

Measuring the Economic Value of Chemicals on Ecological System and Human Health

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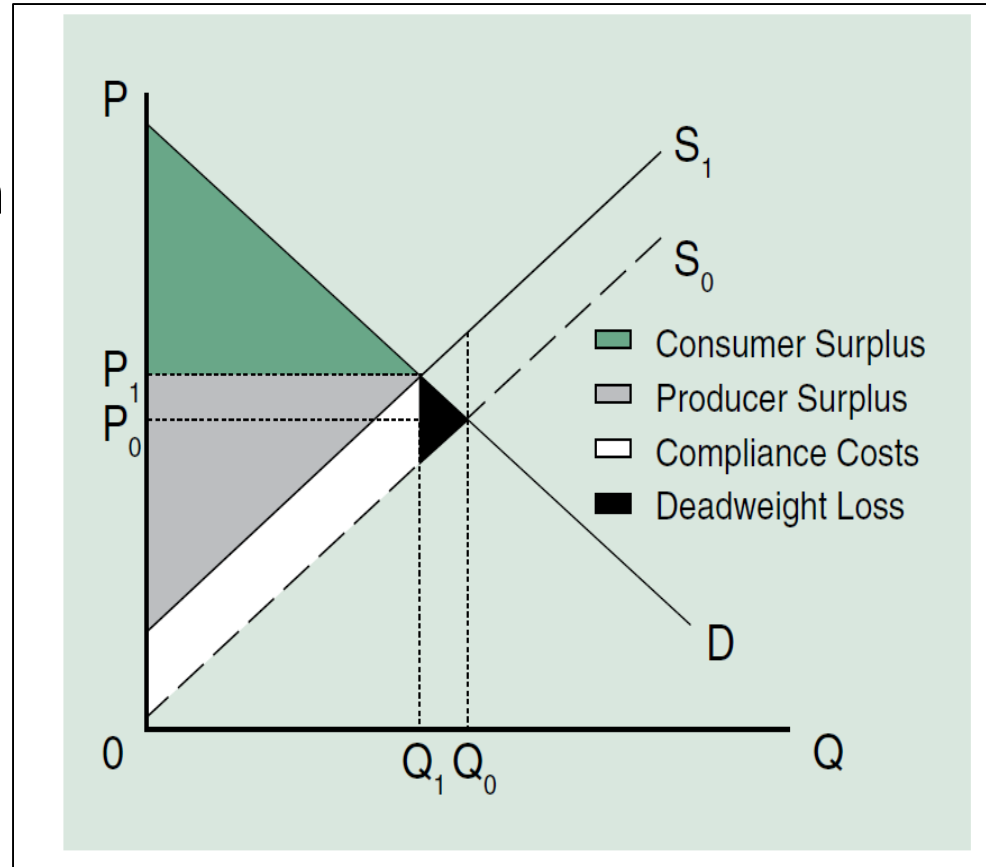
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Regulating Chemicals

- Chemicals – contained in products, released into the environment
- Should they be regulated?
- Cost-benefit analysis
 - An input into decisionmaking about regulation
 - Convert the various “positive” and “negative” effects of proposed regulation into one metric: euro or dollars
 - Regulation makes sense if benefits > costs
 - Not easy

Costs

- Expenses incurred or resources diverted from other uses to comply with the regulations
- Value of reduction in output
- Limited to one or two markets (partial equilibrium analysis)...
- ...or economy-wide (general equilibrium analysis)



Source: US EPA, Guidelines to Economic Analyses (2012).

Benefits

Benefits = The beneficiaries' Willingness to Pay
for the regulation or the policy

How do we estimate benefits?

- List likely physical or market effects (compared to no-policy baseline), beneficiaries
- Attach a monetary value to each unit of these effects
- Seek valuation method appropriate for each such effect
- Methods
 - Market methods
 - Non-market methods

Types of Benefits

Environmental benefits

- Losses/gains to fisheries, agriculture, manufacturing, etc.
 - To producers
 - To consumers (higher prices, lower output)
- Recreation
- Aesthetics (visibility, odors, noise, etc.)
- Non-use values
- Avoided costs of supplying alternate ecosystem services

Human health

- Illnesses and fatalities due to
 - occupational exposure (workers)
 - environmental exposure (general public)
 - Consumption of products containing the chemicals (consumers)

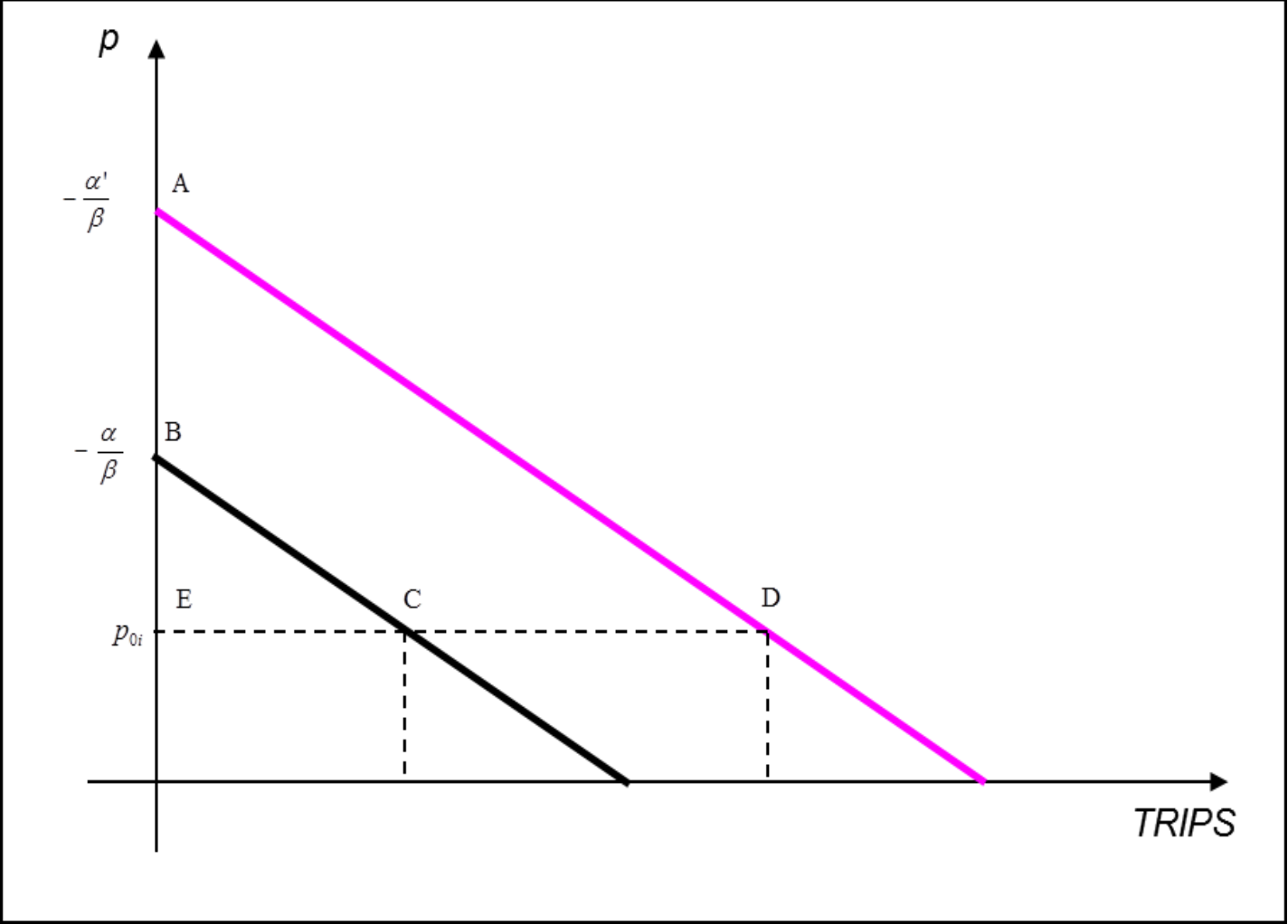
Productivity effects

- Work days lost to illness
- Worker reduced productivity even if at work

Non-market methods

- Travel cost method (TCM)
 - Suitable for recreation sites
 - Only use values
 - Single-site visitation models v. discrete choice models
- Hedonics
- Stated preference methods

TCM: Single-site models



Weak
complementarity
assumption

TCM: Discrete choice models

- Based on random utility model
- Sites are described by attributes, including environmental quality
- Explicitly allow for trading off attributes, substitution between sites
- Can estimate the WTP for a change in one attribute and/or the WTP for an entire “modified site”

Where
shall we
go
fishing?

A

B

cost € 15

boat YES

catch ~~OK~~ ~~OK~~

H₂O quality good

C

cost € 25

boat YES

catch ~~OK~~ ~~OK~~ ~~OK~~

H₂O quality v. good

Hedonic pricing methods

- The price of a good is explained by the levels of its attributes
- Housing prices (or rents) should depend on structural characteristics of the home, location, environmental quality at the site
- Regression equation:

$$(\ln)P_i = \mathbf{x}_i\boldsymbol{\beta} + E_i\gamma + \varepsilon_i$$

Hedonic pricing methods (2)

- Use coefficient on environmental quality to see how housing values increase if environmental quality is improved
- Can be applied to other goods (e.g., cars, wages, etc.)
- Difficulties:
 - Environmental quality likely to be correlated with other, unobserved attributes of the neighborhood that influence price
 - If so, we may attribute to environmental quality effects that are really due to something else
 - Look for exogenous “shocks” (e.g., Davis, 2004) or repeat sales
 - Conventional housing price hedonics capture value of environmental quality only if environmental quality doesn’t change the decision to sell the home (Guignet, 2014)

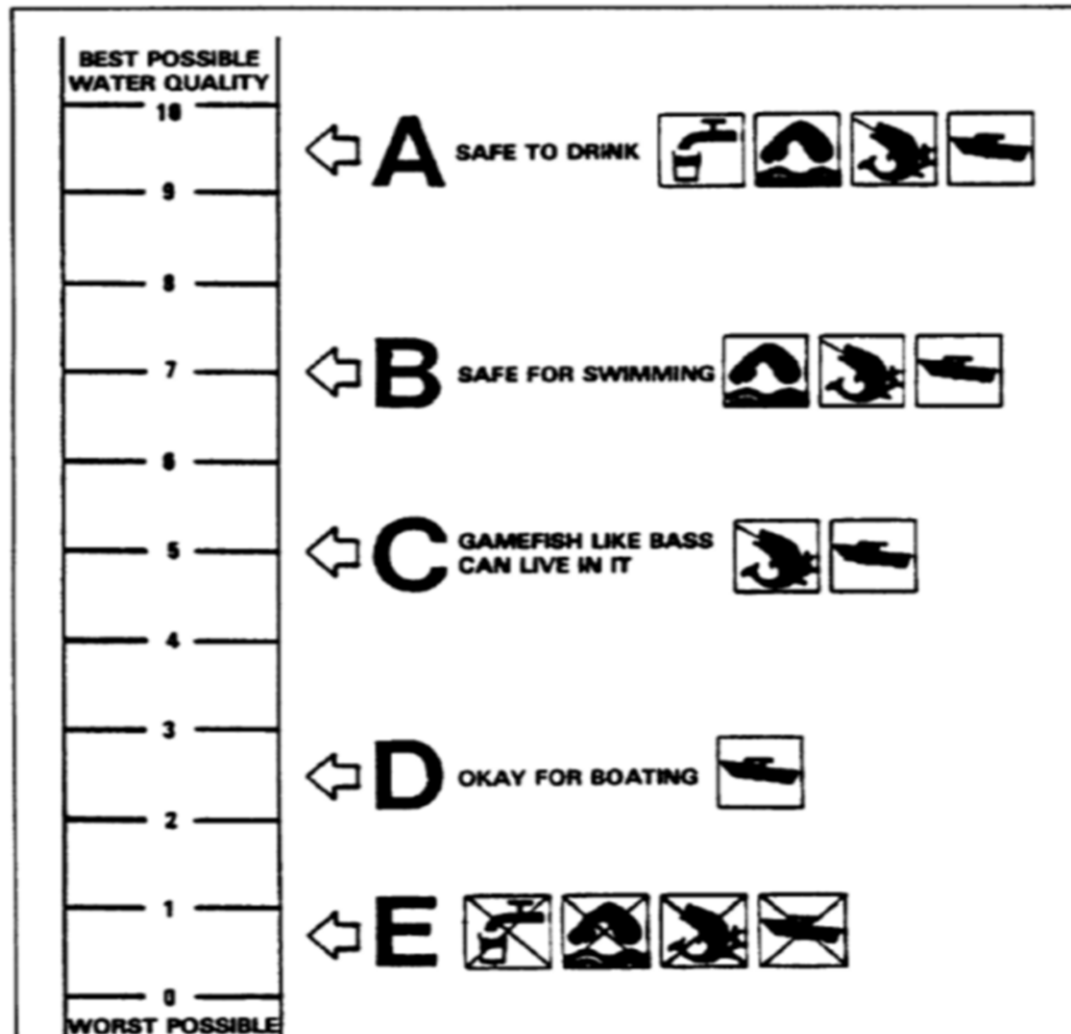
Stated preference methods

- Based on surveys of members of the public
- Ask people what they would do, or how much they would pay, under hypothetical but well specified circumstances
- Suitable for a wide variety of goods, contexts, changes in environmental quality (including any not experienced before)
- Sometimes criticized because they are hypothetical

Stated preference methods (2)

- Contingent valuation
 - “Would you pay X euro for...?” yes/no
- Contingent behavior
 - “Would you continue buying/going or stop altogether if the price was X euro?”
- Discrete choice experiments
 - “Which would you choose—A, B, or neither?”

The Water Quality Ladder (Mitchell and Carson, 1993)



Valuing effects of chemicals on human health

- Types of effects
 - Morbidity
 - Mortality
- Description of effects
 - Duration or frequency (acute v. chronic)
 - Severity (bed disability day, work loss day, restricted activity day)
 - Affected parties (children, elderly, sensitive individuals)

A Simple Model for Morbidity

- Individual or household utility depends on consumption, leisure time, and sick days: $U(X,L,D)$
- Dose-response function: $D=D(P,A)$
- Choose consumption and leisure time to maximize utility, subject to budget constraint
- Budget constraint states that...
 - we spend what we earn
 - sick days reduce work time (and hence income) *and* create medical expenditures
 - plus we spend money on averting activities (self-protection)

What is the WTP to reduce pollution?

$$WTP = \frac{dD}{dP} \times \left[w \frac{dW}{dD} + p_M \frac{dM}{dD} + p_A \frac{dA^*}{dD} - \frac{U_D}{\lambda} \right]$$

Slope of the
dose
response
function

Work
income
lost to
illness

Averting
expenditures

Value of the
disutility and
discomfort of
illness

Cost of illness

WTP to pay to avoid a sick day

Assumptions

- Pollution enters in the utility function only via its effect on sick days
- Work time is flexible
- The specific nature of the chemical is not important. All that matters is the effect of pollution or chemicals on sick days.

Is this model suited for chemicals?

- Yes and no
- Yes: if the chemicals cause minor symptoms without lasting consequences (e.g., itchy eyes, headaches, ...)
- No: if the chemicals cause serious chronic illnesses (e.g., diabetes), neurological and developmental problems in babies and infants, irreversible reproductive system effects

Chemicals with neurological and developmental effects

- Lead, mercury, heavy metals
 - Effects on babies, infants, children
 - Exposures to high levels → physical and neurological effects → cognitive difficulties, reduced school attendance → lower educational attainment → lower wages
- Damage from chemical = (Lifetime wage differential + additional costs) × attributable cases
 - Landrigan et al. (2002), Grosse et al. (2002), Drake (2016), Trasande (2016)
 - Misses the disutility and suffering of individual and parents
 - A lower bound to true damage

Landrigan's figures

- Average lead level in blood in 5-year-olds: 2.7 $\mu\text{g}/\text{dL}$, which is predicted to reduce IQ by 0.675 points
- 1 IQ point lost \rightarrow 2.39% loss in lifetime earnings
- So 0.675 IQ points lost = 1.61% loss in lifetime earnings
- ...or USD 21,014 for boys and USD 12,394 for girls
- Nationwide USD 27.8 billion (boys) and USD 15.6 billion (girls) (1997 USD)

Loss of productivity

- In air pollution context, loss of productivity is because of work loss days
- ...and in the air pollution context,
 - Zivin et al. (2011) with agricultural workers
 - Chang et al. (2014) with workers at a pear-packing plantfind lower productivity *at work* on high pollution days
- Can chemicals have similar effects?

Mortality effects

- Exposure to chemicals via the environment or use of products linked to increase mortality risks (cancer, effects on cardiovascular system, kidneys, liver, etc.)
- Diabetes and shorter life expectancy
- Benefits of regulation:
 - Expected lives saved \times Value of a Statistical Life (VSL)
 - or
 - Expected life-years saved \times Value of a Statistical Life year (VOLY)

What is the Value of a Statistical Life? (a.k.a. Value of a Prevented Fatality)

- A summary measure of how much someone is prepared to pay to reduce his risk of dying by a small amount
- Grounded in economic theory
- If I am willing to pay 500 euro to reduce risk by $1/10,000$ ($=0.0001$), the VSL is $500 \times 10,000 = 5,000,000$ euro
- Values used by agencies in policy analyses:
 - US EPA USD 7.4 million (2006 dollars)
 - DG-Environment central value EUR 1.5 million
 - OECD recommends a base value USD 3.6 million for EU-27

How is the VSL estimated?

Compensating wage studies

$$w_i = \beta_0 + \mathbf{x}_i\boldsymbol{\beta}_1 + p_i\beta_2 + q_i\beta_3 + (q_i \times WC_i)\beta_4 + \varepsilon_i$$

- VSL inferred from the coefficient on fatal risks
- Econometric difficulties, measurement of risks, assumption that workers actually know their risks, heterogeneity and self-protection

Hedonic regressions for other goods

- Car prices depend on car characteristics, including safety
- Home prices change when environmental risks are discovered

Consumer expenditures on safety equipment

Stated preference studies

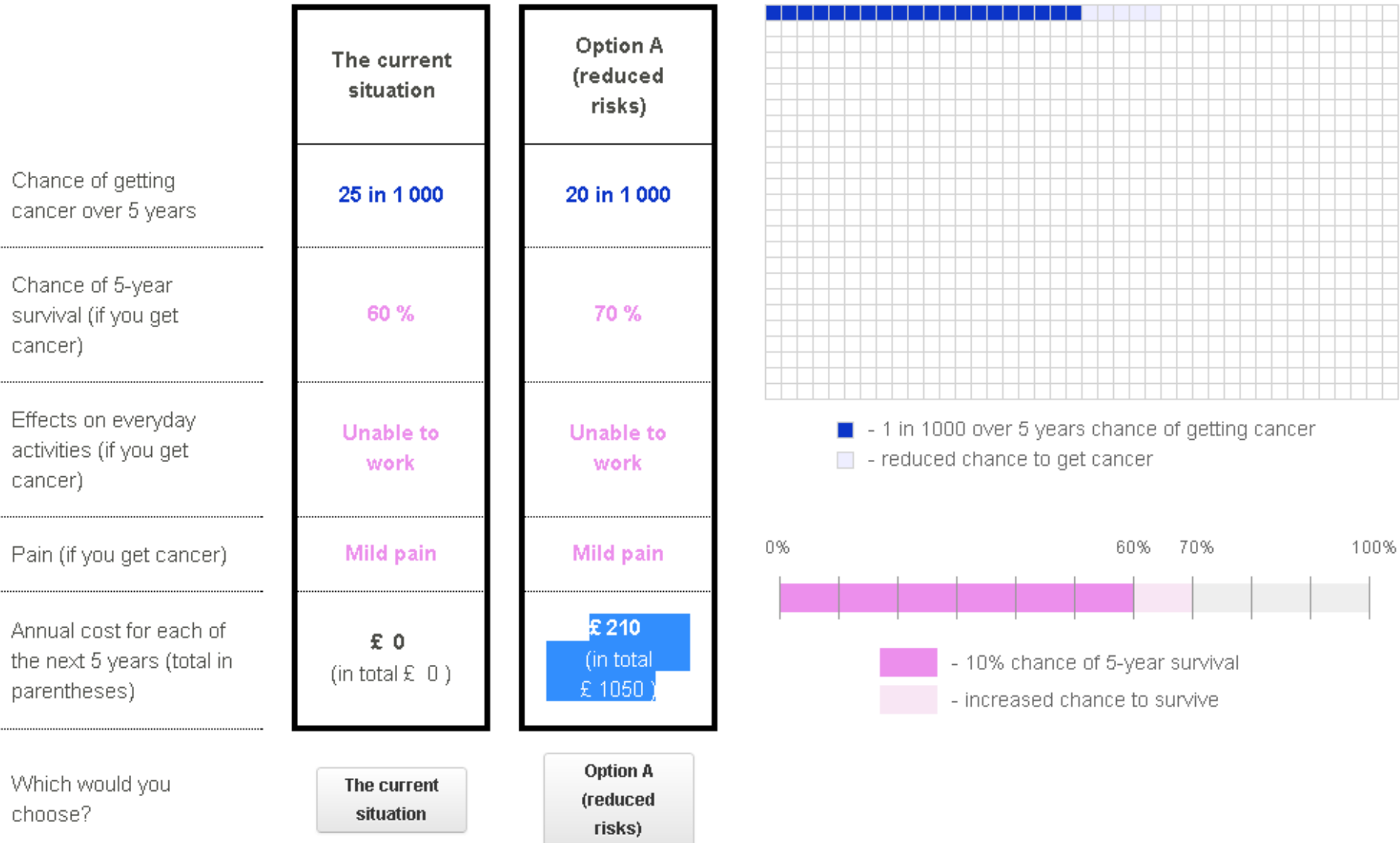
Can we apply existing estimates of the VSL to the effects of chemicals?

- Only if we presume that VSL figures from workplace or transportation accident context can be applied to chemicals
- Must adjust for latency—risk reductions from regulating certain chemicals now likely to occur in the future
- Is the cancer VSL higher?

Cancer risks

- Risk assessments estimate excess lifetime *cancer risks*, i.e., number of cases of cancer
- Useful to separate the Value of a Statistical Case of Cancer (VSCC) (just getting cancer, being ill and receiving treatment) from the cancer VSL (dying from it)
- Avoid double counting

Alberini and Scasny (2015): Example Choice Card



Estimating the VSL -- The Model

$$WTP_{ij}^* = \alpha + \mathbf{QOL}_{ij}\boldsymbol{\beta} + PAIN_{ij}\gamma + \Delta MORT RISK_{ij}\delta + \varepsilon_{ij}$$

Latent WTP



Reduction in the unconditional
risk of dying from cancer

Cancer VSL

The Model (cont'd)

But

$$\Delta MORT RISK = \Delta R \cdot (1 - S_0) + R_0 \cdot \Delta S - \Delta R \cdot \Delta S$$

Where

ΔR =reduction in the risk of cancer

ΔS =increase in the chance of surviving cancer

R_0 =baseline risk of cancer

S_0 =baseline chance of surviving cancer

So...

$$WTP_{ij}^* = \dots + \delta \cdot [\Delta R \cdot (1 - S_0) + R_0 \cdot \Delta S - \Delta R \cdot \Delta S] + \varepsilon_{ij}$$

Estimating the VSL

$$WTP_{ij}^* = \dots + \delta \cdot [\Delta R \cdot (1 - S_0) + R_0 \cdot \Delta S - \Delta R \cdot \Delta S] + \varepsilon_{ij}$$

VSL

Only this if choice cards
1-3, blocks 1-16

Only this if choice
cards 1-3, blocks 17-32

Estimating the VSCC

$$WTP_{ij}^* = \dots + \delta \cdot [\Delta R \cdot (1 - S_0) + R_0 \cdot \Delta S - \Delta R \cdot \Delta S] + \varepsilon_{ij}$$

So...

$$VSCC = \frac{\partial WTP^*}{\partial \Delta R} = \delta(1 - S_0) - \delta \Delta S$$

- The VSCC declines with the size of the improvement in the chance of survival
- If $\Delta S=0$ (choice cards 1-3, blocks 1-16), then $VSCC=VSL \times (1-S_0)$

The Data: Sample Sizes

Country	Pilot	Main wave
Czech Republic	148	1 145
United Kingdom	128	733
Netherlands	-	910
Italy	-	824
Total	276	3 612

Key Results — t stats in parentheses

	(A): Blocks 1-16 Choice cards 1-3 Only $\Delta R \neq 0$ Nobs: 3483	(B): Blocks 17-32 Choice cards 1-3 $\Delta S \neq 0$ Nobs: 3759	(C): All blocks, all choice cards Nobs: 16873
QOL=1 dummy	-0.1343 (-1.067)	0.1625 (1.269)	-0.0486 (-1.175)
QOL=2 dummy	0.0026 (0.018)	0.1762 (1.107)	-0.0892 (-1.918)
QOL=3 dummy	-0.1701 (-1.148)	0.1357 (0.827)	-0.1756 (-4.083)
Moderate pain dummy	0.1246 (1.311)	0.0867 (0.977)	0.0190 (0.620)
Δ MORTRISK	15023.027 (8.070)	6136.54 (10.175)	5324.53 (30.271)
Cost	-0.00265 (-9.223)	-0.00325 (-7.938)	-0.00249 (-25.181)
Implied VSL (mill. PPP euro)	5.676 (s.e. 0.866)	1.887 (s.e. 0.284)	2.144 (0.102)
Implied VSCC (mill. PPP euro)	0.551 (s.e. 0.084)	n/a	Varies with ΔS

VSCC from all choice cards, all blocks

Value of $\Delta S=0$	VSCC (million PPP euro)
No change	0.339 (s.e. 0.035)
5% at 5 years	0.266 (s.e. 0.025)
10% at 5 years	0.198 (s.e. 0.021)
20% at 5 years	0.073 (s.e. 0.032)

Chemicals as emerging pollutants

- How should valuation be done when the effects of chemicals are unknown or only tentative?

Points for discussion

1. Responses in related markets have been observed even when causation had not been established (Davis, 2004) or chemicals are not identified (e.g., fracking)
2. The public has consistently demonstrated to be willing to switch to and pay more for safer products
 - Survey of the Canadian public by Industrial Economics (2015)
 - CAD 49 a month to switch to non-carcinogenic products, and CAD 17 – 35 a month to avoid adverse effects on soil, air or water.

Discussion 2

4. When the effects of a chemical are uncertain, we say that they are “ambiguous.”

6. Ambiguity may arise when people are told conflicting information on such effects.

Discussion 3

7. Fox and Tversky (1995) warn that ambiguity aversion may arise when people are comparing ambiguous and clear risky prospects, but diminishes or disappears when risky prospects are evaluated in isolation.
8. Ambiguity aversion would lead to attaching a lower value to an ambiguous risky prospect than to a comparable but clear risk prospect.
9. But do these claims carry over to when the human or environmental effects are ambiguous?

Discussion 4

10. Theoretical work by Treich (2010) and Courbage and Rey (2015) about the VSL and ambiguity aversion

- Effect of ambiguity aversion on VSL cannot be signed (Courbage and Rey)
- Ambiguity premium likely to be small (Treich)

11. Empirical work: WTP to reduce or eliminate health risks not affected by ambiguity, whether or not in isolation (Goldberg et al., 2009; baby formula contaminated with pathogens).

12. Nature of the chemical unlikely to influence WTP much.

In conclusion...

- Various methods for estimating the benefits of reducing exposure to chemicals via the environment or consumer products
- All methods have $\pm s$
- Many benefits are...
 - underinvestigated (productivity, reproductive health or birth defects)
 - require major updates (e.g., Landrigan figures with lead and IQ; chronic bronchitis, see Alistair Hunt)
 - miss out important components of WTP (suffering and disutility)

Conclusions (2)

- But my reading of the evidence is that ambiguity and the specific chemical or its source are unlikely to make a big difference on the WTP for the symptoms/effects
- Difficulties with..
 - valuing probabilistic outcomes
 - Valuing multiple/simultaneous/cumulative chemical exposures
- Recommend research on the above, but also going ahead with applying WTP figures to chemicals regulations

Thank you!

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Reproductive health effects

- Ex ante v. ex post
- Scasny and Zverinova (2014) for ECHA
 - Ex ante
 - Stated preference study to value an increase in the probability of conception
 - Vitamins (private good) or chemical-free product (public good)
- Value of a Statistical Pregnancy (VSP):
 - 40,000 euro (private good)
 - 33,000 euro (public good)
 - 40,000 euro (public good but respondents who intend to have a child)
- Controlling for possible co-benefits, the VSP is
 - 25,000 euro
 - 11,000 euro
 - 20,000 euro
- The same survey also elicits WTP to reduce the risk of low birth weight and birth defects

Value of a Statistical Life

- Well-grounded in economic theory
- In a static model expected utility model,

$$VSL = \frac{\partial WTP}{\partial R} = \frac{U(y) - V(y)}{(1 - R) \cdot U'(y) + R \cdot V'(y)}$$

**The Benefits of Avoiding Cancer (or
Dying from Cancer):
Evidence from a Four-country Study**

Anna Alberini and Milan Scasny

Research Questions

- What VSCC and cancer VSL figures should be used in EU/ECHA policy analyses?
- How important are quality of life and pain in explaining the willingness to pay to reduce cancer mortality risks?
- In stated preference studies
 - Can respondents handle several quantitative attributes (here, two probabilities and one cost)?
 - How do qualitative attributes fare?

Approach

- Stated Preferences
- In each choice card, the respondent must choose between an alternative that reduces risks (at a cost) and the status quo =
- = dichotomous-choice (DC) contingent valuation (CV) questions
- Total of 7 DC CV questions per respondent

What Good Are We Valuing?

- Reduction in the risk of dying from cancer
- This risk is the product of
 - Risk of getting cancer
 - Risk of dying from cancer, conditional on getting cancer in the first place
- Generic cancer (no mention of organs affected, type, etc.)
- Description of quality of life impacts and pain

Attributes and Levels

Reduction in the chance of getting cancer within the next 5 years	0 (baseline), 2, 3, 5 in 1000 over 5 years
Chance of survival at 5 years (if you get cancer)	60% (baseline), 65%, 70% and 80%
Effects on everyday activities (if you get cancer)	Fully active No heavy physical work Unable to work Confined to bed half of the time
Pain (if you get cancer) during treatment, recovery, or any other times	Mild pain Moderate pain
Cost (euro)	110 225 370 540

Estimation details

- We don't observe the actual WTP
- We only have yes/no responses to each choice card
- Probit model – RHS is augmented with COST
- Random effects probit to allow for correlated responses
- In earlier slides, QoL and Pain are additive—in alternate specifications, they can be entered as interactions with the reduction in the risk of dying
- Country fixed effects always included

Example Benefit-Cost Analysis: Rule for Mercury from Power Plants, US EPA

Category of benefits or costs	Annual benefits of the final rule in 2016 (3% discount rate)(2007 USD)
Total monetized benefits	USD 37 to USD 90 billion
Partial Hg-related benefits (consumption of fish and its effects through maternal exposure)	USD 0.004 to USD 0.006 billion
PM _{2.5} -related co-benefits (mortality, non-fatal illnesses, hospitalizations, restricted activity days)	USD 36 to USD 89 billion
Climate related co-benefits	USD 0.36 billion
Total social costs	USD 9.6 billion
Net benefits	USD 27 to USD 100 billion
Non-monetized benefits	Include visibility in class I areas; other neurological and health effects of Hg exposure; health effects of ozone; ecosystem effects; health effects from commercial and non-freshwater fish