Uncertainty of Damage Costs

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Sources of uncertainty:

(some overlap between categories)

i) uncertainty of **data** and **parameters** of models

e.g. slope of a dose-response function, cost of a day of restricted activity, and deposition velocity of a pollutant;

ii) uncertainty about **choice of models**

e.g. assumptions about causal links between a pollutant and a health impact, assumptions about form of a dose-response function (e.g. with or without threshold)

iii) uncertainty about **policy** and **ethical choices**

e.g. discount rate for intergenerational costs, and value of statistical life;

iv) uncertainty about the **future**

e.g. the progress of medicine in the treatment of cancers;

v) idiosyncrasies of **the analyst**

e.g. interpretation of ambiguous or incomplete information, and human error.

Uncertainty ≠ variability

Don’t confuse uncertainty and variability of impacts!
Both can cause estimates to change,
but in very different ways and for totally different reasons:

Uncertainty: insufficient knowledge at the present time,
future estimates may be different when we know more.

Variability: damage cost can vary with the type of source
(where, ground level or tall stacks, …).
Damage cost per kWh are proportional to the emissions and vary with the technologies used.
These variations are independent of the uncertainties.

Difficulties

Quantifying the sources of uncertainty in this field is problematic because of a general lack of information.

Usually one has to fall back on subjective judgment, preferably by the experts of the respective disciplines.

The uncertainties due to **strategic choices of the analyst**, e.g. which dose-response functions to include, are difficult to take into account in a formal uncertainty analysis.

$\Rightarrow$ the **comprehensive uncertainties** can be much larger than the ones that have been quantified (uncertainties due to data and parameters).

Systematic analysis of uncertainties of environmental impacts has rarely been done: usually people indicate simple "high" and "low" estimates, taking only high and low estimate for a particular parameter.

Methods for Estimating the Uncertainty

i) For uncertainty of data and parameters of models:

Statistical analysis

ii) uncertainty about choice of models:

Expert judgment and Statistical analysis

iii) uncertainty about policy and ethical choices:

Sensitivity analysis

iv) uncertainty about the future:

Sensitivity analysis

v) idiosyncrasies of the analyst:

Be careful! And use require peer review!

Statistical analysis for all sources if one can characterize the sensitivity scenarios by probability distributions

Uncertainty due to Lack of Information on Toxicity of the Constituents of PM

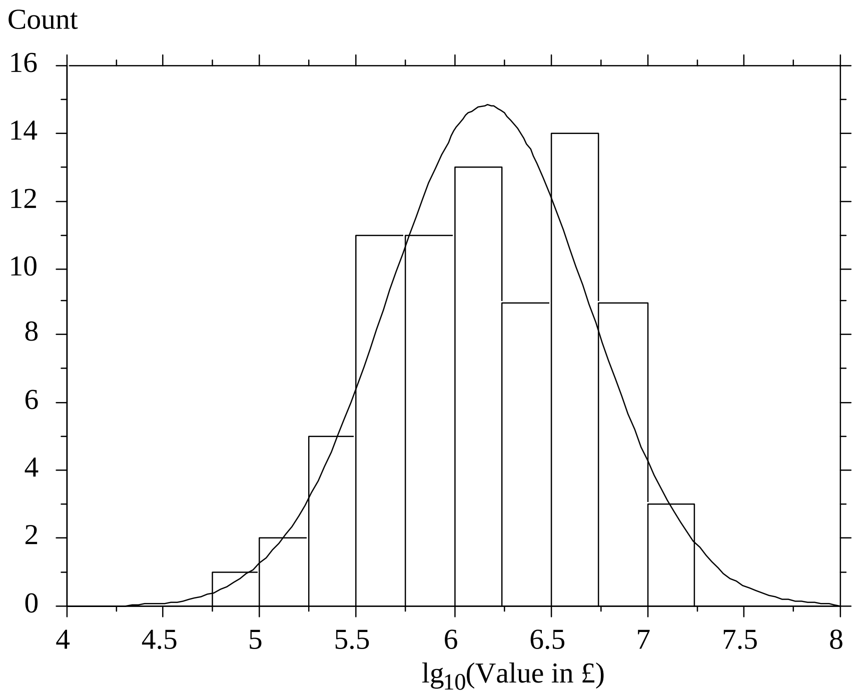
Most CRFs (Concentration-Response functions) for air pollution are based on **PM_{10} or $PM_{2.5}$ in ambient air** (including natural soil particles, apparently not very toxic),

but for environmental policy one needs to know what damage is caused by each of the **pollutants emitted** (by cars, power plants etc):
•primary particles from combustion (apparently very toxic),
•NO_x (precursor of nitrate aerosols, hardly any data on toxicity),
•SO_2 (precursor of sulfate aerosols, apparently toxic).

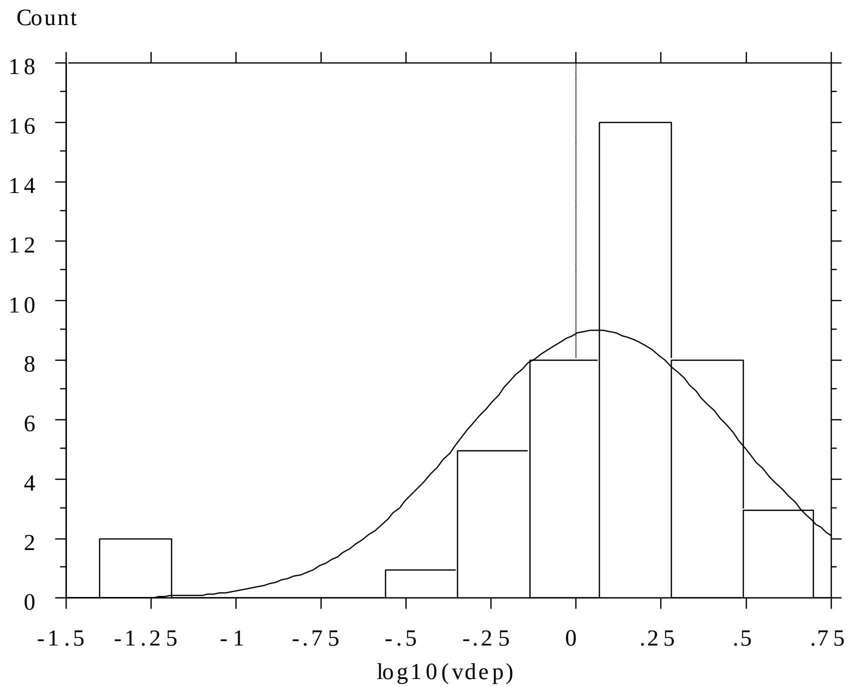
At the present time epidemiologists and toxicologists are not yet very certain about causal links between individual pollutant and impacts

$\Rightarrow$Large uncertainty about contribution of individual pollutants but overall cost of health damage is quite firm

Shape of the Distributions



Distribution and **lognormal** fit of **VSL**, in $£_{1990}$, in review of 78 studies [data of Ives, Kemp and Thieme 1993]



Distribution and **lognormal** fit of values for dry **deposition velocity** [in cm/s] of SO_2 over different surfaces [data of Sehmel 1980].

Simple Model

Calculation is approximately **multiplicative**

Uncertainty of product $y = x_1 \, x_2 \dots x_n$

Uncertainty of sum $\ln(y) = \ln(x_1) + \ln(x_2) + \dots + \ln(x_n)$

Central limit theorem

$\Rightarrow$ lognormal distribution is "natural" distribution for products

(if y=ln(u) is lognormal, u=exp(y) is normal).

$\Rightarrow$ **distribution of errors is approximately lognormal**

(unless dominated by a distribution that is very different from lognormal)

characterized by **geometric standard deviation** $\boldsymbol{\sigma_g}$

$\Rightarrow$ **Multiplicative confidence intervals** about **median** $\boldsymbol{\mu_G}$ (=geometric mean)

68% between μ_G/σ_G and $\mu_G \, \sigma_G$

95% between μ_G/σ_G^2 and $\mu_G \, \sigma_G^2$

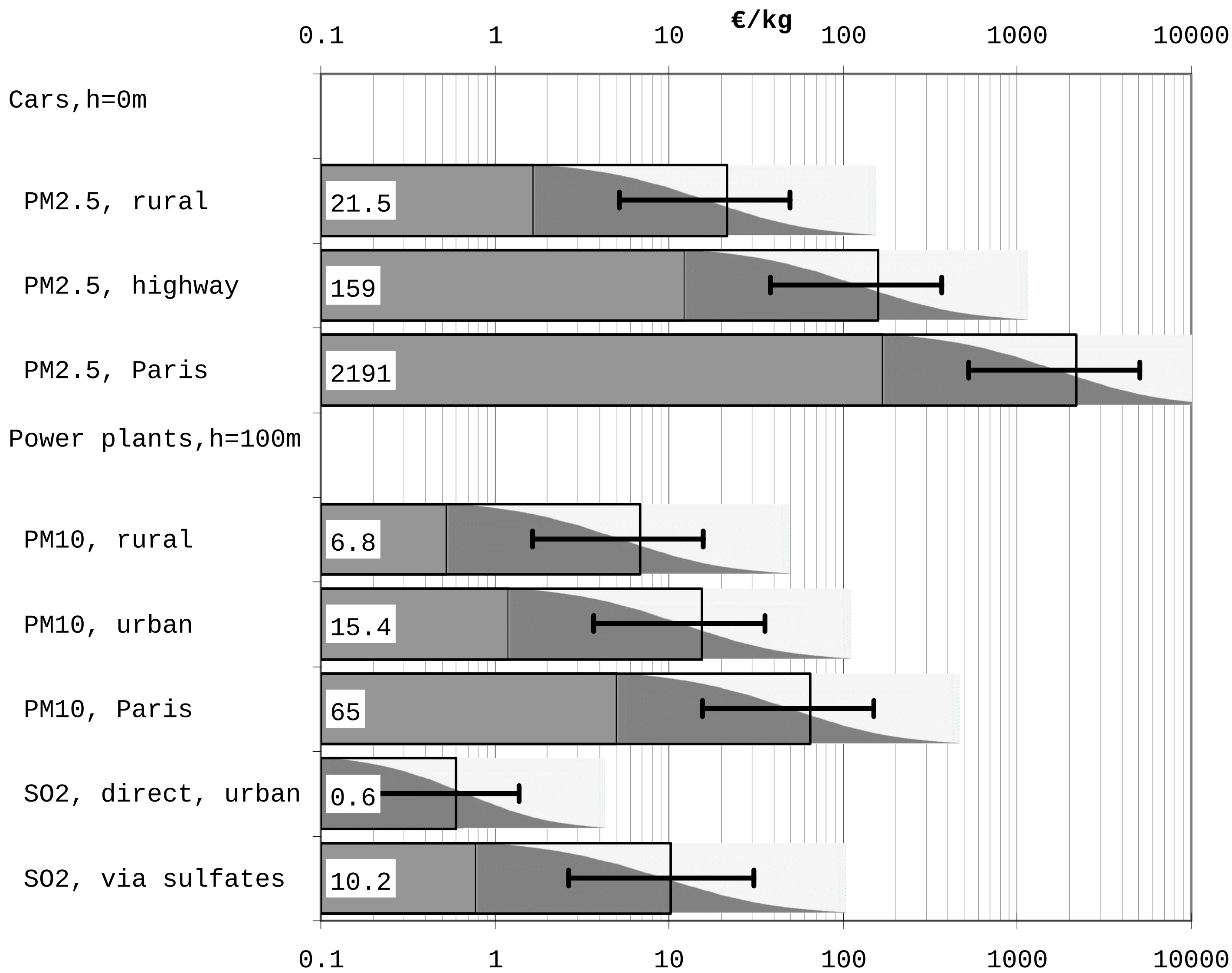
Uncertainty of the Components of the Analysis

Step of calculation	Lognormality	PM	Sulfates	Nitrates
Emission	probably yes	1.2	1	1
Dispersion	yes	1.8	2.2	2.5
FER regression	no	1.3	1.3	1.3
fER transfer composition)	?	1.5	1.5	1.5
YOLL, given RelRisk	probably yes	1.2	1.2	1.2
VSL (value of statistical life)	yes	2	2	2
Value of YOLL, given VSL	?	1.3	1.3	1.3
Discount rate&latency	probably yes	1.3	1.3	1.3
Total σ_g		**3.08**	**3.41**	**3.72**
mean/median, total uncorrected		1.88	2.12	2.37
σ_g dispersion		1.80	2.20	2.50
mean/median, dispersion		1.19	1.36	1.52
mean/median,total, corrected for dispersion		1.33	1.14	1.02
median/mean		0.75	0.88	0.98
lower/mean		**0.24**	**0.26**	**0.26**
upper/mean		**2.31**	**2.99**	**3.63**

Uncertainty of the Components of the Analysis

Step of calculation	Lognormality	As, Cd, Cr, Ni	Radionuclides
Emission data	approximately	1.2	1.5
Dispersion	yes	1.8	1.8
factor for noninhalation pathways	?	2	2
dose-response function (unit risk)	?	1.5	2
dose and dose-rate effectiveness factor			1.5
fraction that is fatal			1.3
YOLL (years of life lost) probably	yes	1.2	1.5
VSL (value of statistical life)	yes	2	2
Value of YOLL, given VSL	?	1.3	1.3
Latency (including discount rate) probably	yes	2	1.3
Total σ_g		**4.24**	**4.84**
mean/median,total uncorrected		2.84	3.47
σ_g dispersion		1.80	1.80
mean/median, dispersion		1.19	1.19
mean/median,total corrected		2.01	2.45
median/mean		0.50	0.41
lower/mean		**0.12**	**0.08**
upper/mean		**2.11**	**1.97**

Some Results



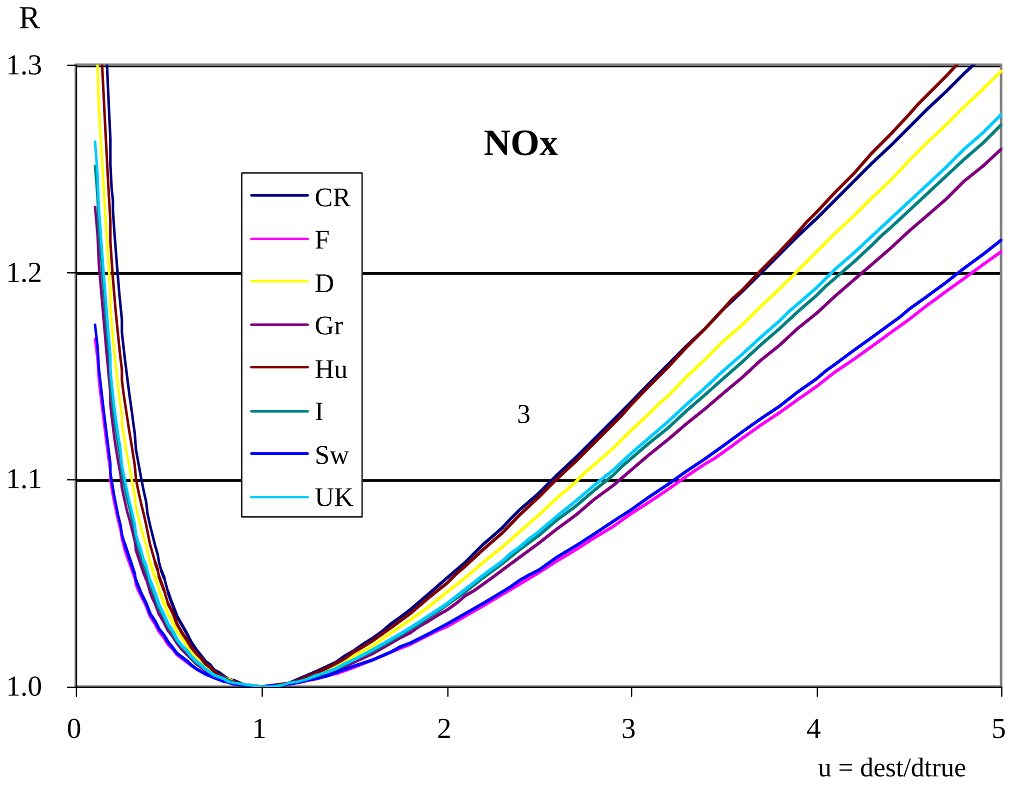
How Much Do Uncertainties Matter?

Key question: what is cost penalty for wrong decision?

For continuous choices, e.g. National Emission Ceilings:

Cost penalty R (=cost with wrong choice/cost with right choice)

vs **u = error of damage cost estimate**



⇒ Penalty <15% with uncertainties of ExternE

How Much Do Uncertainties Matter?
Cont'd

Key question: what is cost penalty for wrong decision?

For **discrete choices**, e.g. nuclear or coal:

No cost penalty if ranking not affected by uncertainties

Example: Comparison benefits for a reduction of average emission from 20 to 5 mg/m^3 (of emission limit from 50 to 15 mg/m^3). Costs and benefits are shown on two scales: per $t_{clinker}$ (bottom) and per kg_{PM} (top). Error bar indicates uncertainty of benefit. The uncertainty of the cost is indicated by a high and a low estimate.