Distribution issues and benefit transfer

Distributional considerations

Cost–benefit analysis (CBA) is used to ensure that limited economic resources are allocated efficiently. A project is considered worthwhile if its **discounted benefits** are greater than its **discounted costs**. When multiple projects are evaluated, CBA aims to select the combination that maximizes total value while staying within resource limits.

However, projects can affect different income groups in different ways. Some groups may benefit (gainers), while others may face costs or disadvantages (losers). This is particularly relevant for projects involving environmental goods and services, where gainers and losers often belong to distinct income groups.

Efficiency vs. Distribution: Economic theory recognizes that efficiency (maximizing total benefits) doesn't always align with fair distribution of gains and losses among groups

Using weights in CBA: Distributional impacts can be included in CBA by assigning **weights** to the net benefits of each group- For example, if a project affects two groups (Group 1 and Group 2), their net benefits are NB1 and NB2, and are adjusted with relative *a1* and *a2,* to reflects their relative importance.

$$NB = a1NB1 + a2NB2$$

Conventional CBA assumes all groups are treated equally, with $a1=a2=1$ so no special consideration is given to the distribution of gains and losses.

- If more than one income group is affected by the project, then the criterion that

incorporates distributional considerations is that a project should be undertaken if: $\Sigma aiNBi>0$ where *ai* varies for all groups.

Ex: group 1receives the benefit: B1= 200

Group 2 pays the costs of the project : C2= -200 (NB < 0 : costs)

Conventional CBA: NBproject = -100 + 200 > 0

Distributional weights (determina by asking What weight should be assigned to 1 and 2 so that the project's NPV is zero?) : 0 = NBproject= 200 − $(a2)$100 ⇒ $a2$= 2. —> the loss of group 1 should be weighted twice as much as the gain of group 2.

Explicit distributional Weights
To provide numerica estimates for distributional wieghts is to consider the relationship between avarage income per capita in the economy *(Ȳ)* and income per capita of a specific group.

$$ai = (\bar{Y} / Yi)^{e}$$

e: elasticità of the marginale utility of income which reflects society's aversion to income inequality. In conventional CBA we assume e=0 so a1=1.)

Distributional CBA and Climate Change Damage
We assume that country are divided in rich and poor countries, so world damages from climate change can be defined as:

$$D_{world} = a_{Poor} \times D_{Poor} + a_{Rich} \times D_{Rich}$$

aP and aR are calculated with $a_i = (\bar{Y} / Y_i)^e$ where Y_i is a rich or poor country's avarage per capita income (adjusted with purchasing power).

$WTP_S = WTP_P$. → $D_{\text{WORLD}} = \$106\text{bn} \times \left(\frac{\$3{,}333}{\$1{,}110}\right)^e + \$216\text{bn} \times \left(\frac{\$3{,}333}{\$10{,}000}\right)^e$.

Distributional issues and damages for climate change depends on SCC principale which change the weight attached to the well- being of citizens abroad ω which varies with sovereignity (=1), altruism (<= 1), cooperation, equity and good neighboor (0.5) or compensato ($0<\omega<1$), so this also makes a (Equity weirght) change.

Benefit Transfer
the transfer of existing estimates of non-market values to a new study which is different from the study for which the values were originally estimated.

- Broader concept: The use of existing information designed for one specific context (original context) to address policy questions in another context (transfer context)
- Narrower concept: the use of values of a good estimate in one site (the study site) as a proxy for values of the same good in another site (policy site). This is the most used in CBA.

BT Methods

1. Unit (Naive) BT : estimates the value of an ecosystem by multiplying its average value (from a study site) by the quantity at the target site. Values can be per household (calculated based on the population benefiting) or per area (calculated based on ecosystem size).
2. Adjusted Unit Transfer: tweaking the values from one site to fit another by considering differences like income levels or price changes over time or between sites.
3. Value (Demand) function transfer: uses formulas (based on methods like travel cost or surveys) to estimate values at one site. These formulas are adjusted using data from the new site to calculate values that match its specific characteristics.
4. Meta-analytic function $WTP_P / WTP_S = Y_P / Y_S$. transfer: uses a value function based on many studies instead of just one. It combines this broader data with specific information about the new site, like its social, economic, and physical features, to estimate more accurate values.

1. **Unit or Unadjusted (Naive) WTP transfer**
Borrowing an estimative of WTP from the study site S and apllying it to the policy site P.

Various unit values can be transferred, with mean or median measures.
Factors that differ between the study and policy site which impact WTP are:

- Socioeconomic and demographic characteristic of the population (income, age, education)
- Physical characteristic of the two sites (Environmental services)
- Changes in the provision of the vaued good between the sites (the value derived from studies involving minor improvements in air quality may not apply to a policy entailing a substantial change in size of the area).
- Disparities in market condition, and the presence of market power
- Temporal changes (shift in valuation over time due to factores such as increasing incomes or diminishing avaibility of an environmental good).

2. Adjusted Methods: Efficient BT
To ensure accurate benefit transfer, the following factors are important:

- Relevance: The study and policy sites should be similar in characteristics like environment, demographics, and socioeconomic factors.

- Transferability: The benefits being transferred (e.g., water quality improvements) must depend on similar conditions at both sites.

- Data Availability: Reliable data on environmental, social, and economic factors should be available for both sites, collected using comparable methods.

- Compatibility: The sites should have similar policies, regulations, and governance to ensure the transferred benefits can be applied effectively.

- Adjustments: If differences exist between the sites, adjustments (like scaling or statistical techniques) may be needed for accurate transfer.

$$WTP_P = WTP_S \left({}^{Y_P}/_{Y_S} \right)^e$$

If e=1

Ex. Consumer surplus transfer (Rosenberger, 2001)

$$CS_P = \frac{CS_S}{\Delta d_S}(d_1 \cdot N_1 - d_0 \cdot N_0)$$

CSp : consumer surplus for evaluating policy impatti on recreation of policy sites
CSs : consumer surplus of the study site

di: amount of recreation use in activity days before (i=0) and after (i=1) the policy action

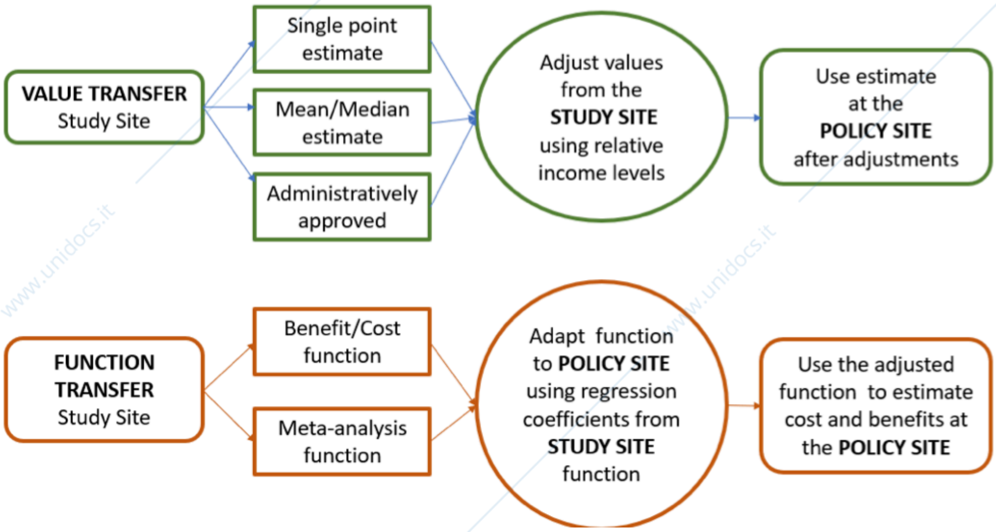
Ni: Number of people partecipati in the recreation activity before (i=0) and after (i=1) the policy

Δds: change in recreation participation or affected resource in the literature providing CSs.

3. Function Transfer Methods

Uses formula (value functions) to estimate WTP by factoring the characteristics like income, age, education or enviromental features. These formulas are used to fit the policy site using its specific data.

Ex: *WTPp=3+0.5·(Yp)Income−0.3·AgeP +2.2·EducationP.* *(Assume increase in income and education bus decrease in age).*



Challenges in BT Methods: Transfer Errors

1. Measurement Error: Errors from weak methods or unreliable data at the study site.
2. Generalization Error: Transferring values without accounting for key differences between sites.
3. Publication Bias: Research focuses on certain results, limiting usable data for BT.

<u>Aggregation of Values</u>

- Per Beneficiary: Multiply WTP per person by the number of people at the policy site.
- Per Area: Multiply WTP per unit area by the total area.
- Multiple Services: Sum up the values of different services but avoid double counting.

<u>Spatial Scale:</u> Consider how services operate at different scales (local, regional, global). For instance, a forest offers local recreation and global climate benefits. Include beneficiaries at all scales and apply spatial discounting if benefits diminish with distance.

<u>Testing Transfer Reliability:</u> Reverse the roles of study and policy sites, compare estimates, and calculate transfer error to assess accuracy. This ensures accurate, fair, and reliable value estimates.

$$\text{Transfer error} = \frac{(\text{transferred estimate} - \text{own-study estimate})}{\text{own-study estimate}} \times 100.$$

4. Meta-Analysis BT
Meta-regression analysis is a method used to estimate the value of an environmental benefit at a new location by using data from multiple studies conducted in other places. It is useful when conducting a new study isn't practical. There are 3 steps:

1. Combine data from studies that estimate the value of a benefit (e.g., clean water or biodiversity) in different locations.

2. Use a statistical model to find relationships between the estimated value and factors like site characteristics, socioeconomic conditions, or study methods.

3. Apply this model to the new location by using its specific characteristics to predict the value.

- The basic formula is: $y_i = \alpha + \beta x_i + \epsilon_i$
  y is the estimated value
  x represents site and study characteristics
  ϵ is the error term
  - Meta-analysis identifies which factors significantly affect the value and adjusts for them.

- Assumptions and Challenges:
  - The relationship between factors and values must be consistent across sites.
  - The quality and comparability of the studies used are critical.
  - Careful handling of uncertainties ensures reliable results.

- Benefits: Meta-analysis provides a cost-effective way to estimate values for new locations and supports better policy and decision-makioo

<u>Cost Benefit Analysis: Risk Assessment</u>
Risk assessment is associated with uncertainties regarding the parameter values which are used to estimate the flows of costs and benefits.
Art. 101 of EU Regulation: risk assessment must be included in the CBA of a major project if it seeks co-financing from the EU.
The steps to assess the project disks are:
1. Sensitivity Analysis
2. Probabilistic risk analysis
3. Qualitative risk analysis
4. Risk prevention and mitigation

1. Sensitivity Anlaysis
Sensitivity analysis checks how risky a project is by seeing how much key financial measures (like NPV, IRR, or B/C ratio) change when project variables are adjusted. It uses two methods:

1)Variable Adjustment: change one variable at a time (e.g., increase or decrease it by 5%) and see how the financial results are affected.
2) Break-even Analysis: find how much one variable would need to change to make the NPV equal to zero (break-even point).

This helps to identici the most critical variables and understand the project risks.

Stages of sensitivity Analysis
1. Identification of variables which will have significant impacts on the NPV, if their future values vary around the forecast values.
- variables that have significant impact are called **sensitive variables** or **critica variables**
- Variables are considered critical if a variation of ±1% of the value adopted in the base case gives rise to a variation of more than 1% in the value of the NPV .
2. The variables are rande in order od their monetari impact on the NPV
3. The most sensitive variables are further investigate by management

Terminology within the Analysis
- Sensitivity and break-eden analysis = scenario / what if analysis
- Point values of fercasts = optimistic / most likely / pessimistic analysis
- Breakeven variables give a “breakeven” value of zero to the NPV for the project, or an IRR equal to the cost of capital, or a B/C = 1

Selection criteria of variable in the analysis
- Degree of management control
- Management’s confidence mi the forecast
- Aumount of management experience in assessing projects.
- Use of intrinsic rather than extrinsic (exogenous) variables wherever possible, because extrinsic variables are more problematic.
- Time and cost of analysis.

2. Probabilistic risk analysis - Monte Carlo simulations’ procedure
Monte Carlo simulations assess project risks by using random values for key variables (like prices or costs) based on their probability distributions. Here's how it works:

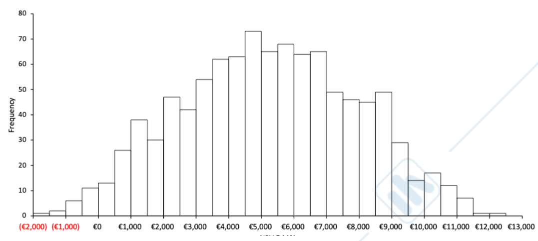
1. Random values are picked for each variable from their probability ranges.
2. These values are used to calculate financial results like NPV, IRR, or B/C ratio for one scenario.
3. The process is repeated 1,000–2,000 times, generating unique results each time.
4. All results are combined into an overall distribution, showing the range of possible outcomes and their likelihood.

This helps managers understand the level of risk in a project.

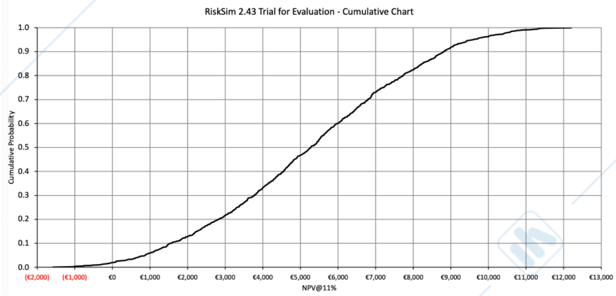
Simulation terminology:
- stochastic modelling = treatment of risk by using simulation
- Simulation = risk analysis, venture analysis, risk simulation, monte carlo simulazione
- each execution of the model = replication, iteration

Outputs : help the management to view and assessthe risk associated with the project in particular
- Probability of Outcomes: Managers can estimate the chance of the NPV falling between two specific values.
- Risk of Loss: They can calculate the likelihood of a negative NPV (area left of zero on a graph).
- Confidence Intervals: Simulations provide a range of likely values, offering more confidence in decision-making.

Histogram



Cumulative chart



<u>Benefits and Costs simulation</u>
A Monte Carlo simulation:
• Focuses on a detailed definition and analysis of risk;
• Provides sophisticated analysis and clearly portrays the risk of a project;
• Gives the probability of a loss-making project;
• Allows simultaneous analysis of all variables.

However, the simulation:
• Requires a significant forecasting effort;
• Can be difficult to set up for computation;
• May produce output that can sometimes be difficult to interpret.

3. Qualitative risk analysis
Qualitative risk analysis helps management understand risks without using numbers. It includes:

1. Listing potential risks that could harm the project’s cash flows
2. Creating a risk matrix for each event, showing its probability and severity.
3. Combining probability and severity into an overall risk level.
4. Interpreting the matrix to assess which risks are acceptable.
5. Describing strategies to reduce or prevent major risks, including who will implement them and when. (Riisk mitigation)

<u>Probability of occurrence</u>

- Very unlikely (0–10% probability)
- Unlikely (10–33% probability)
- About as likely as not (33–66% probability)
- Likely (66–90% probability)
- Very likely (90–100% probability)

Total Economic Value

The total economic value (TEV) of any change in well-being due to a project or policy associated with environmental goods and/or services, is the aggregate of all types of values generated by these goods and/or services.
- WTP + WTA (sum of all the relevant wtp and the corresponding wta)

Measures:

- Waste "sink" : helps manage waste from production and consumption, like absorbing emissions from burning fossil fuels.
- source of amenity and quality of life for people (mountaneering)
- provider of vital basic life supporting services (global climate regulation, nutrient cycling and water cycling).

Missing Markets

- When there are no clear property rights for enivronmental resources — the market doesn't refelct their value
- Leads to enviromental damage and market failures which need to be fide by envirnomental regulation.
- Important to estimate nonmarket values (environmental good not trade in markets)

With utility and production function :

U = U (X, Z, W) : utility depends on market goods (X), Environmental goods (Z) and water quality (W)

X = F(L, K, W) : a market good is produced using Labour, Kapital and Water quality

changes is W directly affect utility : $dU = \frac{\partial U}{\partial W} dW.$

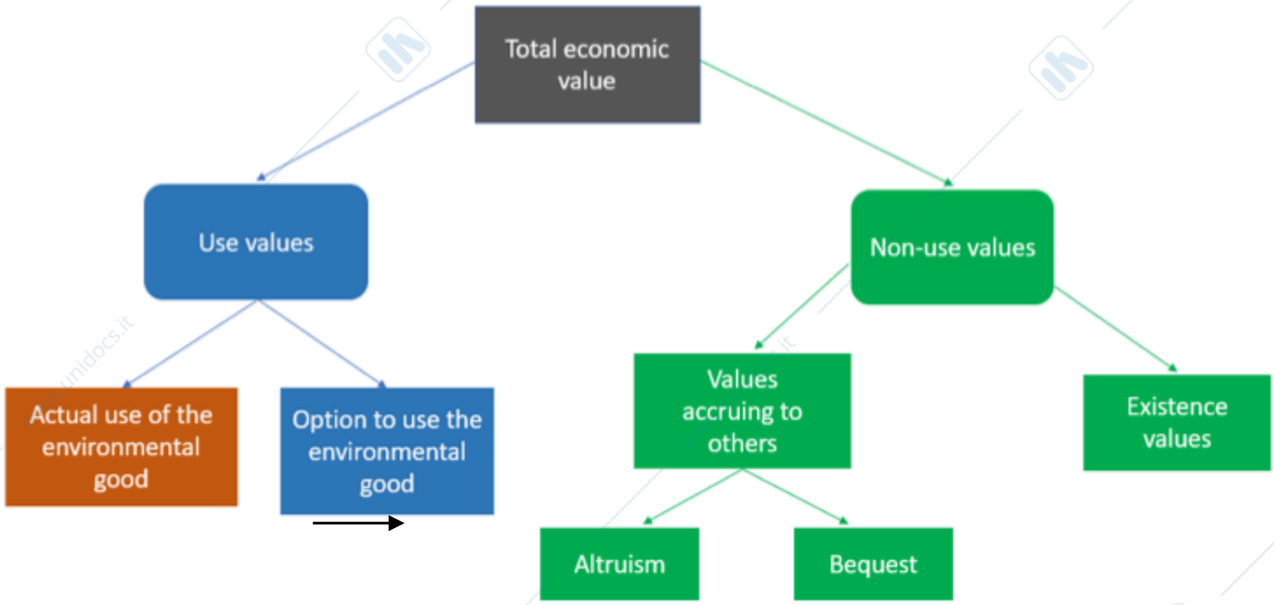
And indirectly the output of the market good: $dQ_{X_1} = \frac{\partial F_1}{\partial W} dW$

TEV by types

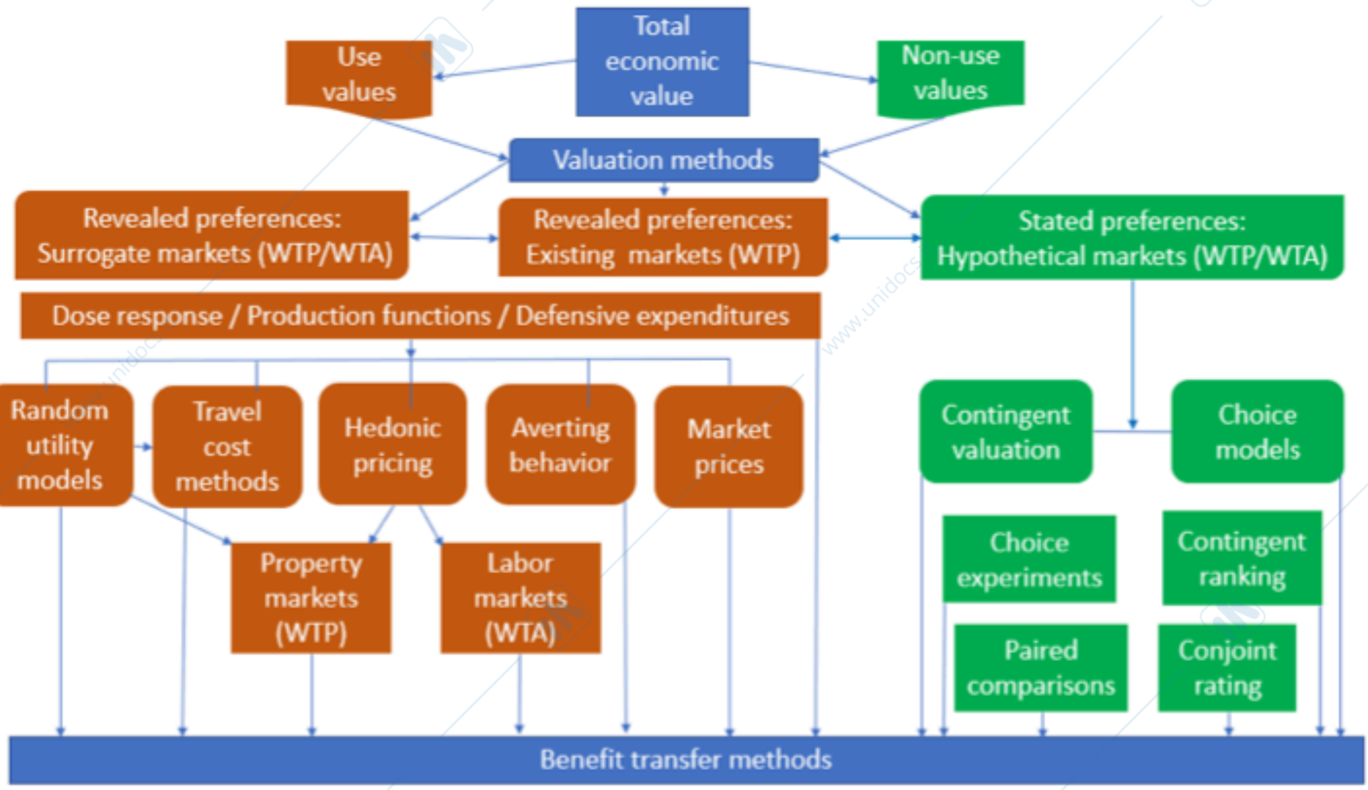
- **Use value** is the economic value that people derive from the direct or indirect use of an environmental resource. It is the value that people place on the benefits that they receive from the resource, such as food or timber, or the recreational opportunities that they enjoy from ecosystems. The potential future uses of the environment are referred to as option value.

- **Non-use value** is the economic value that people derive from the mere existence of an environmental resource, even if they never use it directly or indirectly. It is the value that people place on the knowledge that the resource exists, or the desire to preserve it for others, or the desire to pass it on to future generations.

Components of TEV:



TEV: componente and evaluation techniques:



TEV and Cost benefit analysis
Total economic value is a crucial component in any environmental cost–benefit analysis.

Ex. : the annual TEV generated by an environmental system has been calculated to be
TEV 1, TEV 2, ….TEVt

The annual flow can be interpreted as the flow of ecosystem services.

A conservation project will guarantee that the flow of the TEV will

remain for the next T years. The conservation project will cost C and can be

completed within a year. There will be no other costs (e.g., operation or

maintenance). Without the project, the flow of the TEV = 0

The project Will go ahead if $NPV(r) = -C_0 + \frac{TEV_1}{(1+r)} + \frac{TEV_2}{(1+r)^2} + \cdots + \frac{TEV_T}{(1+r)^T} > 0.$

- r and risk assestmets of the flow of TEV can be estimated as we said in previous lecture

Question: how much is the justifiable cost for conserving the ecosystem ?

$$C_0 = \frac{TEV_1}{(1+r)} + \frac{TEV_2}{(1+r)^2} + \cdots + \frac{TEV_T}{(1+r)^T}$$

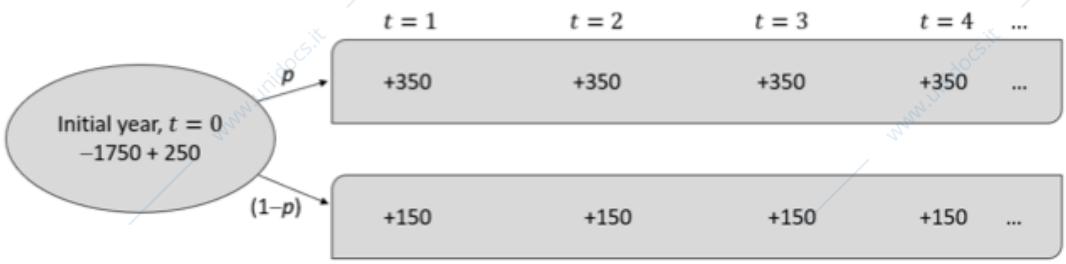
(Quasi) Option Value and Preservation vs Conversion

1. Environmental Option Value: the value of preserving natural resources and ecosystems for their potential future benefits, like biodiversity, clean air, or cultural enjoyment.

2. Environmental Quasi-option Value: The value of keeping the flexibility to decide later about using or preserving natural resources. It accounts for uncertainty and the potential to learn new information before making irreversible decisions. (Future decisios).

3. Real Option Value: The value of having the flexibility to act on tangible assets or projects in response to changing market conditions or new information, often used in finance and investment decisions.

The Value of Flexibility
following Dixit and Pindyck's (1994) example:
A firm hai to decide whether to undertake an irreversible investment with C=1750
It will produce one item per year forever
Current Price of the item: 250 bit will change next year
Probability = *p = 0.5* that price will be 350
Probability = *(1-p)* price will be 150
Cashflow:



If $r = 0.12$ and $p = 0.5$ $$NPV(0) = -1750 + 250 + \sum_{t=1}^{\infty} \frac{p350+(1-p)150}{1.12^t} = 583.33.$$

If we wait for a year, the price uncertainty will be resolved and the investment will be undertaken only if the high price of p = 350 emerges.

$$NPV\ (0/1) = p\left[-1750 + 350 + \sum_{t=1}^{\infty} \frac{350}{(1.12)^t}\right]\frac{1}{1.12} = 677.08.$$

Value of Flexibility Option = 677.08 - 583.33 = 88.75
We would be willing to pay 88.75 more for a flexible investment that can be undertaken now ora year from now., so it's the QOV

Environmental Quasi-Option Value = the value of waiting to make an irreversible decision until more information becomes available, reducing uncertainty about future outcomes.

Ex. Developing or preserving a forest

A forest can either be converted to agriculture now (period 0) or preserved for future decision-making (period 1).
- If the forest is converted now, period 0, it cannot be preserved in period 0 or in the future period 1. But if it is preserved now, it still leaves open the choice of converting or preserved it in period 1.
- We assume that benefits from agricolture are deterministic and benefits from preservation in the future are stochastic.

- Converting now = $D(0)$ and $D(1)$
- Preserving now = $V(0)$: certain preservation value + $V(1)$ stochastic conservation value
- Future preservation value could be high (p) or low ($1- p$), so there are 2 possible V

If the forest is preserved now (period 0), the expected value of preservation benefits in both periods is:

$$EP = V_0 + pV_{1,high} + (1-p)V_{1,low}.$$

If the forest is converted in period 0, the expected value of agricultural benefits will be:
$ED = D(0) + D(1)$
If the decision has to be taken now than: ED > EP
If the decision is postponed:
Assume that $V1(high) > D1 > V2(low)$ than the expected value of waiting (EW) is:

$$EW = V_0 + pV_{1,high} + (1 - p)D_1.$$

• "Conventional" cost–benefit analysis will choose development if $ED > EP$.

• The "options" will choose development if the stricter rule, $ED > EW$, is satisfied.

• $QOV = EW - \max(ED, EP)$.

QOV is not a distinct type of economic value but reflects the **added benefit** of postponing an irreversible decision to gather new information that could lead to a better outcome.

It arises only when:

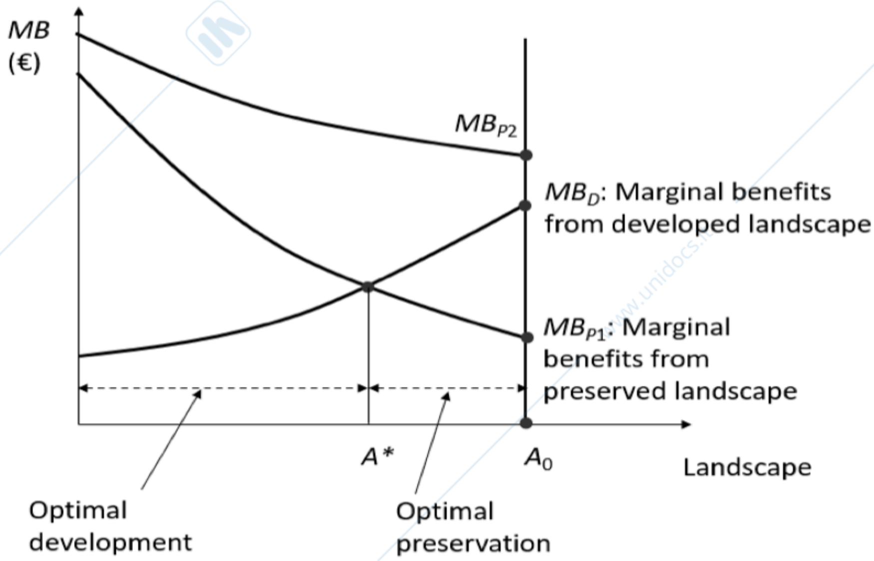
1. The decision cannot be reversed.
2. There is uncertainty that can be resolved through learning.

Without the potential to learn and reduce uncertainty, QOV does not apply.

<u>Preservation vs Conversion</u>
It is a central issue in the management of ecosystem services.

- **Preservation**: Protecting natural ecosystems to maintain services like carbon storage, wildlife habitat, and recreation. While it helps mitigate climate change and supports biodiversity, it generates no revenue from resource extraction.
- **Conversion**: Transforming ecosystems (e.g., into timber plantations) to generate income. This provides timber but reduces carbon storage, harms wildlife habitats, and may cause environmental damage from pesticides and fertilizers.

Ex: Forest Ecpsystem
- Preservation: Forest absorbs carbon, supports wildlife, and offers recreational benefits, but no income from timber.
- Conversion: Timber provides income, but carbon storage is lower, and biodiversity and cultural services are lost. Environmental harm may also occur.



<u>Optimal one-time conversion time</u>
The optimal time (t*) to converti land balances the benefits of delaying conversion with the costs. It is determined by maximizing the total value of:
- Development benefits (R) after conversion
- Ecosystem service benefits ($B(u)$) before conversion.

$R'(t) + B(t) = rR(t).$ → $R'(t) + B$: the gain of delaying the development one period. It includes the increase in rental value of developed land plusthe additional ecosystem benefits during that period of delay.

$rR(t)$: the cost of delaying development. The value of the land, if sold in period t, could be invested to earn interest. The average interest rate on other assets in the economy is clearly key to the opportunity cost of delaying development another period. A higher interest rate means that it is costly to delay, whereas the lower interest rate has the opposite effect.

<u>Countinous Transformation</u>
Assume that we have an area of size *A0* where species live. At each Instant of time, part *u(t)* of the area in transfromed into a state that produce direct economic benefits, the area remaining can provide ecosystem services.
- you decide how much of the land you want to develop each year
- as you develop more land the remaining natural land becomes smaller (less Environmental benefits bus more economic returns but also costs)
- Goal: figure out how much land to develop each year and how much to keep natural, to maximize total benefits over time.
- If you develop too quickly, you lose long-term environmental benefits. If you wait too long, you miss out on economic gains.
- Reaching a steady state: over time, the system finds a "balance point" where the amount of developed and natural land stays stable. This balance depends on factors like how much money developed land makes, how valuable the environment is, and how expensive it is to develop more land.

$$\lambda^*: 0 = -h(\lambda^*), \quad A^*: \lambda^* = \frac{B'(A^*) - f'(A_0 - A^*)}{r}, \quad A^* \geq 0.$$ With s.s. solution