Calculate the economic impact: counts, YLL, DALYS, monetary impact

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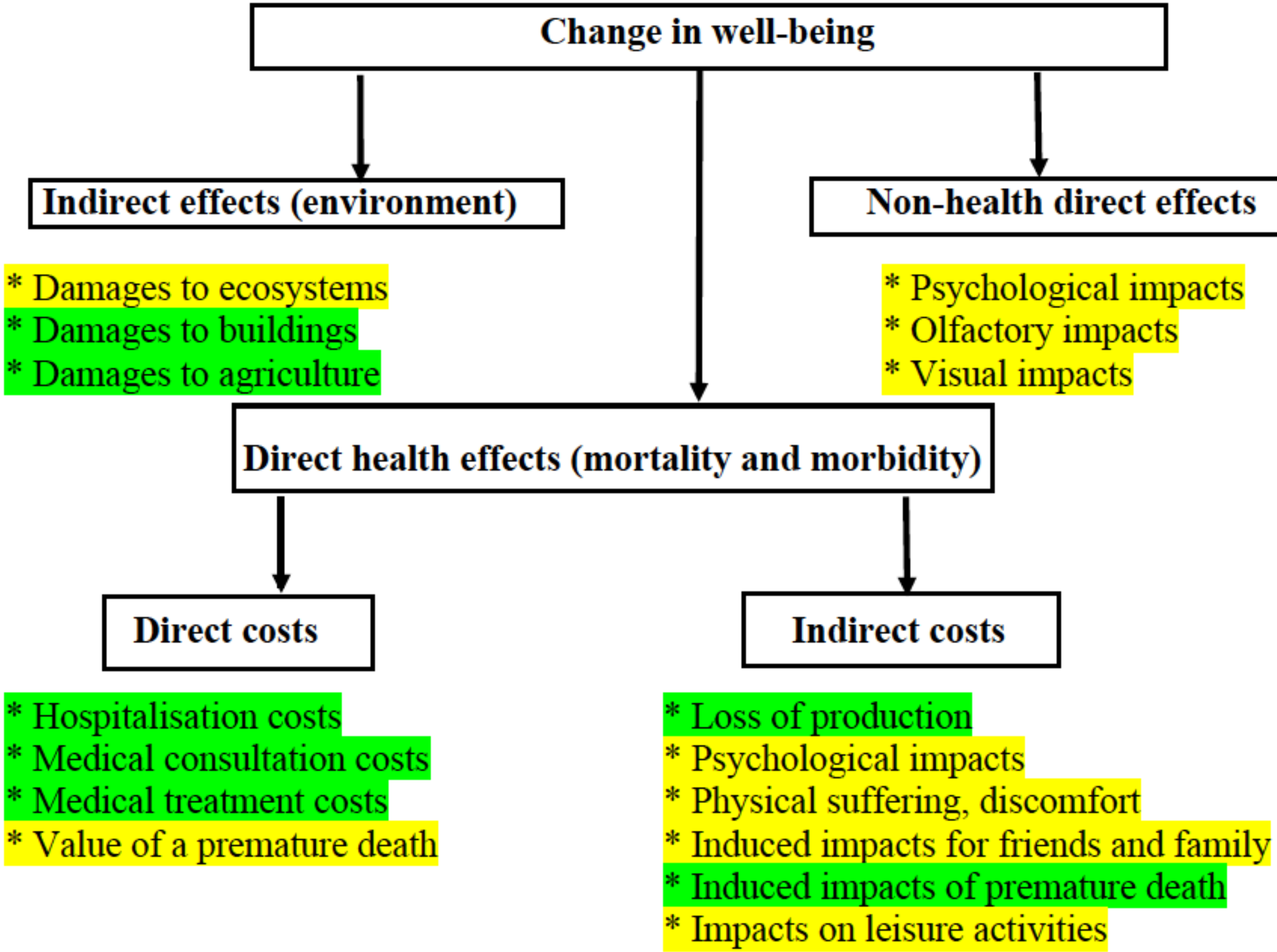
IEHIA, Trieste, April 23-27, 2018

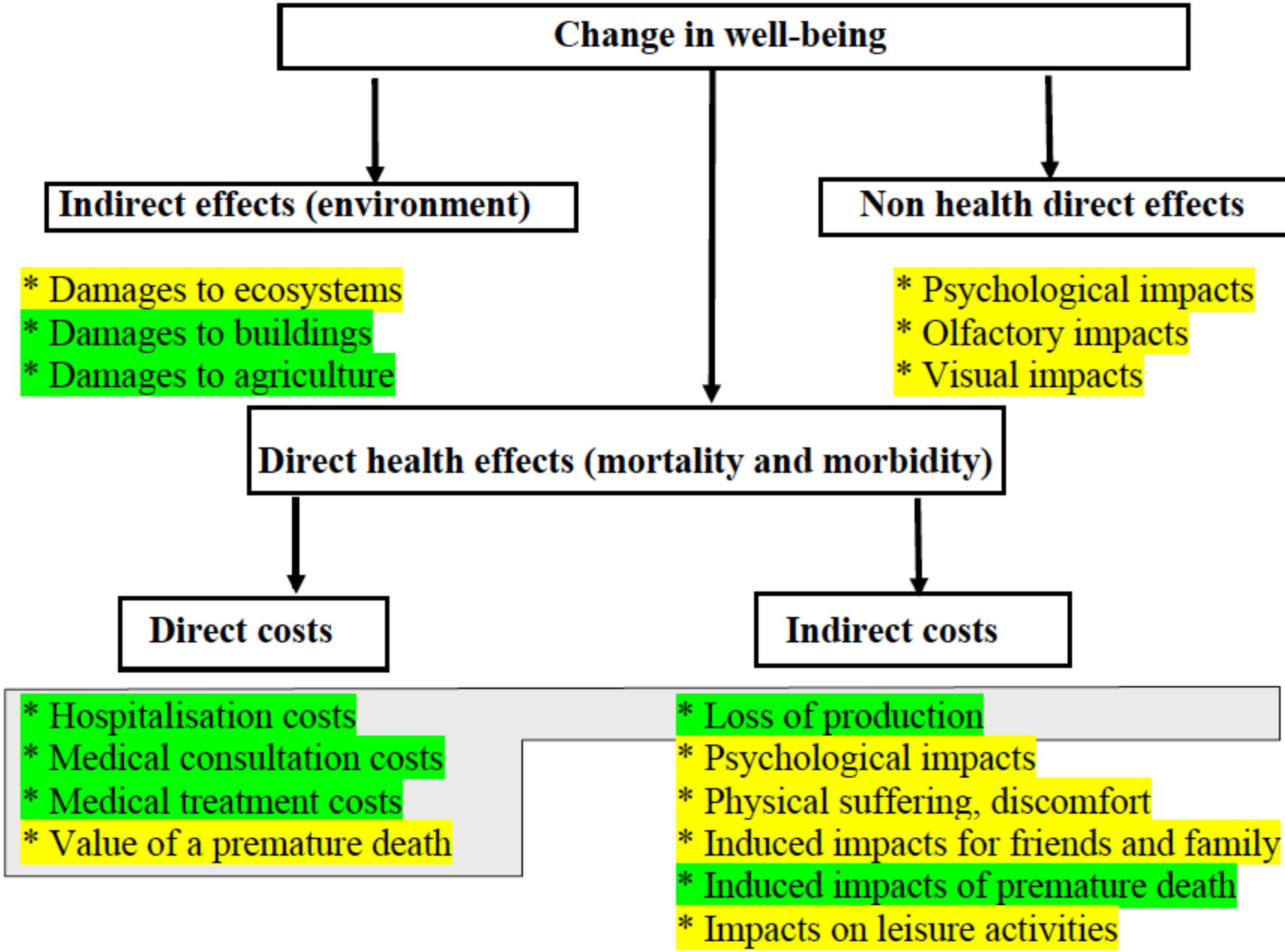
Sketch of the presentation

NO CONFLICT OF INTEREST

1. Assessment standpoint

1.1 Focus is on health effects

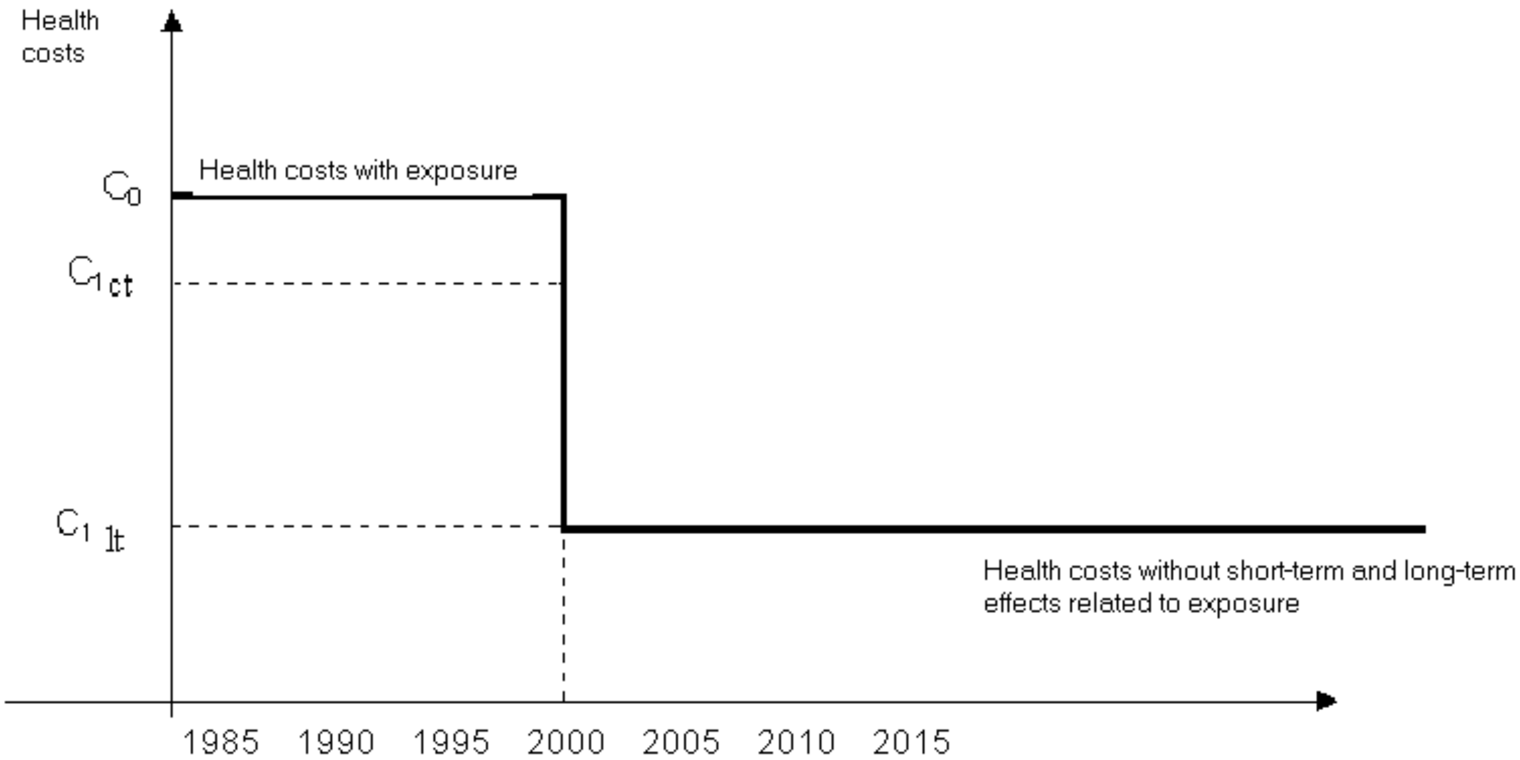



Change in well-being
Indirect effects (environment)
Non health direct effects
* Damages to ecosystems
* Damages to buildings
* Damages to agriculture
* Psychological impacts
* Olfactory impacts
* Visual impacts
Direct health effects (mortality and morbidity)
Direct costs
Indirect costs
* Hospitalisation costs
* Medical consultation costs
* Medical treatment costs
* Value of a premature death
* Loss of production
* Psychological impacts
* Physical suffering, discomfort
* Induced impacts for friends and family
* Induced impacts of premature death
* Impacts on leisure activities

1.2 What are we looking for?

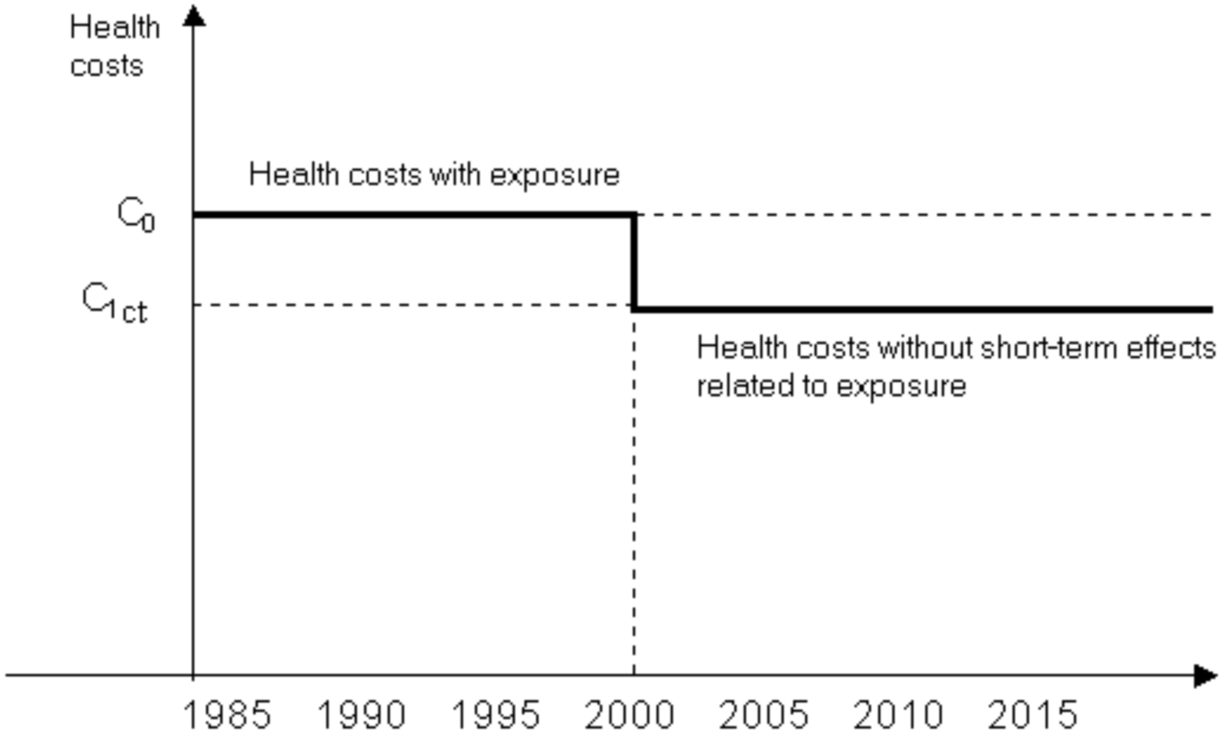
a) The global burden of air pollution (AP)

Use a **"steady-state" (or counterfactual) analysis.** Compute the global burden of AP as the difference in health costs between two levels of AP exposure.

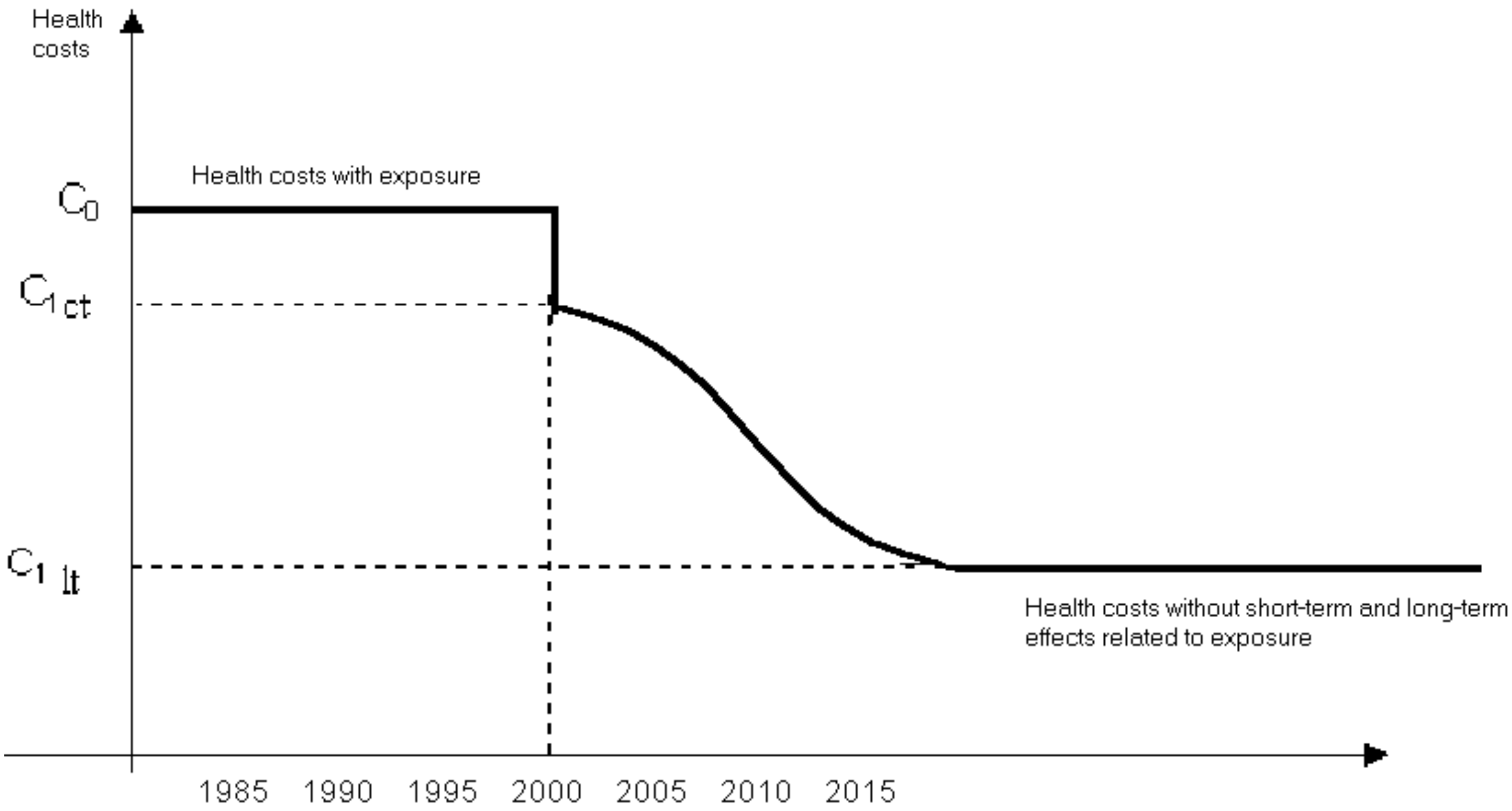


b) The future economic burden of today's AP

Use a **marginal (benefit) approach.** We estimate how a reduction in AP exposure today is going to impact the future flow of health costs.



For long-term (LT) health effects (chronic mortality and morbidity), a reduction in AP exposure today is not going to lead to the achievement of all chronic effects the same year, due to their cumulative properties.



The **“steady-state”** approach gives an idea of the magnitude of the public health issue.
☺ easy to compute (avoid epidemiological and parametric assumptions),
☺ easy to understand for people / stakeholders,
☺ informative and pedagogical,
☺ correct for short term effects,
☹ misleading for economic analysis (especially CBA) in presence of LT health effects.

The marginal approach is more useful from a policy / CBA perspective.
☺ correct for short term and long term effects,
☺ assess when and how long term effects occur (delay in getting the full LT benefits),
☺ can account for the delay in implementing a regulation,
☺ can account for change in population distribution (in age and health),
☹ more complex to implement,
☹ requires assumptions on discounting and delays used in the assessment.

Under standard assumptions, **LT health effects computed with the steady state approach should be divided by 1.6 to 2.5 in order to** be used in a CBA.

1.3 Accounting for uncertainty

Economic valuation cumulates uncertainties from other disciplines to own uncertainties.

Sensitivity analyses are common practice:

- very basic: restricted to economic values and epidemiological outcomes separately (with central, low and high values for instance),

- more complex: perform an overall analysis covering epidemiological data as well as economic values (Monte Carlo simulations).

2. Quick overview on economic valuation approaches in health

2.1. The market price approach: Observed preferences

Morbidity

Cost of illness (COI) use market prices. Especially suitable for the assessment of medical treatment costs, including hospitalizations and production losses due to illnesses.

☺ Easy to implement

☹ Cannot account for intangible costs (pain, grief, sufferings, psychological aspects…)

☹ Market prices and tariffs generally fixed by Governments or Health Agencies.

☹ Does not rely on individual preferences

=> frequently used for morbidity.

Mortality

Loss of production method (also known as Human Capital Approach) assumes that the value of life for a given individual is equal to the future production losses measured by the discounted present value of earnings over the remaining life expectancy.

☺ Easy to implement

☹ Ignore individual preferences, on which every economic value should be established

☹ The value of an individual is only represented by his/er production, and this production is only measured by earnings resulting from work.

- => What about markets imperfections (syndicates, regulations, discrimination…)?
- => What about non-working individuals (children or elderly)?

☹ Discount rate plays a major role, particularly for children and young adults.

=> almost no longer used for mortality.

The two other approaches try to be as close as possible from a market, and allow non-market values to be accounted for.

2.2. Indirect approach: Revealed preferences

Involve situations in which people actually face indirect trade-offs between money and physical risk (of death or of illness) => **willingness to pay (WTP)**.
Use information available on labour markets, housing market (via air pollution exposure), averting goods (smoke detectors, seatbelts, airbags …).

☺ Deal with actual choices resulting from individual decisions.

☹ Difficult to isolate a particular risk reduction when different risks are simultaneously reduced (being injured, loss of goods, disadvantages related to a specific job).

☹ Postulate perfect information on the goods, the associated risks, the influence of risks attributes on the probability of death or of being ill...

☹ Population not necessarily representative due to self-selection and/or specific populations (workers, home owners…).

=> sometimes used for mortality and/or morbidity.

2.3. Direct approach: Stated preferences

Uses surveys to ask individuals more or less directly about their **WTP** for improved safety or decrease the probability of having an illness (or symptoms).

☺ Easy to implement.

☺ Do not require a heavy theoretical framework compared to revealed preferences, besides the fact that individuals are able to assess the risk and will answer truthfully.

☺ Allow a very precise description of the trade-off and the risk at stake (context).

☹ Subject to sources of errors / biases that may not always be controlled:

* hypothetical bias	* strategic bias
* elicitation bias	* framing effect (the way questions are worded)
* context effect	* wrong sensitivity to risk reduction variations.

☹ What about the understanding / experience of an illness for those that never experienced them? For children, should we use parents', own or the general population assessment?

=> increasingly used for mortality and/or morbidity.

Can COI and WTP be combined?

No (generally), because of possible double counting.

A possibility: use the market price approach as an “at least” approach for the costs borne by the society, and the non-market approaches for the costs borne by the victims.

3 Mortality issues

3.1. How to express the mortality effects of AP exposure?

Intuition: the overall number of deaths is unchanged between the two steady states (due to the dead anyway effect) => only ages at deaths are shifted (premature death)

Source: Chanel, Scapecchi and Vergnaud (2006)

Four ways can be used to express a change in mortality risk (based on the same RR).

a) "Number of premature deaths": implicitly assume an average of ***y*** years of life lost (YLL) per premature death. In general, for AP, *y* around 10 years has been used (or implicitly obtained) in several studies for LT effects, *y* around 1 year for ST effects.

b) "**Average change in life expectancy**": applied to the whole population of interest. We obtain an average gain of ***x*** month(s) per individual (generally between 1 and 10 months according to the studies).

c) "Overall number of YLL": ***x*** times the size of the population involved OR ***y*** times the number of premature deaths.

d) "Number of YLL by age": use dynamic life-tables that compares for each age, the number of YLL saved.

For a) => we need a Value for a Prevented Fatality (VPF).
For b) c) and d) => we need a Value Of a Life Year saved (VOLY).

A few studies only estimate the VOLY directly => it is common to derive it from a VPF as a flow of discounted age-independent VOLY (Viscusi et al., 1997; Leksell and Rabl, 2001):

$$VPF_j = VOLY \sum_{t=j}^{T} \frac{S_{t,j}}{(1+\delta)^{t-j}}$$

where: - VPF_j for an individual of age *j*,

- δ is the marginal rate of time preference,

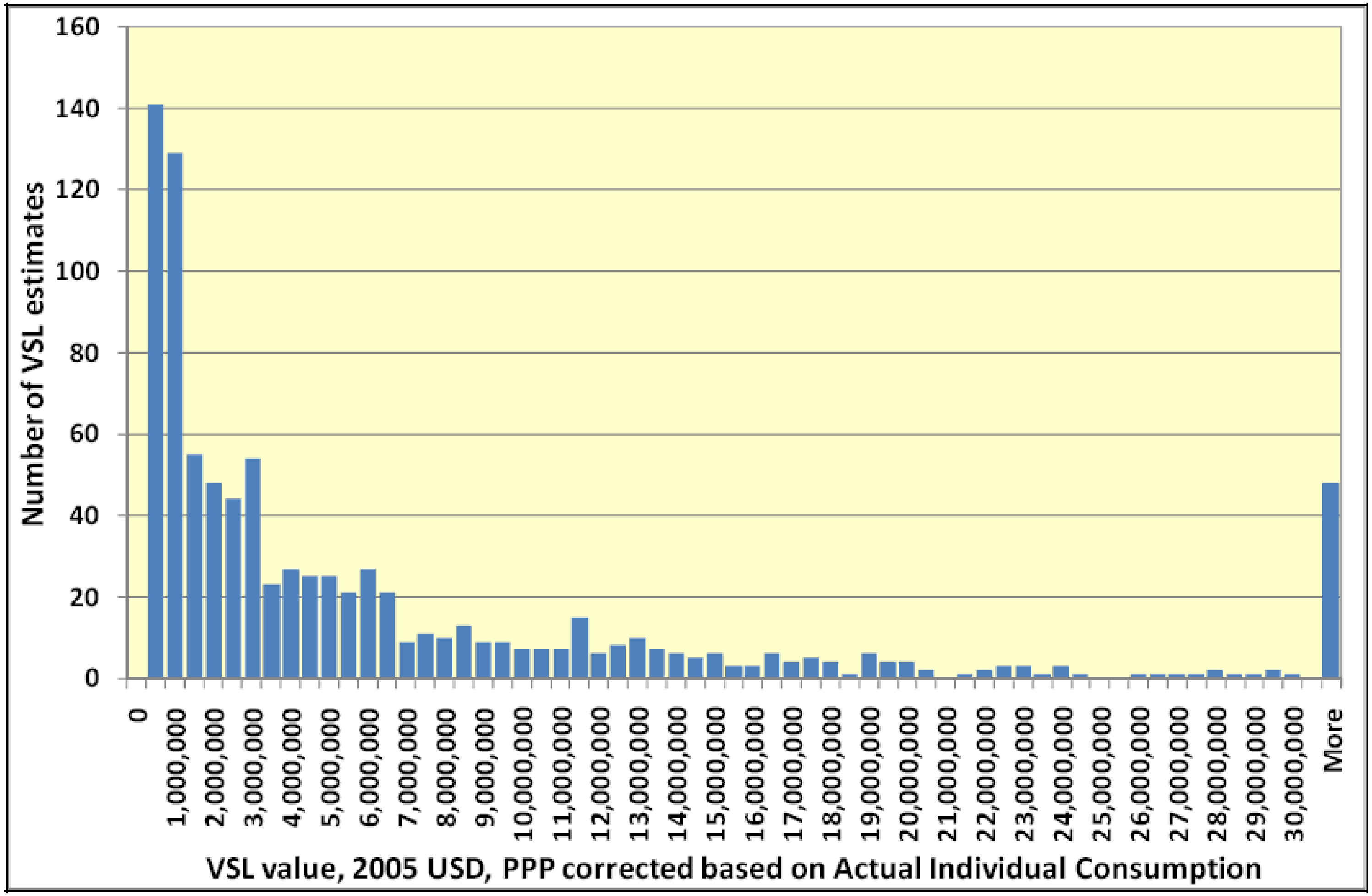
- $S_{t,j}$ is the survival probability at age *t* conditional on having survived until age *j*.

This way to derive VOLY is a controversial issue among economists.

3.2. What do empirical economic evaluations of mortality effects tell us?

Empirical assessments generally provide a range between € 0.8 and € 7 million.

Figure 1. Frequency distribution of mean VSL estimates used in the meta-analysis, truncated

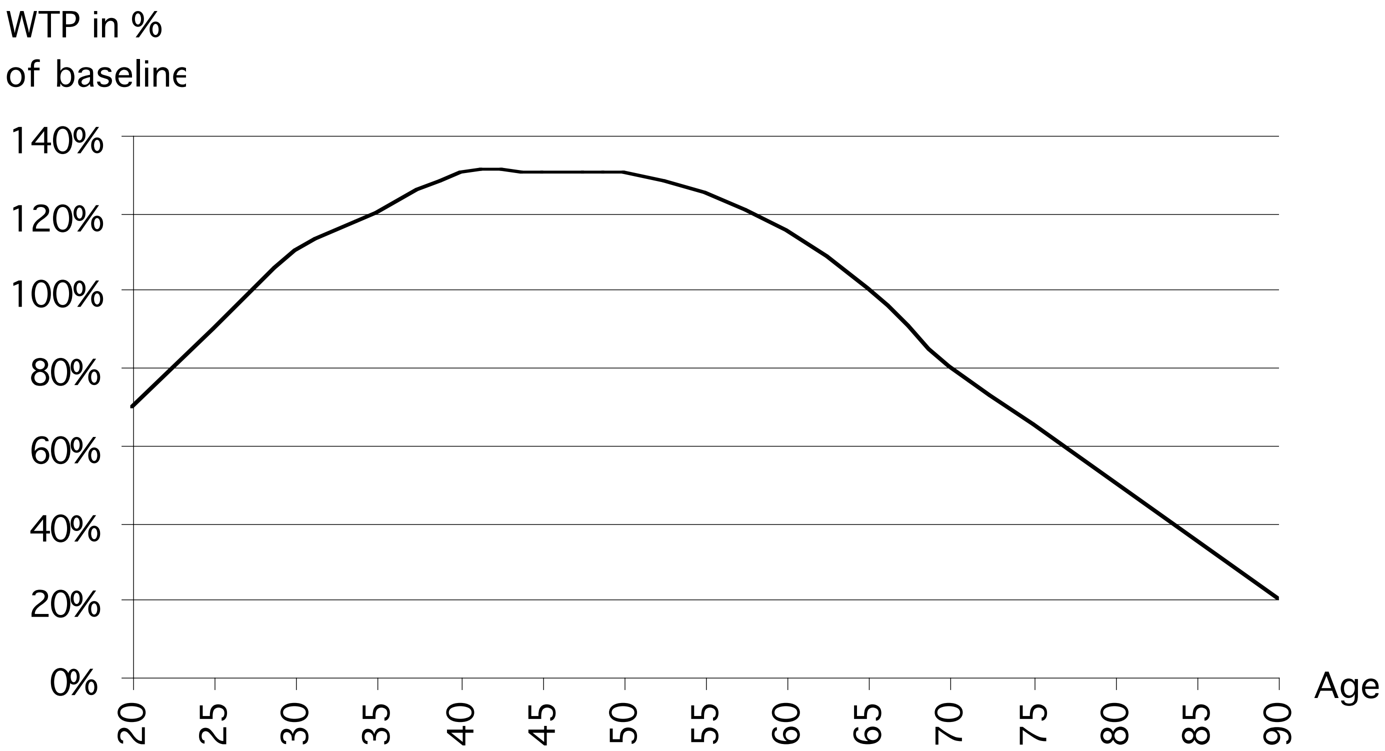


Source: Lindhjelm et al. (2010), p.17 (involves 854 observations from 75 surveys).

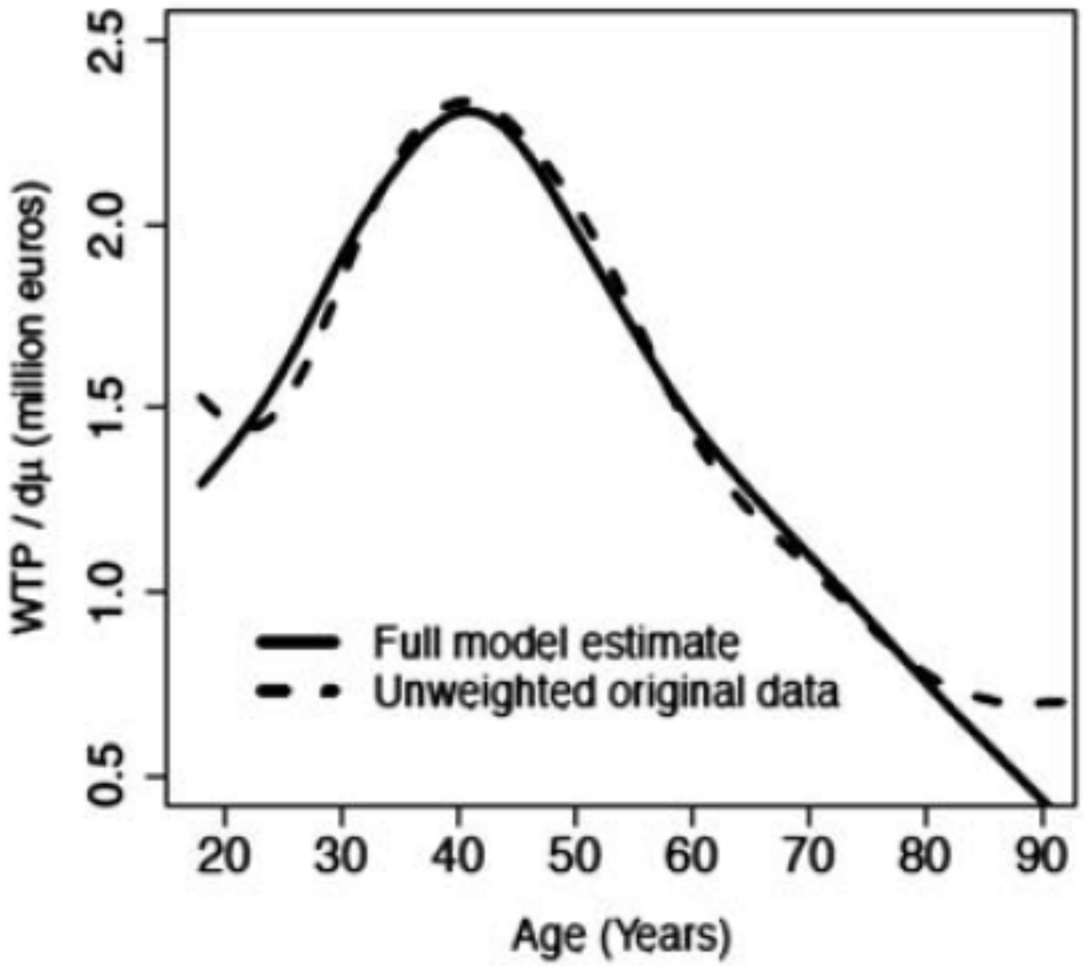
Two lessons: VPF depends on - the attributes of the victims,
- the attributes of the risk of death.

a) Attributes of the victims

* Age at death (and remaining life expectancy)
* Degree of premature death
* Life quality at death (QALY / DALY).



Source: Sommer et al. (1999).



Source: Chanel & Luchini (2014)

Conclusion: it may be appropriate to adjust the VPF to reflect WTP values of people at different ages or to use VOLY.

b) <u>Attributes of the risk of death</u>

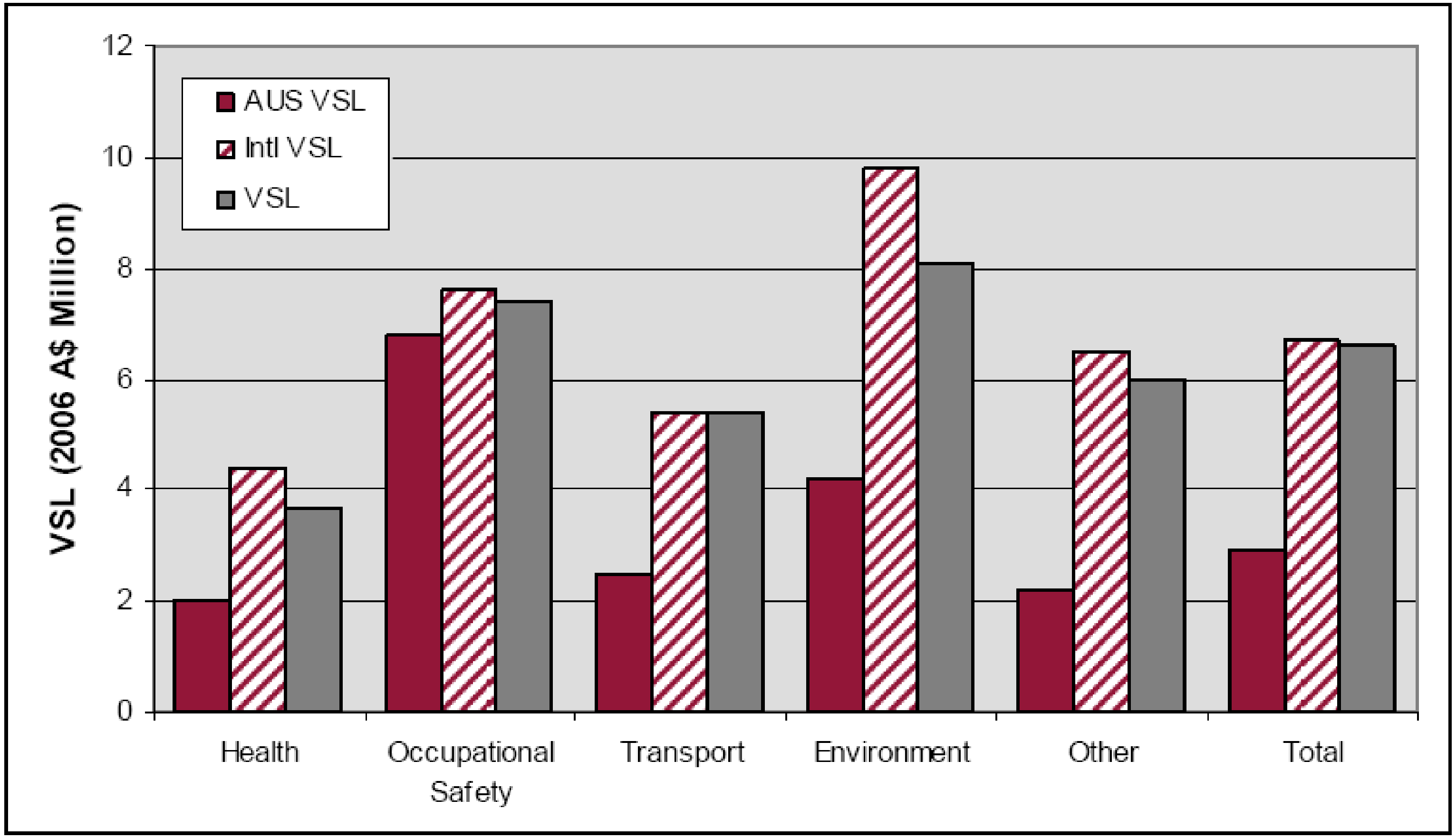
Fischhoff (1989) has shown that the following attributes decrease the tolerance to risk … and hence increase the WTP for a risk decrease => increase VPF.

* Involuntary
* Personally uncontrollable
* Non responsible
* Unfamiliar
* Dreadful
* Uncertain
* Catastrophic
* Unfair
* Immediate
* Memorable
* Trustworthy
* Not related to direct personal benefit

Conclusion: "Accurate valuation requires the use of scenario-specific values" (Hammitt, 2007): VPF should in particular depend on the specific context (here, AP exposure).

Illustration

Figure 4—6 Summary of VSL estimates (medians) by sector and Australia/international, 2006 A$million



Source: ASCC (2008), p. 64 Figure involves 244 studies / observations.

3.3. How to express mortality effects in monetary terms?

Hundreds of studies assess VPF / VOLY in accidental contexts (in transportation, at work, harmful substances in food or medications) but a few deals with the AP context. Four strategies may account for differences in risk and victim attributes.

331) Ex post correction methods

a) Apply an overall correction factor to account for age & quality of life at death

Intuition

The context of road accident related fatal risk differs from air pollution related risk, which is to a large extent involuntary and beyond the responsibility and control of those exposed to it. Moreover air pollution related risk is less often connected to a direct personal benefit

=> AP related risk tolerance is likely to be lower than for fatal road accidents in a range of a factor 1.5 to 2.

However, the average age of the air pollution related fatalities is much higher than for victims of fatal road accidents (75-85 years vs. 40 years of age).

=> correction for advanced age.

Examples

France (Boiteux, 2001)

Start from € 1.5 million for an accidental death in public transportation.

Multiply by 0.67 for a death in private transportation **=>** €1 million.

Multiply by 0.53 to account for differences in quality and quantity of life years lost => € 0.53 million to obtain a VPF due to AP exposure.

Europe (Infras-IWW, 2004)

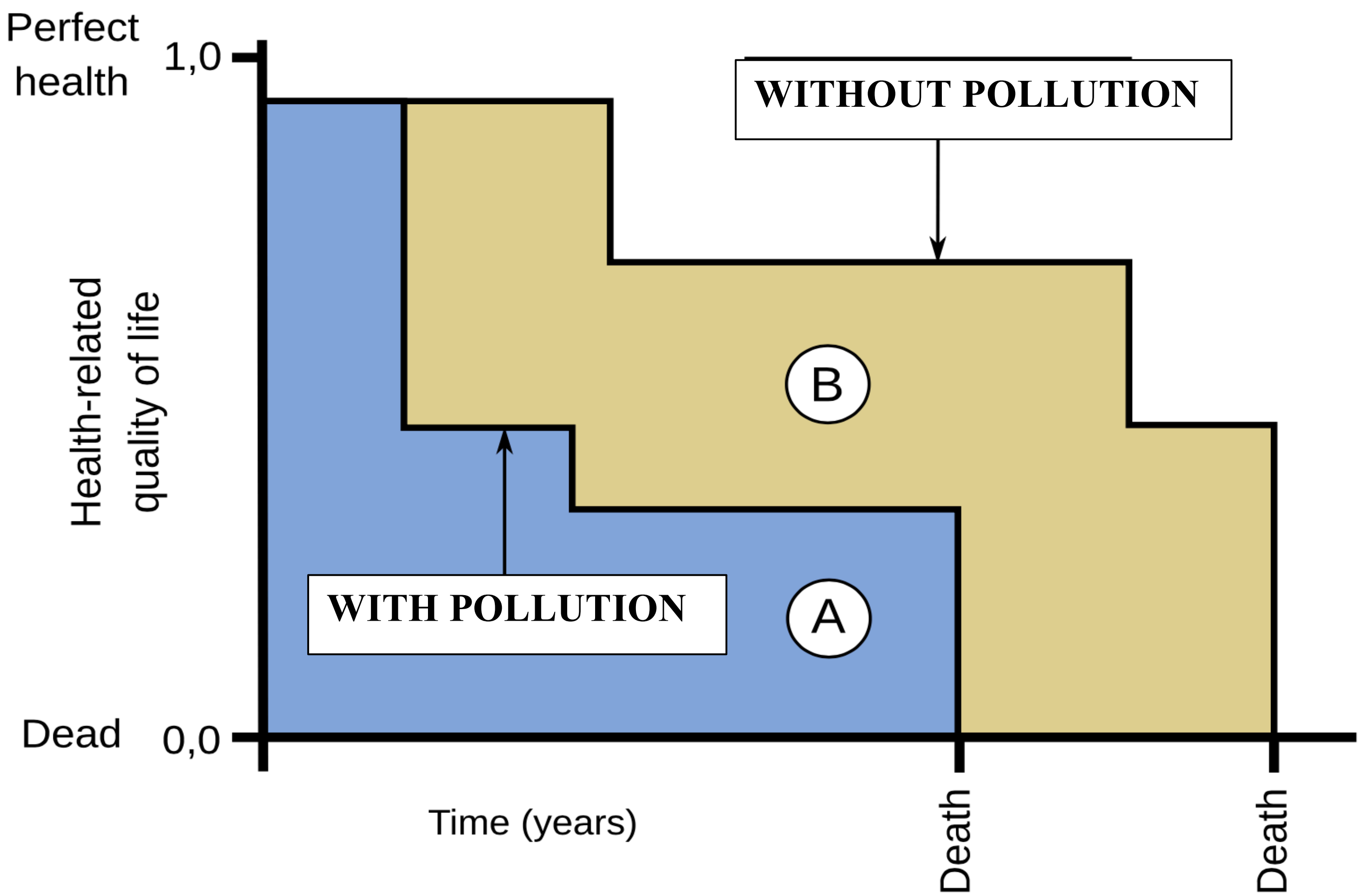
Start from € 1.5 million for an accidental death in transportation.

Divide by 0.61 to obtain a VPF due to AP exposure => € 0.915 million.

Other corrections applied: Pearce & Crowards (1996) and UK DH (1999) proposed 0.7 in UK; Sommer et al. (1999) proposed 0.61 in three European countries; Ostro and Chestnut (1998) proposed 0.8 in USA.

b) Use Quality-Adjusted Life Year (QALY) to account for the health state

1 QALY = 1 year of life x health-related quality of life of this year (utility)
with quality weight = 1 for perfect health and 0 for death.



Source : Jmarchn - wikimedia.org

Problems with QALY

☹ Several ways to assess quality associated to health states:

- Indirecty: EQ-5D (EuroQol-5 Dimensions), HUI2 or HUI3 (Health Utilities Index Mark 2 or 3), AIS (Abbreviated Injury Scale), SF-6D (Short-Form-6 Dimensions), QWB (Quality of Well-Being), AqoL (Assessment of Quality), 15D (15 Dimensions) …
- Directly: questionnaires that categorises health states thanks to surveys.
    - Time-trade-off (TTO): a given health state for a given duration vs. a better health state for a shorter duration,
    - Standard gamble (SG): a given health state vs. a lottery involving perfect health and death,
    - Visual analogue scale (VAS): rate health states thanks to a scale.

☹ Quality of life at death due to AP exposure is unknown and would require strong assumptions.

☹ QALY are not very used in HIA of AP exposure.

☹ Double penalty for people with poor health: they are ill, and their YLL have less value than those in perfect health!

332) Ex ante correction method in stated preferences

a) Mimic air pollution context

Idea: Mimic the AP context with hypothetical scenarios that involve some of the features of the AP-related health effects (Alberini and Krupnick teams):

- similar diseases (mainly respiratory, cardiovascular and lung cancer),
- similar magnitude in annual risk mortality change (1-in-10,000 to 5-in-10,000),
- similar age-class of the victims (generally 40 to 75-year-old).

Median VPF (in €million): Japan (0.5), Canada (1.3), USA (1.1), France (1.1), Italy (1.6), UK (0.69), and Brazil (0.8-1.3).

VOLY for France, Italy and UK: €54,000 (median), €163,000 (mean); for Brazil $60,000 to $ 150,000.

Note that these studies never mention AP as the source of the reduction in mortality risk.

b) Use an air pollution contextual scenario in stated preferences

Explicitly mention that AP was the origin of an increase in mortality risk.

- Chilton et al. (2004) in UK => **VOLY of € 45,000**.

- Desaigues et al. (2011) in 9 European countries => **VOLY of € 40,000** for Europe-25.

- Chanel and Luchini (2014) in France => **VPF of € 2.15 million** and **VOLY of € 150,000**.

- Hammitt and Liu (2004) in Taiwan => **VPF in the range € 1.5 -2.2 million**.

- Wang and Mullahy (2006) in China => **VPF equivalent to € 2.5 million** in USA.

- Vassanadumrongdee and Matsuoka (2005) in Thailand => **VPF in the range € 0.8 - 1.4 million**.

SUMMARY ON MORTALITY VALUATION

Best choice: use a (country)-specific contextual VPF or VOLY.

Reasonable choice: use the meta-analytic value proposed by OECD 2012, and used by World Bank-IHME in 2016 and WHO-OECD in 2015 to assess health effects of AP:

Suggested VPF: €3 million for OECD countries and adjust for differences in average income / Gross Domestic Product (GDP)/ Purchasing Power Parity (PPP) between countries.

Suggested VOLY: €40,000-120,000 as central estimate

The use of QALY is currently not widespread in environmental HIA (including AP)

4 Morbidity issues

4.1. Economic valuation of acute health effects

Literature is rich enough to allow us to select the most relevant values for the health outcomes at stake **(COI or WTP)** and valuation of loss of production.

Table 13. Air Pollution-Related Health Impacts -- Physical Units & Costs

Impact	Unit	Physical Impacts	Unit values (€)
Years of Life Lost (YOLL)	[1000 years]	886	104760
Congestive heart failure older 65	[1000 cases]	14.3	3260
Chronic bronchitis, adults	[1000 cases]	107	169330
Restr. Activity days, adults	[1000 days]	110000	110
Bronchodilator usage, adults	[1000 cases]	24600	40
Cough, asthmatics, adults	[1000 days]	26100	4
Lower resp. symptoms, adults	[1000 days]	9400	8
Bronchodilator usage, children	[1000 cases]	2950	40
Cough, asthmatics, children	[1000 days]	5100	45
Lower resp. symptoms, children	[1000 days]	4000	8
Chronic cough, children	[1000 epis.]	2280	240
Cerebrovascular hosp. Adm.	[1000 cases]	29	16730
Respiratory hosp. Admission	[1000 cases]	27	4320
Minor restr. Activity days, adults	[1000 days]	14000	45
Asthma attack, asthmatics	[1000 days]	390	75
Symptom days	[1000 days]	85000	45
Total			

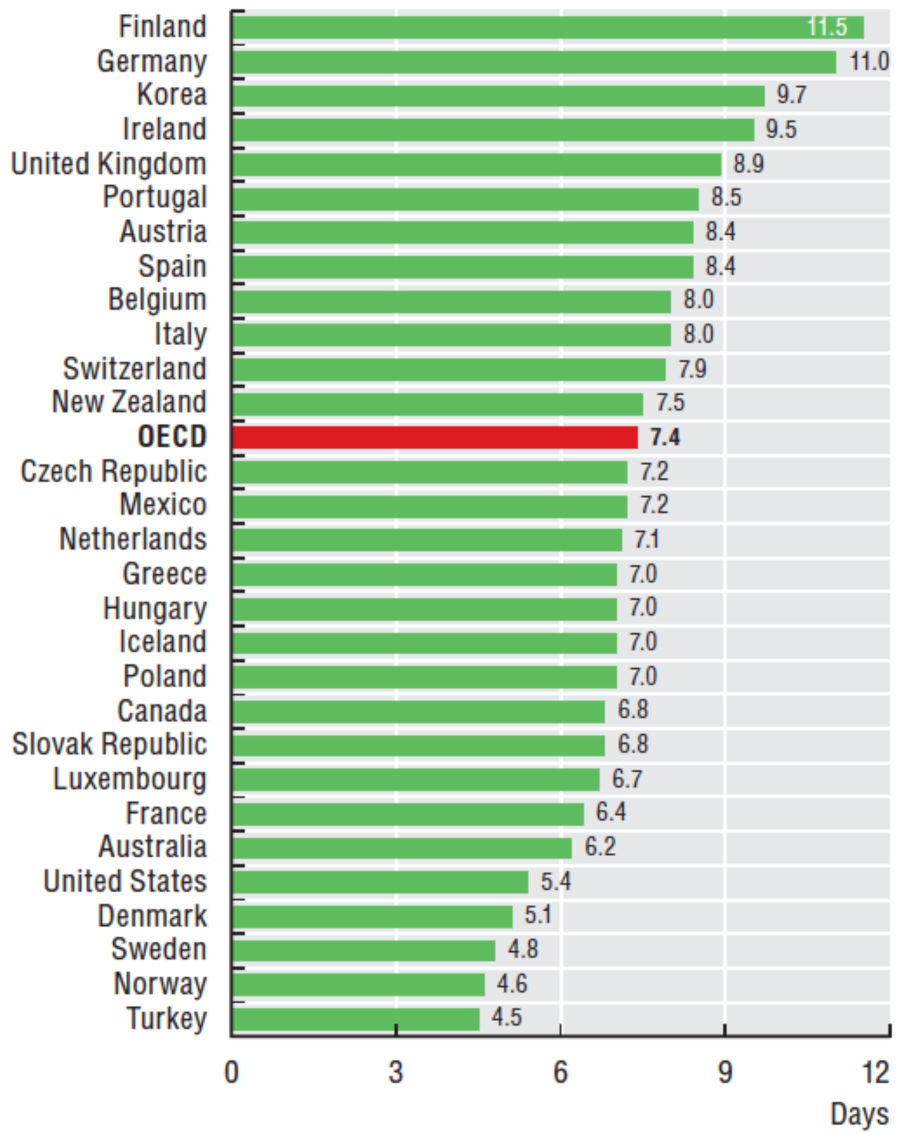
Source: Hunt and Ferguson (2010), p. 17; derived from Droste-Franke and Friedrich (2004).

Valuation (all units – €/case): distribution – normal	Standard error	Best estimate
Chronic mortality (VOLY, mean, €/life year)	14,600	120,000
Chronic mortality (VOLY, median, €/life year)	3,700	52,000
Chronic mortality (VSL, mean, €/death)	235,000	2,000,000
Chronic mortality (VSL, median, €/death)	74,000	980,000
Infant mortality (€/death)	1,000,000	3,000,000
Chronic bronchitis, >27 years (€/case)	63,000	190,000
Respiratory hospital admissions (€/event)	670	2,000
Cardiac hospital admissions (€/event)	670	2,000
Restricted activity days, working age (€/day)	27	82
Lower respiratory symptoms, adults and children (€/day)	13	38
Consultations asthma, URS (€/event)	18	53
RADs, young, elderly (€/day)	23	69
Use of respiratory medication (€/day)	0.33	1

Source: Cafe Methodology (2005).

BUT we should account for differences in Health systems, both for health outcomes and economic valuation.

4.5.2 Average length of stay following acute myocardial infarction (AMI), 2007 (or latest year available)



Source: OECD (2009)

4.2. Economic valuation of chronic health effects

Economic valuation based on COI

At least four ways to assess the economic cost:

- Standard COI: average remaining life duration in years x average number of episodes per year x average cost per episode. For instance, the total per-person annual costs of asthma averaged $4,912, with direct and indirect costs accounting for $ 3,180 (65%) and $ 1,732 (35%), respectively (Cisternas et al., 2003).

- COI using difference in average cost: For instance, the difference in hospital and primary care costs per person year for COPD population and non-COPD in Denmark is evaluated at $4,412 (Bilde et al., 2007).

- COI using matching methods: Baser (2006), for instance, compares estimated total health-care expenditures for patients with asthma and patients without asthma, and obtain an annual estimation of $4,400 in USA.

- Estimated COI using Markov model: It computes costs of COPD by starting from mutually exclusive COPD states (from mild to death), makes subjects move through these states in pre-specified time intervals, with costs associated to each states.

Economic valuation based on WTP

Literature is rich enough to allow us to select the most relevant values for the health outcomes at stake.

Open issue: Can the WTP to avoid an outcome caused by AP exposure and the WTP to avoid an outcome caused by another factor (or a non-specified factor) be considered as similar?

SUMMARY ON MORBIDITY VALUATION

Suggested choice: use COI as partial assessment and WTP for actual social cost (to account for intangible costs).

Use country-specific data for both health outcomes and economic unit value.

Account for loss of production based on country-specific average wage per day.

5. Quantifying the global Burden of Disease: DALY

Proposition by World Bank (1993) to quantify the global Burden of Disease by using one metric for mortality and morbidity: Disability Adjusted Life Years (DALY).

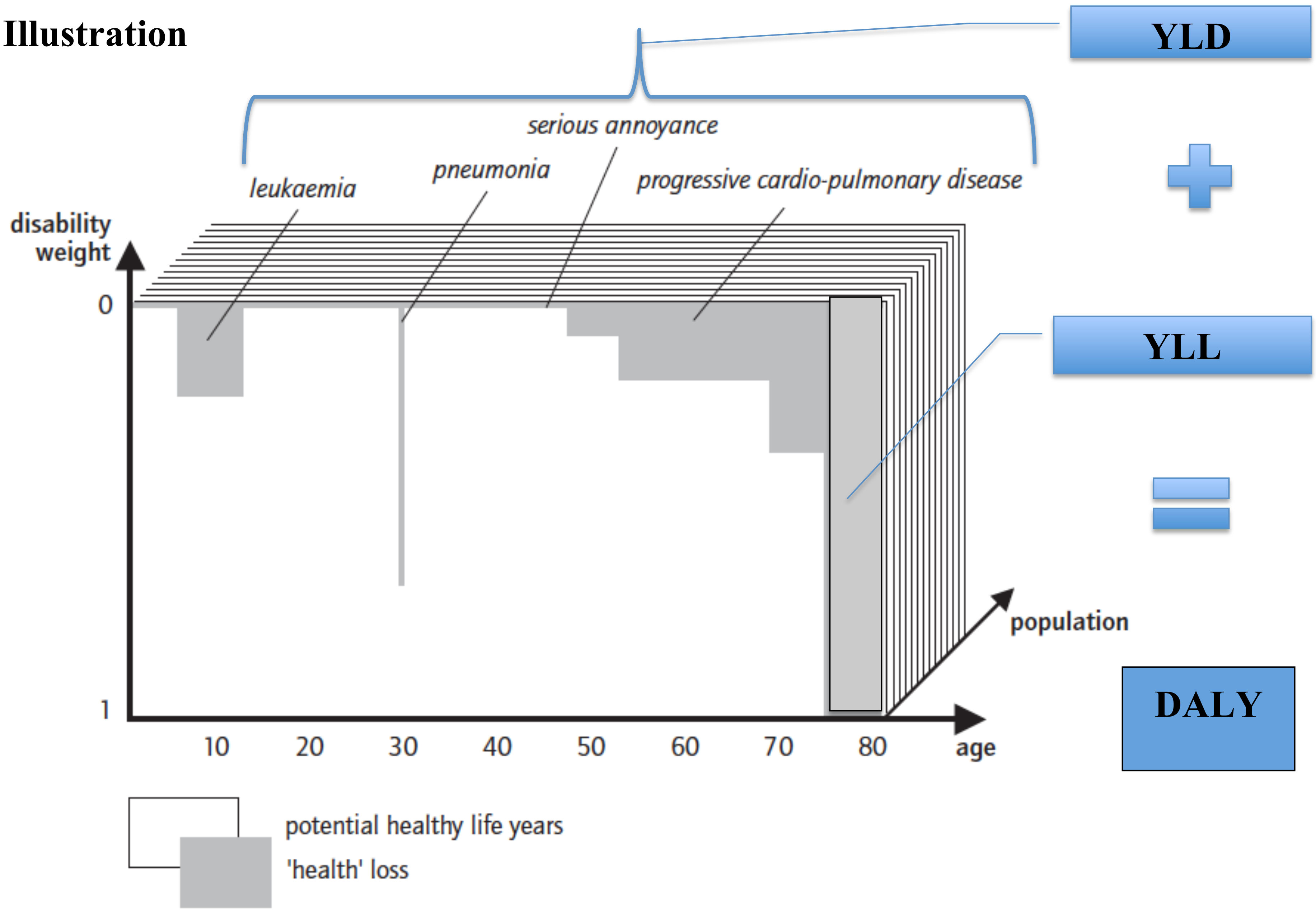
DALY = Years of Life Lost + Years of Life lost due to Disability = YLL + YLD

with: - YLL = number of deaths (#) x number of years life lost (Duration, D)
- YLD = number of cases (#) x Severity (S) x Duration (D)

Severity S is measured with perfect health = 0 and death =1, based on **one** health scale (WHO), with about 250 diseases and symptoms.

Main difference w.r.t QALY:
- assign different weights to life years lived at different ages (discounting),
- the origins of disability and quality of life weights differ.

Illustration



Source: De Hollander (2004)

Environmental factor	Health outcome	#[a]	S[b]	D[c]	DALYs
particulate air pollution long-term exposures	*mortality*				
	- total	15594	1.0	10.9[d]	169000
	- cardiopulmonary mortality	8041	1.0	8.2[d]	65750
	- lung cancer	439	1.0	13.0[d]	5400
	morbidity				
	- chron. resp. sym. childr.	10138	0.17	1.0[f]	1710
	- chronic bronch. adults	4085	0.31[e]	1.0[f]	1920
particulate air pollution short-term exposures	*mortality*				
	- respiratory	218	0.7[g]	0.25[h]	37
	- coronary heart disease	253	0.7[g]	0.25[h]	42
	- pneumonia	191	0.7[g]	0.25[h]	33
	- other	452	0.7[g]	0.25[h]	92
	hospital admission				
	- respiratory	3520	0.64	0.038[i]	86
	- cardiovascular	6060	0.71	0.038[i]	164
	emergency room visits				
	- respiratory	32500	0.51	0.033[i]	584
	aggravation of asthma				
	- asthmatic attacks	212000[j]	0.22[k]	0.005[l]	253
	- use of bronchodilators	530000[j]	0.22[k]	0.005[l]	630
	aggravation of respiratory symptoms				
	- upper respiratory tract	237500[j]	0.05	0.02	215
	- lower respiratory tract	94300[j]	0.21	0.04	760
	affected lung function				
	- decreased FEV1 >10%	548000[j]	0.000	0.003	0

6. Conclusion

Mortality

- **Best choice: Use country-specific and context-specific data for VPF / VOLY, based on revealed or stated preference method.**
- **Alternative: Adapt the value proposed by OECD for VPF (€3 million) and adapt to country (PPP, GDP, income growth, inflation).**

Morbidity

- **Use COI as lower bound (costs borne by society), WTP as costs borne by victims.**
- **Use country-specific data for both health outcomes and economic unit value.**

Global burden of AP

- **When morbidity data are not available, 10% of the mortality economic assessment seems to be a reasonable estimate (like in OECD, 2014).**
- **If used in a CBA, pay attention to the delay issue for LT effects.**