Environmental Risks

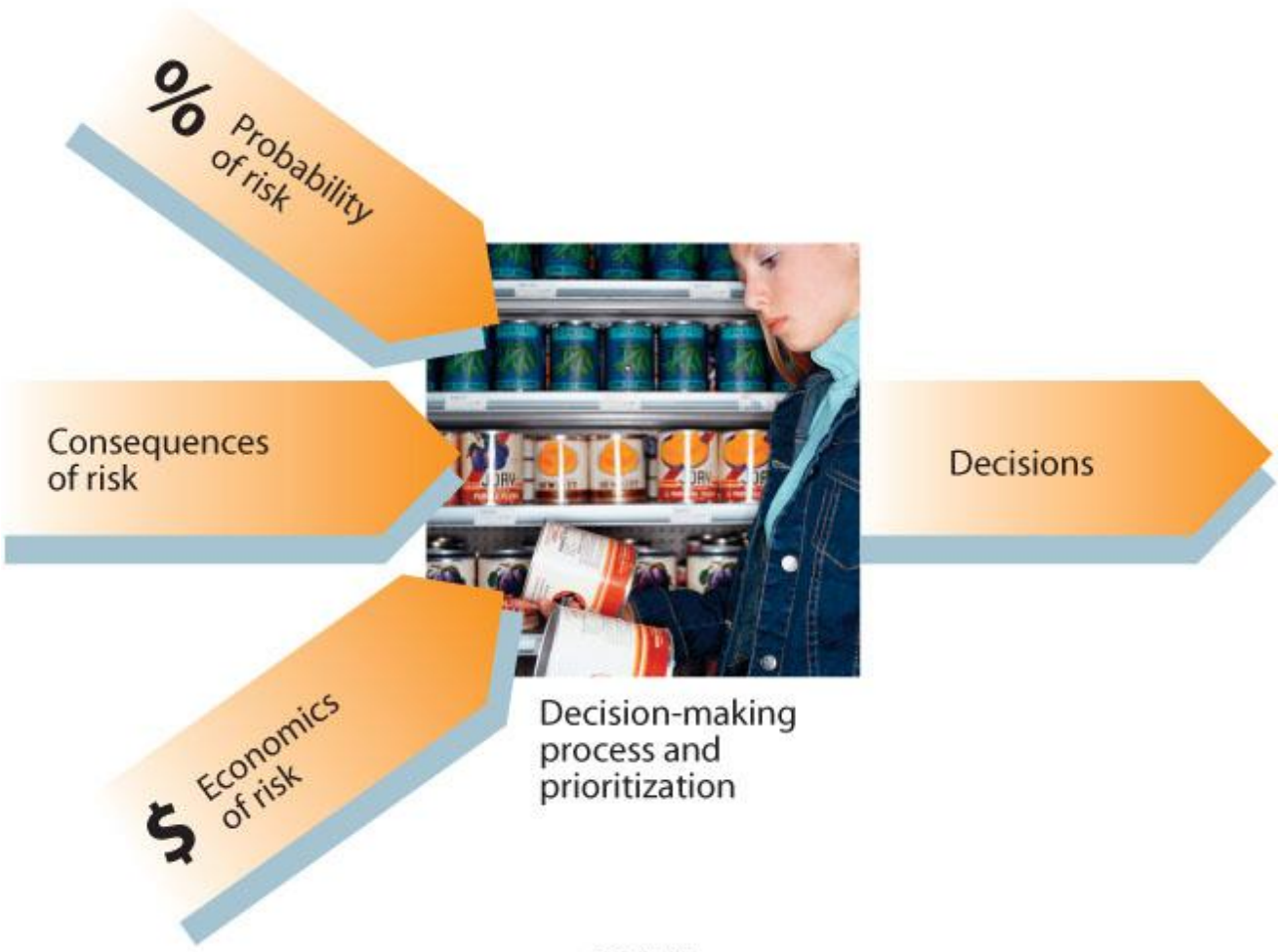
Characterizing Risk

- **Risk** is the probability that a condition or action will lead to an injury, damage, or loss.
- Risk incorporates three main considerations:
  1. Probability of a bad outcome.
     - **Probability** is a mathematical statement about how likely it is that something will happen.
  2. Consequences of a bad outcome.
  3. Cost of dealing with a bad outcome.

Risk and Economics

- Most decisions in life involve an analysis of two factors:
  - Risk
  - Cost
- Most environmental decisions involve finding a balance between the perceived cost of enduring the risk and the economic cost of eliminating the conditions that pose the risk.

Risk and Economics



Decision-making process

Risk Assessment

- Environmental **risk assessment** uses facts and assumptions to estimate probability of harm to human health or the environment that may result from particular management decisions.
  - The assessment process provides an orderly, clearly stated, and consistent way to deal with scientific issues when evaluating whether a risk exists, the magnitude of the risk, and the consequences of the negative outcome of accepting the risk.

Risk Assessment

- If a situation is well-known, scientists use probabilities based on past experience to estimate risks.
- Models are used to estimate risks for situations with no known history.
  - Most risk assessments are statistical statements that are estimates of the probability of negative effects.
  - These estimates are modified to ensure that a lack of complete knowledge does not result in an underestimation of risk.

Disease and Accidental Causes of Deaths	Annual Deaths	Death Risk During One's Lifetime
Heart disease	652,486	1 in 5
Cancer	553,888	1 in 7
Stroke	150,074	1 in 24
Hospital infections	99,000	1 in 38
Flu	59,664	1 in 63
Car accidents	44,757	1 in 84
Suicide	31,484	1 in 119
Accidental poisoning	19,456	1 in 193
MRSA (resistant bacteria)	19,000	1 in 197
Falls	17,229	1 in 218
Drowning	3,306	1 in 1,134
Bike accident	762	1 in 4,919
Air/space accident	742	1 in 5,051
Excessive cold	620	1 in 6,045
Sun/heat exposure	273	1 in 13,729
Lightning	47	1 in 79,746
Train crash	24	1 in 156,169
Fireworks	11	1 in 340,733
Shark attack	1	1 in 3,748,067

Risk Management

- **Risk management** is a decision-making plan that weighs policy alternatives and selects the most appropriate regulatory action by integrating risk assessment results with engineering data, and with social, economic, and political concerns.
  - The purpose is to reduce the probability or magnitude of a negative outcome.

Risk Management

- A risk management plan includes:
  - Evaluating the scientific information regarding various kinds of risks.
  - Deciding how much risk is acceptable.
  - Deciding which risks should be given highest priority.
  - Deciding where the greatest benefit would be realized by spending limited funds.
  - Deciding how the plan will be enforced and monitored.

Risk Management

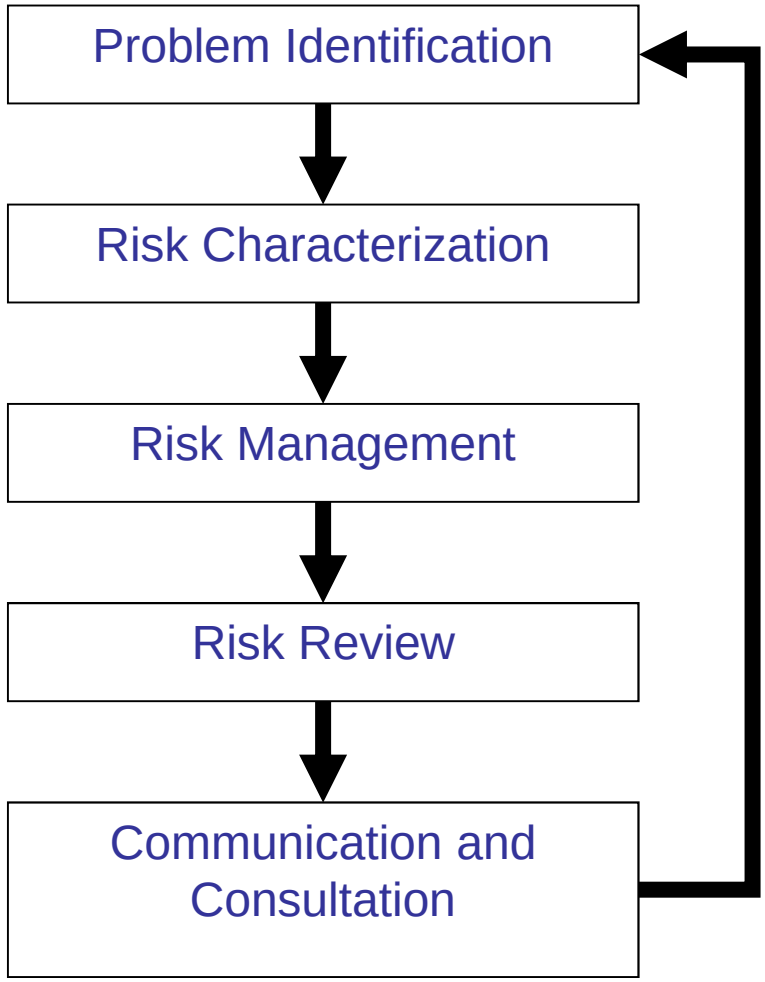
- From a risk management standpoint, whether one is dealing with a site-specific situation or a national standard, the deciding question is:

- What degree of risk is acceptable?

- **Negligible risk** is the point at which there is no significant health or environmental risk.
  - At what point is there an adequate safety margin to protect public health and the environment ?

Environmental Risk Assessment

ERA is a systematic analysis of the likelihood that the environment will experience a specified level of harm as a result of a natural disaster or a planned human activity.



Risk comparison

- **Probability of frequency of events causing one or more immediate fatalities.**
- **Chance of death for an individual within a specified population in each year.**
- **Number of deaths from lifetime exposure.**
- **Loss of life expectancy considers the age at which death occurs.**
- **Deaths per tone of product, or per facility.**

Quantitative risk assessments – a possible scenario

- **quantity of toxic material in the inventory is hazardous;**
- **overpressure in the storage tank in combination with failure of the relief valve leading to tank rupture;**
- **combination of wind speed and atmospheric stability leading to an estimated spatial and temporal distribution of toxic material concentration;**
- **population distribution based on night-time occurrence.**

True and Perceived Risks

- **‘Objective risk’** (also known as real, technical or scientific risk) is risk that can be directly attributed with a quantifiable value.
- For example the risk of premature death of a smoker in the US from smoking in 19904 was 39%

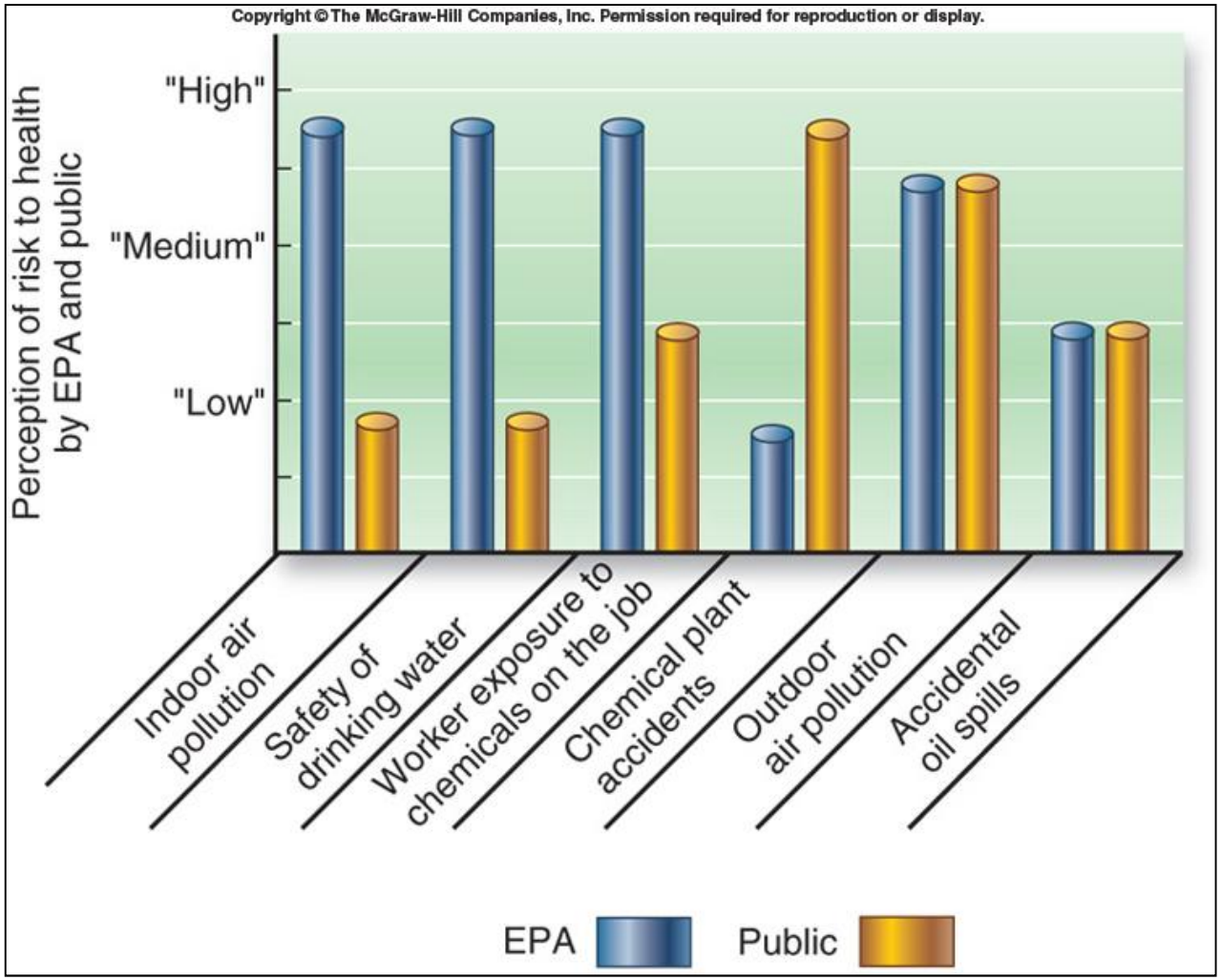
- **‘Subjective risk’** (or risk perception)

- How individuals perceive objective risks based on external influences such as the media, previous experiences, knowledge (related to the risk target) and internal personality traits or when they have no information (i.e. they do not have information pertaining to the objective risks).
- This type of subjective risk is formed nearly entirely by internal emotive or attitudinal traits.

True and Perceived Risks

- People often overestimate frequency and seriousness of sensational causes of death, and underestimate risks from familiar causes that claim lives one by one.
  - The public generally perceives involuntary risks as greater than voluntary risks, and perceives newer technologies as greater risks than old, familiar technologies.

True and Perceived Risks



Perception of risks

True and Perceived Risks

- One of the most profound dilemmas facing decision makers is how to address the discrepancy between the scientific and the public perceptions of environmental risks.
  - Should the government focus available resources and technology where they can have with the greatest impact, or on problems about which the public is most upset?

Different attitudes towards risk

Economic actors have different attitudes towards risks.

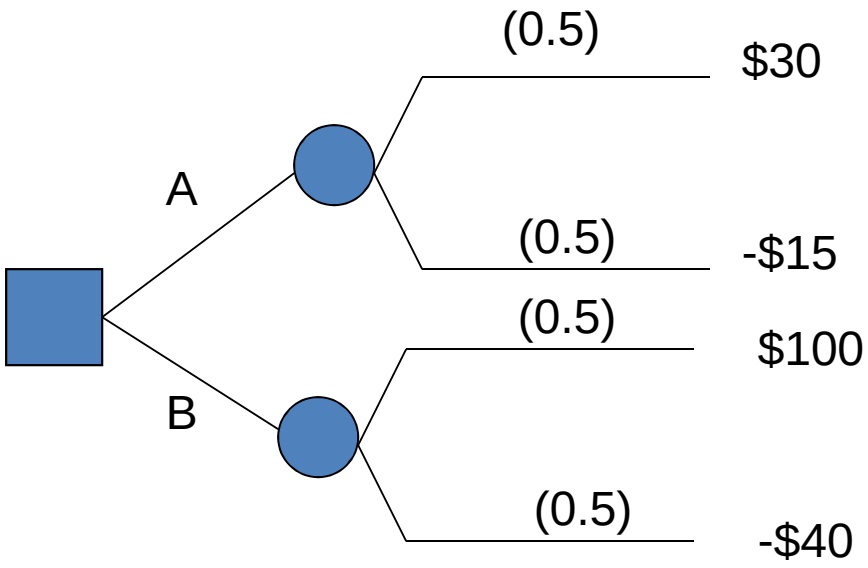
- **risk averse**: if they are willing to pay even more than the actual value of the risk in order to transfer its harmful consequences to someone else;
- **risk preferring**: if they prefer to retain the risk of loss, rather than transferring it by paying upfront an amount equal to its actual value.
- **risk neutral**: if they are indifferent with respect to the alternative between *(a)* retaining the risk and *(b)* transferring it to someone else by paying upfront an amount equal to its actual value.

Different attitudes towards risk

- Attitudes towards risks depend on several factors;
  - the nature of the risk
  - the probability of loss
  - the potential magnitude of the loss
  - the ability to absorb its economic consequences
- Assuming rationality and perfect information, economic actors are able to calculate the actual value of a given risk by discounting the magnitude of the loss (L) by the probability of its occurrence (p) → (**pxL**)

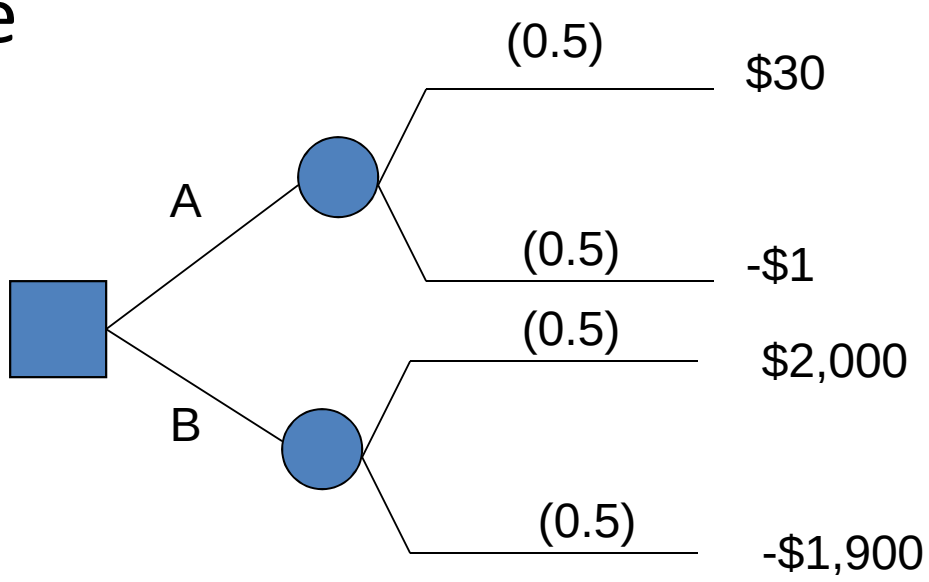
Modeling risk attitudes

- Objective: Develop tools to compare alternative courses of action with uncertain outcomes (lotteries or deals)



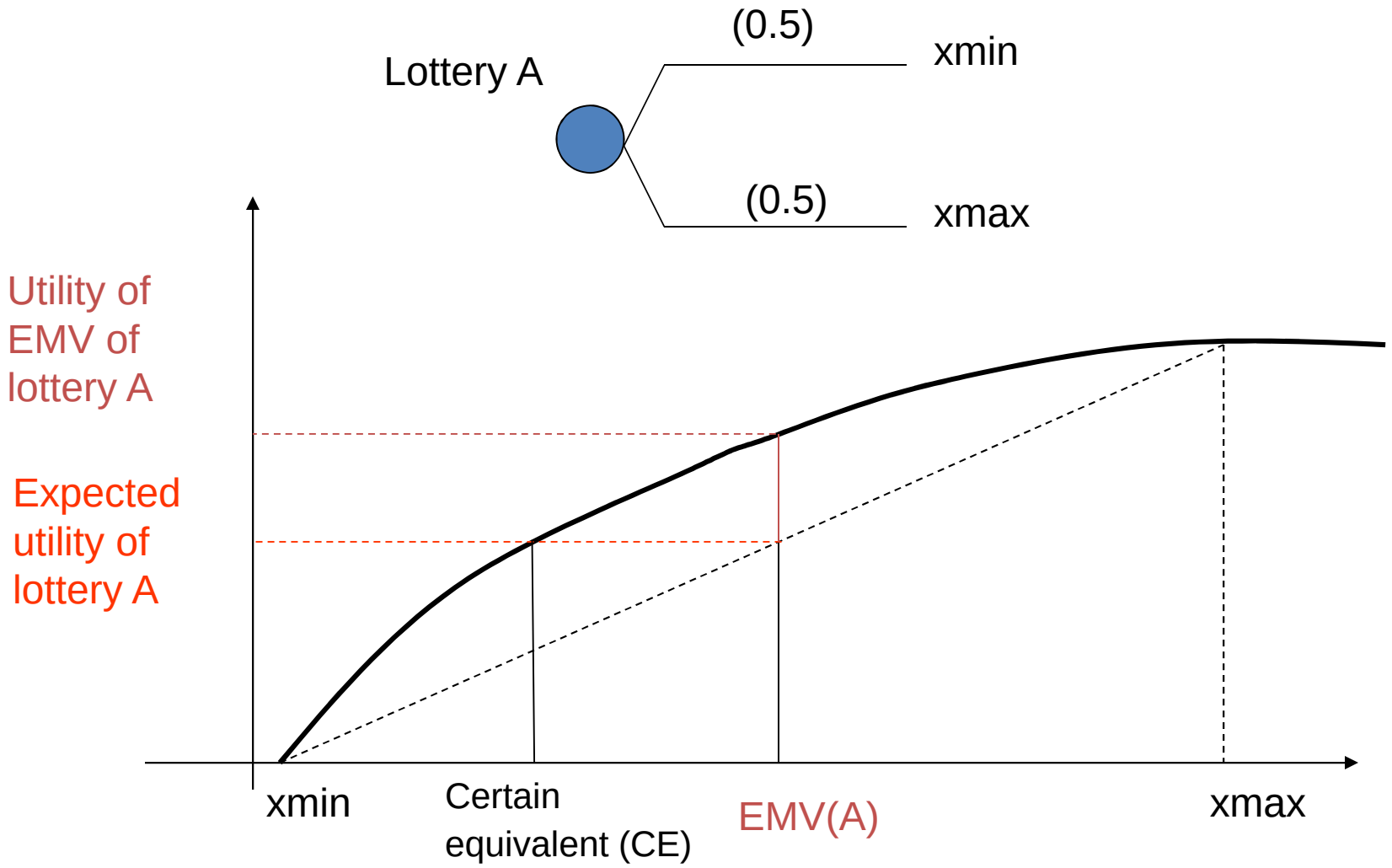
Expected monetary value (EMV) is not a good measure of the value of a deal

- Play same lottery many times, EMV is a good measure of value of a lottery.
- Play a lottery once, EMV is not a good measure



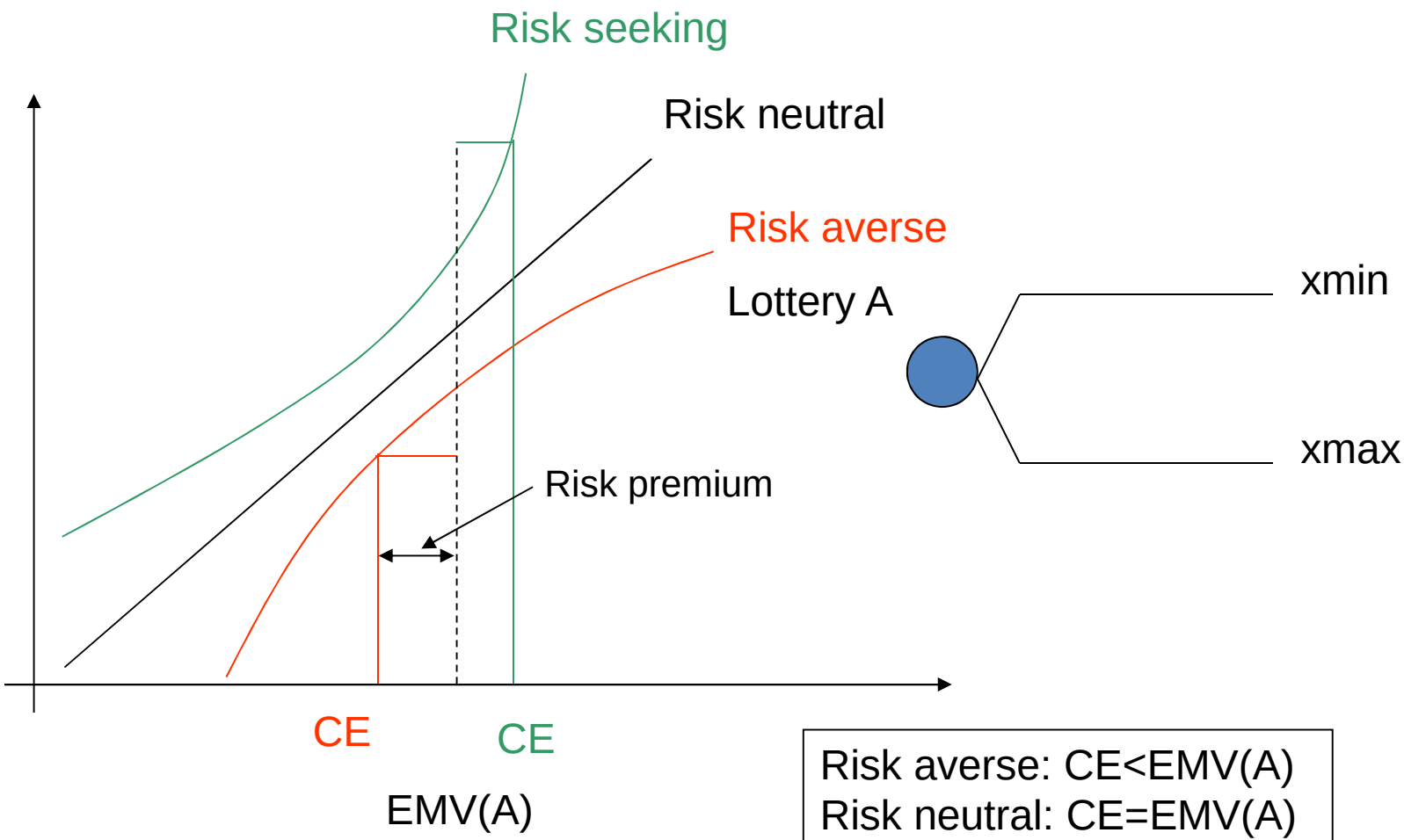
EMV(B)>EMV(A), most people prefer A

Utility function: risk averse decision-maker



Risk aversion: Expected utility of lottery is less than the utility of sure amount equal to expected monetary value

Attitudes toward risk



Risk averse: CE<EMV(A)
Risk neutral: CE=EMV(A)
Risk seeking: CE>EMV(A)

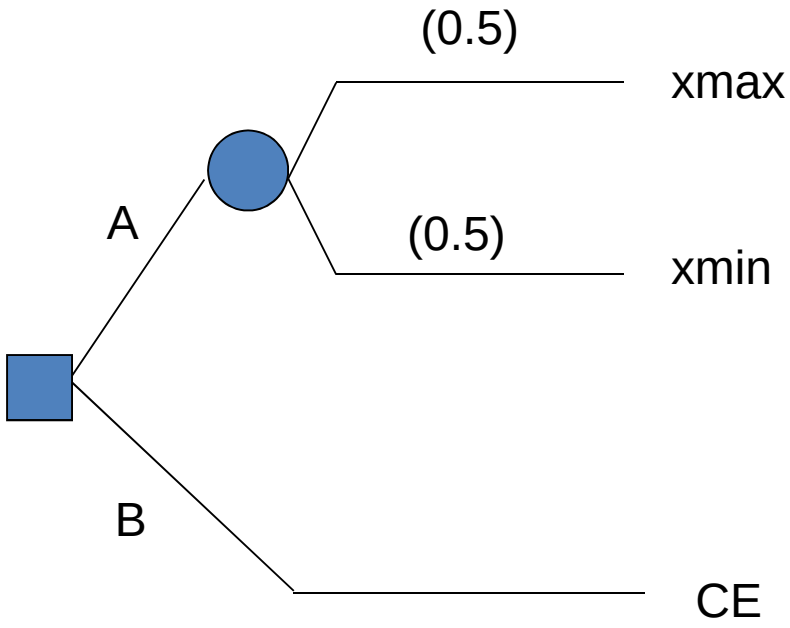
Risk premium of a lottery

- How much we must pay decision-maker to take lottery A instead of sure amount equal to the expected mean value of the lottery.
  - Risk premium=EMV(A)-CE
  - Risk averse decision-maker: Risk premium>0
  - Risk neutral decision-maker: Risk premium=0
  - Risk seeking decision-maker: Risk premium<0

Assessment of utility function

- Assess a decision-maker's utility by observing what gambles he/she is willing to take
- Assessment using certainty equivalents
- Assessment using probabilities

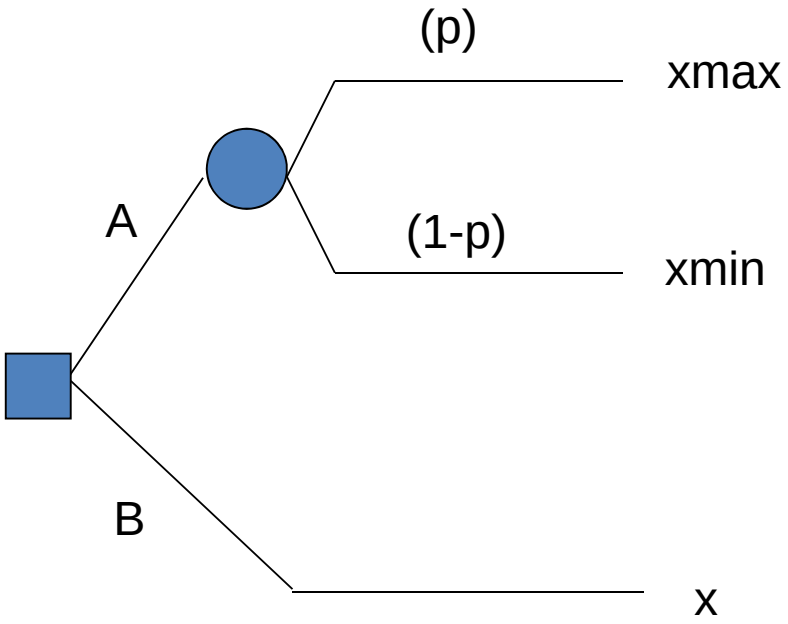
Assessment using certainty equivalents



Find CE so that decision-maker is indifferent between deals A and B

$$U(CE)=0.5U(xmax)+0.5U(xmin)$$

Assessment using probabilities

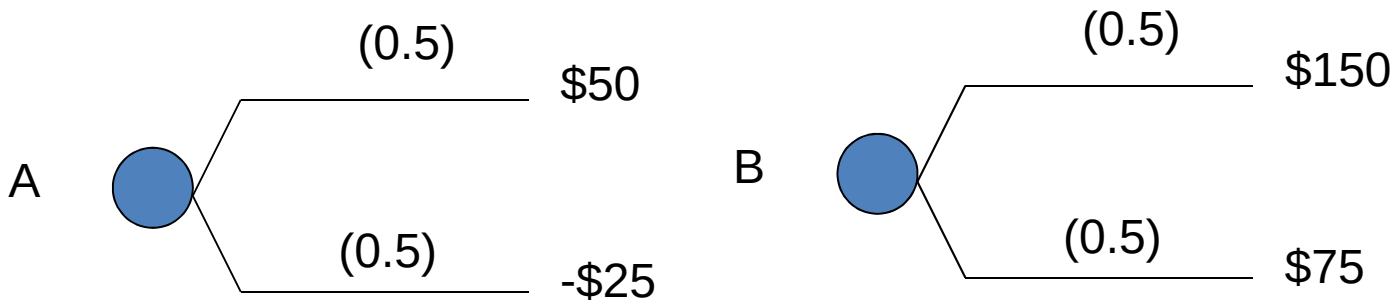


Find probability p so that decision-maker is indifferent between deals A and B

U(x)=pU(xmax)+(1-p)U(xmin)
If U(xmax)=1 and U(xmin)=0, then U(x)=p

Decreasing risk aversion

- When we increase payoffs of a deal by the same amount, decision-maker becomes less risk averse



Risk premium of lottery A greater than that of B

Decreasing risk aversion

Although risk aversion occurs in real life it is not always important to account for it. Only need approximation of utility function to select best alternative

Insurance

- Risk aversion generates demand for insurance.
- Insurance companies, in turn, are willing to undertake the risk in exchange for an amount of money relatively close to its actual value (the premium)
- The law of large numbers makes them able to manage such risks effectively, by making predictable, with reasonable accuracy, the claims they will pay from year to year.
- The larger the number of exposures considered, the more closely the losses reported will match the underlying probability of loss.
- Insurance companies need to pool together a rather **large number of homogeneous but independent risks** in order to become risk neutral.

The traditional insurance mechanism

- **risk assessment** (the evaluation of risk, which is usually performed through statistical and probabilistic analyses)
- **risk transfer** (the shifting of its harmful consequences by way of the insurance contract)
- **risk pooling** (the placement of the risk in a pool of homogeneous but independent risks allows the insurer to spread the risk and to benefit from the law of large numbers)
- **risk allocation** (the pricing of the risk though premium setting)

Insurance

- In order to be insurable, the risk must be predictable, at least by means of past experience and statistical calculations

Some problems are:

- **Generalized uncertainty** – which may undermine the insurer's ability to properly evaluate and assess the risk *ex ante*
- **Informational asymmetries** – in favor of the prospective insured, generating distortions and agency problems:
  - Adverse selection
  - Moral Hazard

Insurance

- Two different kinds of environment-related risks:
- 1. the **environmental liability risk** (i.e. the financial risk associated with environmental pollution and contamination) and
- 2. the **natural catastrophe risk** (i.e. the risk of major damages in connection with the occurrence of natural disasters, such as earthquakes, floods or other extreme environmental conditions)

Environmental liability risk and insurance

- As the magnitude of expected losses increases, **the insurers' financial ability to absorb them can be severely jeopardized**.
- Over and above certain levels of financial exposure, insurers themselves tend to be **risk averse**.
- Coinsurance and reinsurance are viable options for primary carriers who are willing to cede part of the risk they undertook, in exchange for the payment of a fraction of the premiums they collected

Environmental liability risk and insurance

Traditional reinsurance agreements may be of different types, among which:

- **quota share (proportional) treaties** (by which the reinsurer undertakes a quota of the risk transferred to the primary carrier)
- **excess of loss (stop loss) treaties** (by which the reinsurer undertakes the upper layer of the risk, after a certain attachment point).

Environmental liability: compensation and deterrence

Environmental liability regimes should be aimed at achieving efficient levels of

- **compensation for environmental harm** (or restoration of the impaired resources) and
- **deterrence of inefficient activities** (thereby preventing pollution that is not cost justified)

Environmental liability: compensation and deterrence

- Imposing the **obligation to compensate for natural resources damages and cleanup costs** - compared to the indirect protection scheme - has the clear advantage to force the tort-feasor to **fully internalize the negative externalities** of her activity,
- but the **evaluation and quantification of the harm** is still unresolved. The issue of damages is extremely controversial with respect to the **value of natural resources** that cannot be fully restored or replaced after the polluting event.
- In order to overcome this problem, it could be better to hold responsible parties liable for the **cost of clean up of impaired resources**, once clean up standards have been determined by the authority with a sufficient level of predictability.

Environmental liability risk and insurance

- Instead of civil liability, there are other **administrative and/or criminal rules imposing obligations to cleanup contaminated sites**
- In case of pollution, the owner and/or operator of the site or facility, in other words, is forced by the public authority to adopt immediately security and preventive measures and then to decontaminate the site, under the threat of fines, or even imprisonment
- It is very important to **distinguish** between **liability** (being it civil, administrative or criminal) **for cleanup of soil or water pollution** and **the obligation to pay natural resources damages (NRDs)**

Environmental liability risk and insurance

- Should the liability be imposed on an **individual basis** or should all the polluters be held **joint and severally liable** for the clean-up costs?
- If the compensation profile is considered alone, joint and several liability clearly offers great advantages to the injured parties
- The deterrence goal, however, requires that each polluter pays for the consequences of her own activity: if liability is not individual, the mechanism of incentives will not work, given the difficulties for the potential polluter to perform a costs-benefits analysis.

Environmental liability risk and insurance

- both the compensation and the deterrence functions are *de facto* undermined by the so-called ‘judgment proof’ problem
- if the polluter, after the accident has no assets to repay the damage caused, the whole system of environmental liability could collapse and the result would just be an additional waste of the resources invested in litigation

Environmental liability risk and insurance

- The **modern environmental insurance** works in a quite different way.
- If the amount of the insurance premium and the conditions of coverage **accurately reflect the level of risk created by the insured**, then the insurance relationship, while giving effect to the **compensation** function, will **add incentives to the liability system**, working as a **private surrogate regulation** mechanism, with the flexibility of a case by case determination of applicable standards

Environmental liability risk and insurance: factual uncertainty

- Environmental risk, however, presents many difficulties to the insurance industry, specially when the focus is on the so-called **gradual pollution** phenomena, which are characterized by:
  - **factual uncertainty** and
  - **long terms effects** (long tail liabilities).

Environmental liability risk and insurance: factual uncertainty

- **Moral hazard -** the industry could erroneously perceive the insurance coverage and the insurance premium as a license to pollute
- **Adverse selection** - the classification of every specific risk undertaken is not accurately performed by the insurer

Environmental liability risk and insurance

- The value of impaired resources is very difficult to determine and there is no agreement on the subject
- The only damage measure that at present seems to be reasonable and predictable is the **cost of cleaning up impaired amenities**

Environmental liability risk and insurance

- - First party v. Third party coverage
- - Known v. Unknown pollution
- - On site v. Off site contamination

Environmental liability risk and insurance

- **Environmental liability policy (EIL)** (third party coverage)
- **Coverage for on site cleanup liability** (first party coverage)
- **Cleanup cost cap (brownfield site)** (this type of policy covers excess remediation costs due to unknown or undiscovered contamination, poor remedial technology performance, regulatory changes and natural disasters. It is generally designed to address the risk and uncertainty associated with beginning or continuing an environmental remediation project)
- **Contractors pollution legal liability**
- **Transportation coverage**
- **Environmental coverage for landfills** (integrated insurance/ financial products)

Environmental liability risk and insurance

- **the issue of retroactive liability and the limits of liability**
- Retroactive liability and insurance are, in principle, incompatible.
- Limited applications: cleanup cost cap coverage (brownfield sites).
- Limits of liability:
  - Past pollution
  - Chronic pollution
  - Diffuse pollution
- Suitable alternative **Restoration fund**.