertemporal expected utility model
Empirical Data

Epstein-Zin (JPE, 1991) examine consumption-portfolio choices under recursive preferences with
\[ v(z) = \frac{(z)^{1-\gamma}}{1-\gamma} \] and \[ u(z) = \frac{(z)^{1-\alpha}}{1-\alpha} \]

Reject the assumption that \( \gamma = \alpha \) ! (i.e., reject EU)

Elasticity of substitution \( (1/\alpha) \): \( \alpha \) in range \( [2.4, 4.8] \)
Relative risk-aversion: \( \gamma \) in range \( [0.4, 1.4] \)
Some Other Estimates

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5. Physical Risks

Outline:
- State-dependent utility
- A prevention model
- WTP vs. WTA
- Value of statistical life
- Human capital
- Life Insurance
State-Dependent Utility

• Until now, we have assumed that the utility was state-independent: No matter the outcome (or state of the world), same vNM utility \( u(.) \)

• Sometimes unrealistic to assume state-independence

• The utility function may depend on the « state of the world »
An Example

• Assume two states of the world: either I will be alive (state 1), or dead (state 2)

• The utility should probably be allowed to be different depending on the state of world

• In other words, being dead or alive do not only have financial consequences, but also may directly affect the utility of wealth
More Generally

• State-dependence may be involved for representing preferences w/r to most «physical» risks, e.g. risks to health

• May also include preferences w/r to the environment (pollution, environmental catastrophes, «intangible» damages..)

• Broader class of events: Success vs. failure at love, life with or without kids, loss of freedom, sports’ results..
State-Dependent Utility

Foundations:


For what follows, see e.g. Weinstein et al. (1980, JPE) and the book of Jones-Lee (1982), *The Value of Life and Safety*, North-Holland.
State-Dependent Utility

• Axiomatics:

vNM EU can be generalized to state-dependent EU using similar axioms leading to a representation theorem

• No difficulty with objective probabilities

• However identification problem when subjective probabilities are involved: The subjective probabilities cannot be identified from observable choices (see, e.g., Karni, 1985)**
A Prevention Model

• We will first study a particular case of state-dependent model, that is a model of prevention

• There is a possibility of a bad outcome (e.g., death)

• A way to mitigate this risk is to reduce the probability of occurrence of the bad outcome (prevention)
A Prevention Model (cont’d)

There are two states of the world, the good state and the bad state

• $u(w)$ is utility of wealth $w$ in the good state
• $v(w)$ is utility of wealth $w$ in the bad state (e.g., if sick or dead)

Assume $u(w) > v(w)$ and $u'(w) > 0$, $v'(w) \geq 0$ for all $w$. 
A Prevention Model (cont’d)

Let $0 \leq p(e) \leq 1$ the probability that the bad state occurs in which $e$ is the prevention effort (in monetary units)

Assume $p'(e) < 0$ and $p''(e) \geq 0$.

Under (state-dependent) EU, we have:

$\text{EU} = (1 - p(e))u(w-e) + p(e)v(w-e)$

See, e.g., Weinstein et al. (1980, QJE), Viscusi (1993, JEL)
Optimal Prevention

Maximize \( EU = (1-p(e))u(w-e) + p(e)v(w-e) \) over \( e \)

FOC:

\[-p'(e)(u(w-e)-v(w-e)) = (1-p(e))u'(w-e) + p(e)v'(w-e)\]

Marginal benefit = Marginal cost

SOC satisfied when \( u' > v' \), and \( u \) and \( v \) weakly concave
What is the Shape of $v(.)$?

Some particular cases:

- $v(w) = u(w - L)$
  monetary loss, state-independent
  see, e.g., Jullien et al. (2000, GPRIT)

- $v(w) = u(w) - k$
  additive separability, strong assumption = same marginal utility of wealth

- $v(w) = ku(w)$ with $0 \leq k < 1$
  e.g., if $k = 0$, utility if dead with no bequest motive
  Viscusi and Evans (1990, AER) estimate $k \# 0.7$
Prevention and Risk-Aversion

Monetary loss $L$

Let $EU = (1 - p(e))u(w-e) + p(e)u(w-L-e)$

More risk-aversion does not always increase the prevention effort

Dionne and Eeckhoudt (1985, EL)

Intuition?
Prevention and Prudence

• Need condition on $u$"

• Eeckhoudt and Gollier (2005, ET) show that a risk averse - and prudent - agent should invest less, and not more, in prevention than a risk-neutral agent!

• Intuition: aversion to a downside risk

• Consider two lotteries:

\[
\begin{align*}
A & \quad 1/4 \quad 3,000 \\
 & \quad 3/4 \quad 1,000 \\
B & \quad 3/4 \quad 2,000 \\
 & \quad 1/4 \quad 0 \\
\end{align*}
\]

Same mean and variance
Mortality Risk with No Bequest

Assume $v(w) = 0$
$EU = (1 - p(e))u(w - e)$
Normalize $u(0) = 0$

i) Examine optimal prevention effort under risk-neutrality in wealth ($u$ linear).

ii) Compare to the effort if risk-averse in wealth ($u$ concave).

Financial risk aversion always increases prevention efforts
Valuation of Mortality Risk Reduction

- Important policy issue
- Suppose one wants to implement a public project that is expected to save lives in the society (e.g., reduce pollution)
- What is the social value of this project?
- How to compare this benefit to the monetary cost of the project?
Valuation of Mortality Risk Reduction (cont’d)

• Benefits from mortality risk reductions often dominate benefit-cost analysis

• E.g., represent a large part of benefits from air pollution reduction programs - see Hammitt (2007) for the US and Pearce et al. (2005) for Europe

• Although the « human capital » approach used to be popular, it is now commonly accepted that benefits from mortality risk reduction should be based on an individual willingness to pay approach
Willingness to Pay

• In our context: maximal amount that an individual is willing to pay for a mortality risk reduction

• Theoretically: The amount that keeps constant the level of expected utility
Russian Roulette

• Pure thought experiment: You have to shoot yourself
• The gun has 10,000 chambers, and 5 of them are loaded with bullets
• You are given the opportunity to remove one bullet before shooting. What is your WTP for this removal?

$$(1-p+e)u(w-WTP) + (p-e)v(w-WTP) = (1-p)u(w) + pv(w)$$

with $p=5/10,000$ et $e=1/10,000$

$w$= initial wealth

$u(.)$ utility if alive; $v(.)$ utility if dead
WTP/WTA

• WTA — Willingness to Accept
  (Russian Roulette: Which amount would you accept to add one more bullet?)

• WTP is limited by available wealth; WTA not limited
  – Usually $\text{WTP} \leq \text{WTA}$
  – For small amounts, $\text{WTP} \approx \text{WTA}$
WTP/WTA

Indifference curve

Wealth

0  Survival probability (= 1 - risk)  1

49
WTP/WTA

Indifference curve

Wealth

Survival probability ( = 1 - risk)

WTP

Δp
WTP/WTA

![Graph showing Indifference curve with axes labeled Wealth and Survival probability ( = 1 - risk)].

- **WTP**: Willingness to Pay
- **WTA**: Willingness to Accept
- **Δp**: Change in probability
Introduction to the concept:

- $N$ (= 10,000) citizens in a community
- One avoidable statistical death
- $WTP$ equals 500 euros to eliminate this mortality risk of $1/10,000$
- $VSL$ is thus 5 million euros total within this community

\[
VSL = \frac{WTP}{\Delta p} = \frac{N \cdot WTP}{N \cdot \Delta p} = \frac{Total\_WTP}{E\left(Life\_saved\right)}
\]
VSL : Theory

Let $V = (1-p)u(w) + pv(w)$

VSL: marginal rate of substitution between money and risk

$$V_{SL} = \frac{dw}{dp} = \frac{u(w) - v(w)}{(1-p)u'(w) + pv'(w)}$$
VSL

• Does not measure what an individual is willing to pay to avoid his/her own death with certainty
• It measures WTP (resp. WTA) for an infinitesimal risk reduction (resp. increase)

VSL :

i) Increases with baseline risk $p$ ("dead-anyway effect", Pratt and Zeckhauzer, 1997, JPE)
ii) Increases with wealth $w$ (the sum of two effects) under $u$ and $v$ weakly concave
VSL: Calibration

- Let $y=16,500$ euros (french yearly income, INSEE 2004)
- Let $p=3/1,000$ (average yearly death probability for people aged 25-40)
- Let a life expectancy of 45, neglecting changes in income and interest rate, $w=16,500\times45=742,500$
- Assume $v=0$, no bequest motive
- Assume constant relative risk aversion equals 0.5

$$VSL = \frac{742,500}{0.997\times0.5} \approx 1.5 \text{ millions euros}$$
Remark: VSL and Consumption

Let $V = \max_c u(c) + (1-p)\beta u(w-\rho c)$

in which $(1-p)$ is survival probability and $c$ is consumption

VSL: (still) marginal rate of substitution between money and risk

$$V S L = \frac{dw}{-dp} = \frac{u(w-\rho c^*)}{(1-p)u'(w-\rho c^*)}$$

In which $c^*$ is optimal consumption
Estimations of VSL

• $3 million to $7 million (US and OECD)
  – $6.8 million (used by EPA)
  – $7 million (Viscusi & Aldy, 2003, JRU)

• Income-elasticity of VSL positive but usually < 1
<table>
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<th>Year</th>
<th>Implicit VSL millions US $2000</th>
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« Official » VSL for Road Safety

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Source: Boiteux (2001)
# US Public Prevention Programs

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<td>Trihalomethane drinking water standards (EPA)</td>
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<td>Crane suspended personnel platform (OSHA)</td>
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<td>Hazardous waste land disposal ban (EPA)</td>
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Source: Viscusi (1998), Sunstein (2001)
Why do environmental policies loom so inefficient?

Source: Tengs and Graham (1996) and Lomborg (2001)
Human Capital

• Traditionally, two conceptual approaches
  – Human Capital
  – VSL

• Human Capital: Opportunity cost of early death, or say earning ability
  – In practice: proportional to net income over lifetime

• What is the link between the two approaches?
## Human Capital Table

($1,000, in the US, updated from Hartunian et al., 1981)

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-14</td>
<td>448</td>
<td>306</td>
</tr>
<tr>
<td>15-24</td>
<td>776</td>
<td>525</td>
</tr>
<tr>
<td>25-34</td>
<td>868</td>
<td>538</td>
</tr>
<tr>
<td>35-44</td>
<td>730</td>
<td>476</td>
</tr>
<tr>
<td>45-54</td>
<td>492</td>
<td>370</td>
</tr>
<tr>
<td>55-64</td>
<td>199</td>
<td>212</td>
</tr>
<tr>
<td>65-74</td>
<td>24</td>
<td>85</td>
</tr>
<tr>
<td>75 +</td>
<td>3</td>
<td>31</td>
</tr>
</tbody>
</table>
WTP vs. Human Capital

• In general, WTP per unit of change in risk is higher than human capital

• Let the WTP to eliminate a mortality risk
  \[ u(w-WTP) = (1-p) u(w) + p v(w) \]

• Show that if \( v(.)=0 \) and \( u(0)=0 \), then \( WTP/p > w \) under \( u(.) \) concave

• For small \( p \) (risk change), VSL > w
Implication

- Consider a population of N people, in which Np will die

- Using the WTP approach, we collect ex ante N*WTP to eliminate this mortality risk
- Using the human capital approach, we collect Npw (number of people who die times their human capital w)

- The human capital approach undermines the value of preventing death. It does not take into account preferences (typically financial risk-aversion)
Life Insurance

• Why do people buy life insurance?

• Consider a simple model in which an individual chooses to receive $I$ if he dies:

$$F(I) = (1-p)u(w-(1+\lambda)pI) + pv(w-(1+\lambda)pI+I)$$

where $(1+\lambda)pI$ is the insurance premium

FOC: $F'(I) = -(1-p)(1+\lambda)pu'(I) + p(1-(1+\lambda)p)v'(I) = 0$

SOC satisfied
Life Insurance

FOC: \( F'(l) = -(1-p)(1+\lambda)u'(\cdot) + (1-(1+\lambda)p)v'(\cdot) = 0 \)

• Assume that insurance is actuarilly fair, \( \lambda = 0 \).
  FOC: \( -u'(w-pI) + v'(w-pI+I) = 0 \)

• But by assumption \( u'(z) > v'(z) \) for all \( z \), and \( v' \) decreasing \( \Rightarrow \) \( I \) negative is optimal
• “Selling” life insurance is optimal! What’s going on here? Is there something missing?
**Exercise:** Find the optimal insurance policy for $u(x) = \log x$ and $v(x) = k \log(x)$; assume that the financial loss is $Hw$ if death; and assume $\lambda = 0$.

$$I^* = \frac{(H+k-1)w}{1+(k-1)p}$$

If $k=1 \Rightarrow I^* = Hw$: full insurance under risk aversion

$I^*$ increases in $k$, $I^* > 0$ when $k > 1-H$

$I^*$ (if positive) increases in $w$ (despite DARA!)
Prevention Models: Final Remarks

• Need a general model of prevention with:
  - Individual actions that affect the probability of a loss, but also the loss itself
  - Possibility to purchase life and health insurance contracts
  - Early reference is Ehrlich and Becker (1972, JPE), but few general prevention models exist

• Need a better understanding of the shape of utility in the case of sickness or death
6. Option Values

Outline

- The Concept of Information
- Information Value
- The « Irreversibility Effect »
- The Precautionary Principle
Information

• Information is another, important, way to cope with risk – Allows the decision-maker to better adapt decisions to the knowledge of risk

• Information is obtained from: information search, the passage of time, scientific progress, education, media, social interactions…
Assumption

Information will be
- exogenous (e.g., no learning by doing..)
- non-strategic
- free
Example: Investment Decision


Investment rule: invest if EX>c ; Expected profit: $\max(EX-c, 0)$

Suppose now perfect information.
Investment rule: invest if X=x>c ; Expected profit: $E\max(X-c,0)$

Information Value: $IV=E\max(X-c,0) - \max(EX-c, 0) \geq 0$

Take: c=100, X=(50%, 200, 50%, 50). IV= 50-25=25
Take: c=100, X=(50%, 140, 50%, 50). IV= 20-0=20
The Concept of Information

• Information, as defined in economics, means that the decision-maker will receive a message about the realisation of X

• The value of information is computed ex ante., i.e. before any message is received. Hence, the decision-maker does not know which message (about the realization of X) will come.

=> The information value is always positive
Positive Information Value

- Let \( u(d,X) \) any decision problem in which \( d \) is the decision and \( X \) a random variable

- Value of information
  \[
  IV = E \max_d u(d,X) - \max_d Eu(d,X)
  \]

Show that \( IV \) is always positive

Intuition?
Remark: Information Value

- Value of perfect information: full information versus no information

- Information can be less than perfect

- In economics and statistics: « Better information » is characterized using the Blackwell (1951)’s notion of the comparison of information structures

- Imperfect information not done here.
Determinants of Information Value

• (Small) literature on the determinants of the information value

• The effects of wealth, risk, risk-aversion etc. are all ambiguous. Depends on the decision problem.

• See Hirshleifer and Riley (1992, chapter 5) for a simple and excellent overview
Information and Time

- Information is important in a sequential decision-making framework
- What should I do today given that I will have better information in the future?
- Should I wait? Should I delay decisions? Should I be more cautious?
“Wait and See” Arguments

• DuPont spoken-person (CFC regulation, 1981): “We are going in a very long way into the regulatory process before scientists know what’s really going on”

• White House Conference (1990) (CO2 regulation): “An aggressive strategy to address possible global change based on today’s knowledge may be wholly inappropriate within a decade”
The Precautionary Principle

• Precautionary Principle at Rio Conference (1992) “Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation”

Over-Cautious?

• Greenpeace: “Do not admit a substance unless you have proof that it will do no harm the environment”

• Scientific uncertainty=>refuse any risk-taking

• Inconsistent with economic efficiency and the development of innovations
Emissions of CO₂ (GtC/year)

See: Intergovernmental Panel on Climate Change (IPCC), www.ipcc.ch
Sequential Decision Making

Climate change:

« The challenge is not to find the best policy today for the next 100 years, but to select a prudent and flexible strategy and to adjust it over time » (IPCC, 1995)

« Measures should be periodically reviewed in the light of scientific progress, and amended as necessary" » (European Commission, 2000)

=> Bayesian framework
Prevention vs. Precaution

- Reduce the probability of occurrence of damages
- Select flexible and temporary actions to wait for better scientific information
- Static framework
- Framework: Sequential
- No information arrival
- Information arrival

See Gollier and Treich (2003, JRU)
Development Project

• A project of development of a forest is considered.

• Total cost c. Current benefit b.

• Future discounted cash-flow X is unknown (e.g., loss of biodiversity)

• Investment Rule: Invest if b-c+EX>0

• Is it the best investment rule?
Alternative Rule

• One may want to wait until we know X.

• An alternative rule may be: « Do nothing today and invest in the future if X=x>c »

• Expected profit of the alternative rule: 
  \[ 0^+ \text{E}_{\max}(X-c,0) \]
Alternative Rule

• Reminder: Alternative rule brings $0 + \text{Emax}(X-c,0)$
• To be compared to $\text{Max}(b-c+EX,0)$

• Alternative rule: Loose b but gain the information value

• No info: There is no value of waiting
• With information, the alternative rule may be optimal
• Coined the (quasi-) option Value (Henry, 1974, AER)

• Key features: Information + Irreversibility
• Once the project is developed, cannot be stopped
Modelling the Decision Problem

• Decision Problem- No Information
\[ V_0 = \max_{d_1} b \cdot d_1 + \max_{d_2} (EX-c) \cdot d_2 \]

• Decision Problem- Perfect Information
\[ V_1 = \max_{d_1} b \cdot d_1 + E\max_{d_2} (X-c) \cdot d_2 \]

with \( d_1 \) in \( D_1=\{0,1\} \) and \( d_2 \) in \( D_2(d_1)=\{d_1,1\} \)
The Decision Problem

Hence we retrieve:

\[ V_0 = \max (b + (EX - c), 0) \]

\[ V_1 = \max (b + (EX - c), E\max(X - c, 0)) \]

Modelling irreversibility constraints:

\( D_2(d1) \) represents irreversibility

If \( d_1 = 0 \) then \( d_2 \) in \( \{0, 1\} \)

If \( d_1 = 1 \) then \( d_2 = 1 \) => irreversible choice
The « Irreversibility Effect »

• Assume that an increase in $d_1$ shrinks the decision set $D_2(d_1)$ - Does better information leads to decrease $d_1$?

• In other words, does it make sense to have more flexibility if better information is forthcoming?

Henry (1974, AER): Yes
Epstein (1980, IER): It depends
The Decision Problem

- Previous payoff (Henry): $v(d1,d2,x) = bd1 + (x-c)b2$

- General approach (Epstein): unspecified payoff $v(d1,d2,x)$

- Epstein (1980) showed that $v$ must have a « separable form » for the irreversibility effect to hold
A Consumption-Resource Model**

• Illustration of non-separable payoff

• A cake can be consumed over three periods. The size of the cake is unknown.

• What is the effect of getting perfect information at date 2 on the consumption at date 1?

Eeckhoudt, Gollier and Treich (2004, EER)
The Consumption Model

No Info
Max \( u(c1) + u(c2) + \mathrm{Eu}(X-c1-c2) \)
\( u'(c2^*) = \mathrm{Eu}'(X-c1^*-c2^*) = u'(c1^*) \)

Perfect Info
Date 2: Max \( u(c2) + u(x-c1-c2) \) => \( c2^{**} = 0.5(x-c1) \)
Date 1: Max \( u(c1) + 2\mathrm{Eu}(0.5(X-c1)) \)
\( u'(c1^{**}) = \mathrm{Eu}'(0.5(X-c1^{**})) \)
The Consumption Model**

=> under prudence, c1** > c1* : Perfect information increases, and not decreases, consumption!

Intuition:
• Perfect information: perfect smoothing in the future, less risk in the future => less precautionary savings today under prudence

• More information => less « cautious » in the short-run!