ON THE INFERENCE ABOUT WILLINGNESS TO PAY DISTRIBUTION USING CONTINGENT VALUATION DATA

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Contingent valuation method

- Provide estimates of economic value of non-market goods (e.g., clean air)
- Help determine the value of a good to society (e.g., for benefit-cost analyses)
- Wide range of applications: transportation, health, environment, culture, etc.
- Value estimates derived from preferences stated in surveys
  - Typically large survey studies on representative samples of respondents
  - An example (binary choice) contingent valuation question:

    Would you be willing to pay one-time tax of $100 for the program (specified above) to prevent the effects of the next oil spill?

    Yes/No

  - Various response formats: open-ended, payment card (a selection of one cost amount from a list), etc.

Bounds of willingness to pay (WTP) for a respondent
→ Estimation of mean WTP values for the population

Value estimates from contingent valuation

- They are typically based on relatively <u>simple approaches</u> to modelling survey responses, which likely results in <u>bias</u>
- In legal cases (e.g., damage assessment), conservative (lower-bound) non-parametric estimates seem to be preferred – They do not lead to overestimation, so they may be easier to defend in court, but they are likely downward biased
- Studies that apply parametric approaches rarely go beyond logit, probit and tobit models (that is, logistic, normal and log-normal distributions) – Though, there is no theory guiding the choice of a parametric distribution for modelling WTP values (other than the best fit)
- <u>More flexible approaches</u> are <u>barely used</u>, while they can lead to <u>better fit</u> of the distributions to the data and, hence, to more precise value estimates
- <u>Little guidance</u> regarding econometric approaches that would reliably estimate the values

The study objectives

- To investigate the performance (fit to the data) of various—more and less flexible—parametric approaches to modelling the value distribution based on contingent valuation data
- To propose an empirical approach for selecting the best fitting distribution
- To examine the extend of bias resulting from model selection

Modelling contingent valuation data

- The data informs about bounds of respondents' willingness-to-pay (WTP) amounts
  - For example, for a binary choice question, a 'yes' answer to a specific cost means that the lower bound of the WTP is the cost amount and the upper bound is unknown
  - This can be used to fit a parametric distribution describing WTP in a population
- We assume the WTP distribution is of particular form (e.g., normal) with unknown parameters, describing its mean and standard deviation
- The probability of observing a particular choice is the cumulative distribution function (CDF) of the assumed distribution at the upper bound less the CDF at the lower bound – This gives the probability a respondent's WTP lies between the lower and the upper bound

$$P\left(b_{i,LB} \leq WTP_i < b_{i,UB}\right) = CDF\left(b_{i,UB}, \boldsymbol{\beta}_i\right) - CDF\left(b_{i,LB}, \boldsymbol{\beta}_i\right)$$

- The parameters of the selected distribution ($\boldsymbol{\beta}_i$) can be found by maximizing the log-likelihood function for the observed choices of all respondents (*N*)

$$\log L = \sum_{i=1}^{N} \log\left[CDF\left(b_{i,UB}, \boldsymbol{\beta}_i\right) - CDF\left(b_{i,LB}, \boldsymbol{\beta}_i\right)\right]$$

Modelling contingent valuation data

- Usually, there is a large share of respondents whose WTP is equal to zero and relatively few with very small WTP amounts
- This can be represented by a jump discontinuity in a probability density function of any parametric distribution
- It is typically called a **spike** or a zero-inflated model
- As a result, the log-likelihood function becomes:

$$\log L = \sum_{i=1}^{N} \left\{ \left(1 - q_i\right) \cdot \log\left[CDF\left(b_{i,UB}, \boldsymbol{\beta}_i\right) - CDF\left(b_{i,LB}, \boldsymbol{\beta}_i\right) \right] + q_i \cdot \log\left[CDF\left(0, \boldsymbol{\beta}_i\right) \right] \right\}$$

where *q* is the probability that a respondent's WTP is zero

Modelling contingent valuation data

$$\log L = \sum_{i=1}^{N} \left\{ (1-q_i) \cdot \log\left[CDF\left(b_{i,UB}, \beta_i\right) - CDF\left(b_{i,LB}, \beta_i\right) \right] + q_i \cdot \log\left[CDF\left(0, \beta_i\right) \right] \right\}$$

- This is conditional on selecting a parametric distribution (for calculating CDFs)
- A researcher usually does not know what parametric distribution is the best for approximating the WTP distribution in the population
- <u>We recommend trying many parametric distributions to select the one fitting the data best</u>
- Here, we consider the following parametric distributions:

Normal	Johnson SU	Gamma	Johnson SB
Logistic	Exponential	Birnbaum Saunders	Johnson SL
Extreme Value	Lognormal	Generalized Pareto	Poisson
Generalized Extreme Value	Log-logistic	Inverse Gaussian	Negative Binomial
t Location Scale	Weibull	Nakagami	
Uniform	Rayleigh	Rician	

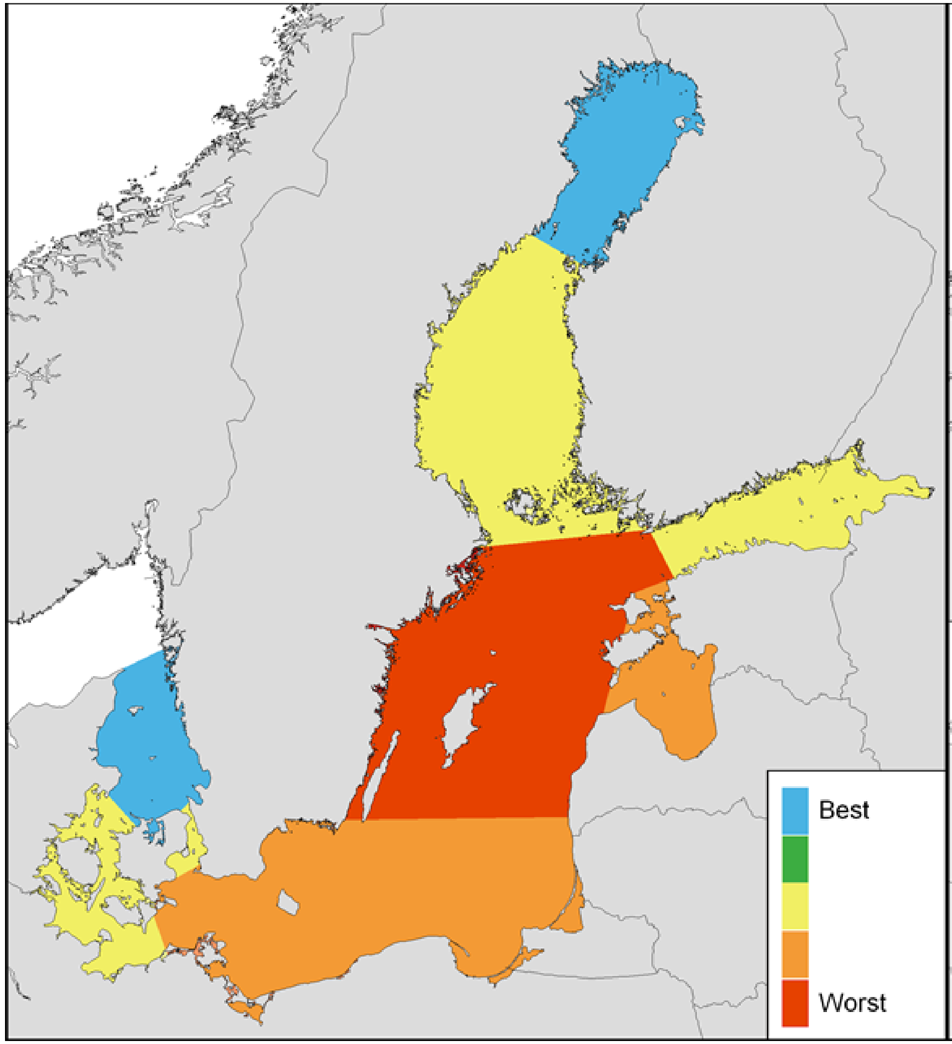
- Because the distributions vary with respect to the number of parameters, we compare them using the Akaike (AIC) and Bayesian (BIC) information criteria

Data: Two flagship contingent valuation studies

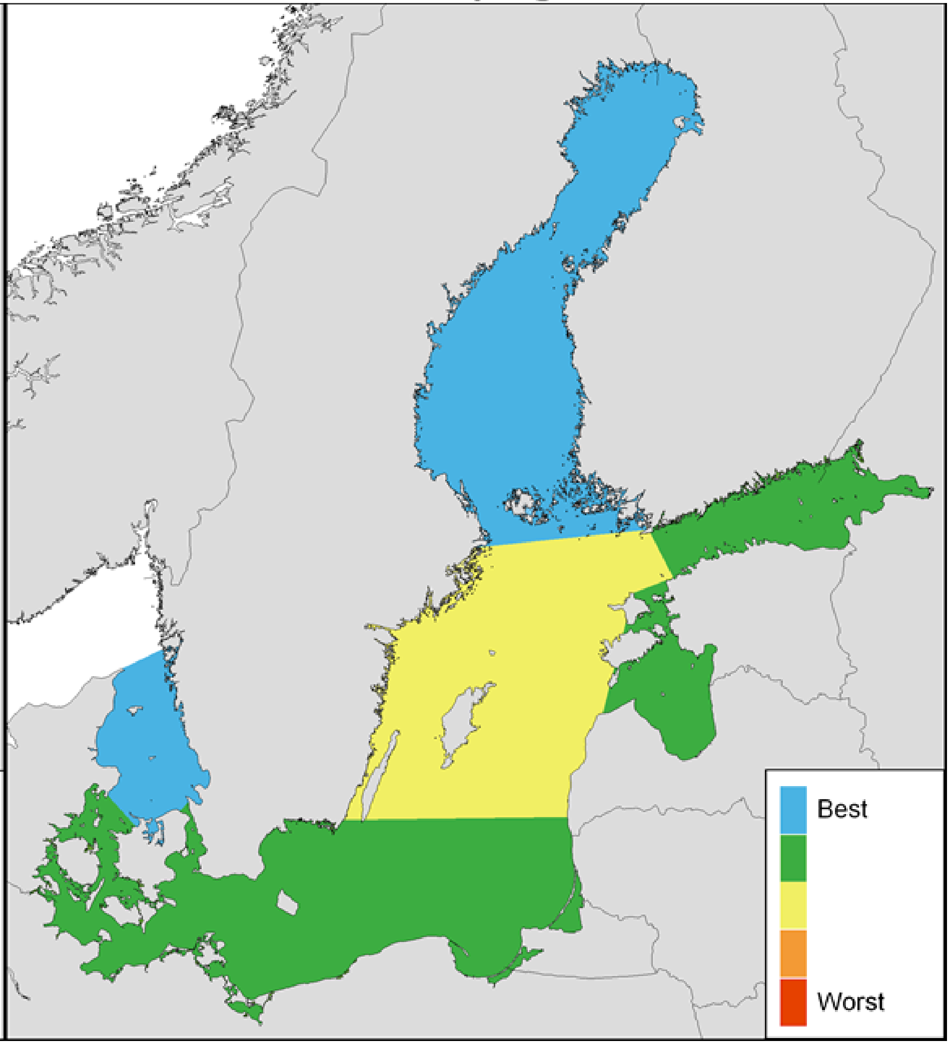
- **The Baltic Sea Action Plan**
  - The social value of the Baltic Sea eutrophication reduction associated with the implementation of the Baltic Sea Action Plan
  - 10,564 respondents surveyed from all 9 countries around the Baltic Sea
  - The most comprehensive and influential valuation study of eutrophication to date
- **Deepwater Horizon damage assessment**
  - The monetary value of the natural resource damage from the BP Deepwater Horizon oil spill for the needs of the lawsuit
  - The largest maritime oil spill in the U.S. history
  - 3,656 U.S. households surveyed
  - The Consent Decree called BP for total payments of $20.8 billion, $8.8 billion of which was for natural resource damages (based on the valuation study)

Survey for the Baltic Sea Action Plan

Baltic Sea in 2050 without the program

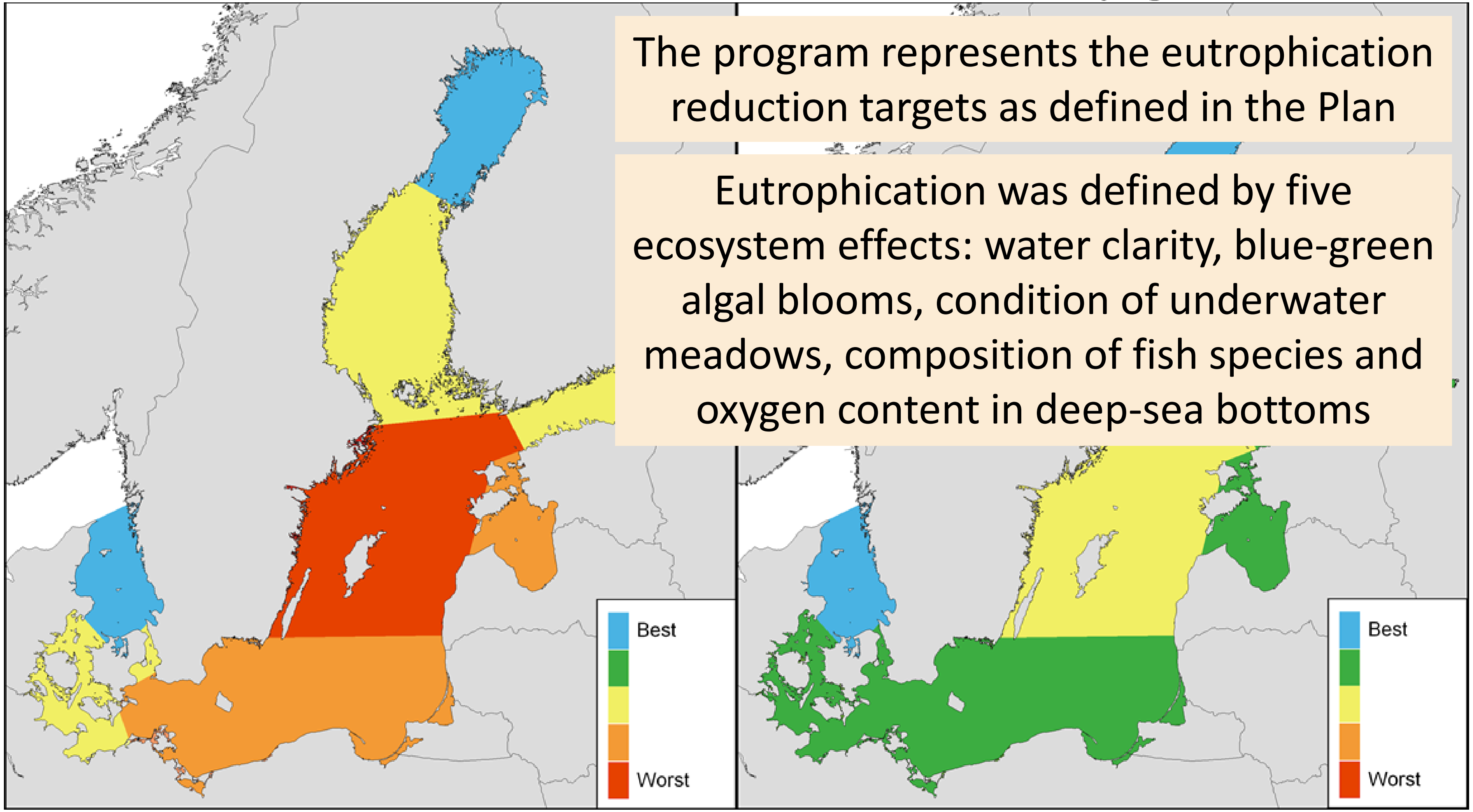


Baltic Sea in 2050 with the program



Survey for the Baltic Sea Action Plan

Baltic Sea in 2050 without the program **Baltic Sea in 2050 with the program**

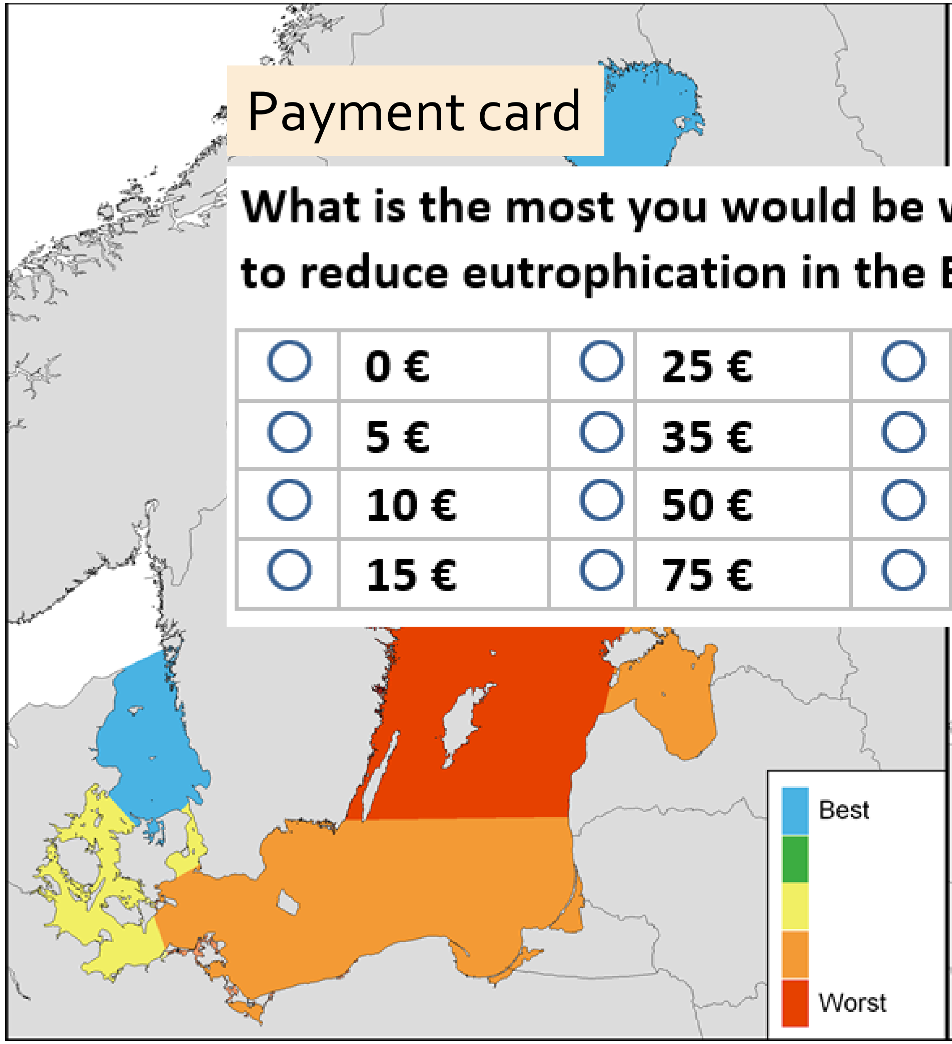


The program represents the eutrophication reduction targets as defined in the Plan

Eutrophication was defined by five ecosystem effects: water clarity, blue-green algal blooms, condition of underwater meadows, composition of fish species and oxygen content in deep-sea bottoms

Survey for the Baltic Sea Action Plan

Baltic Sea in 2050 without the program



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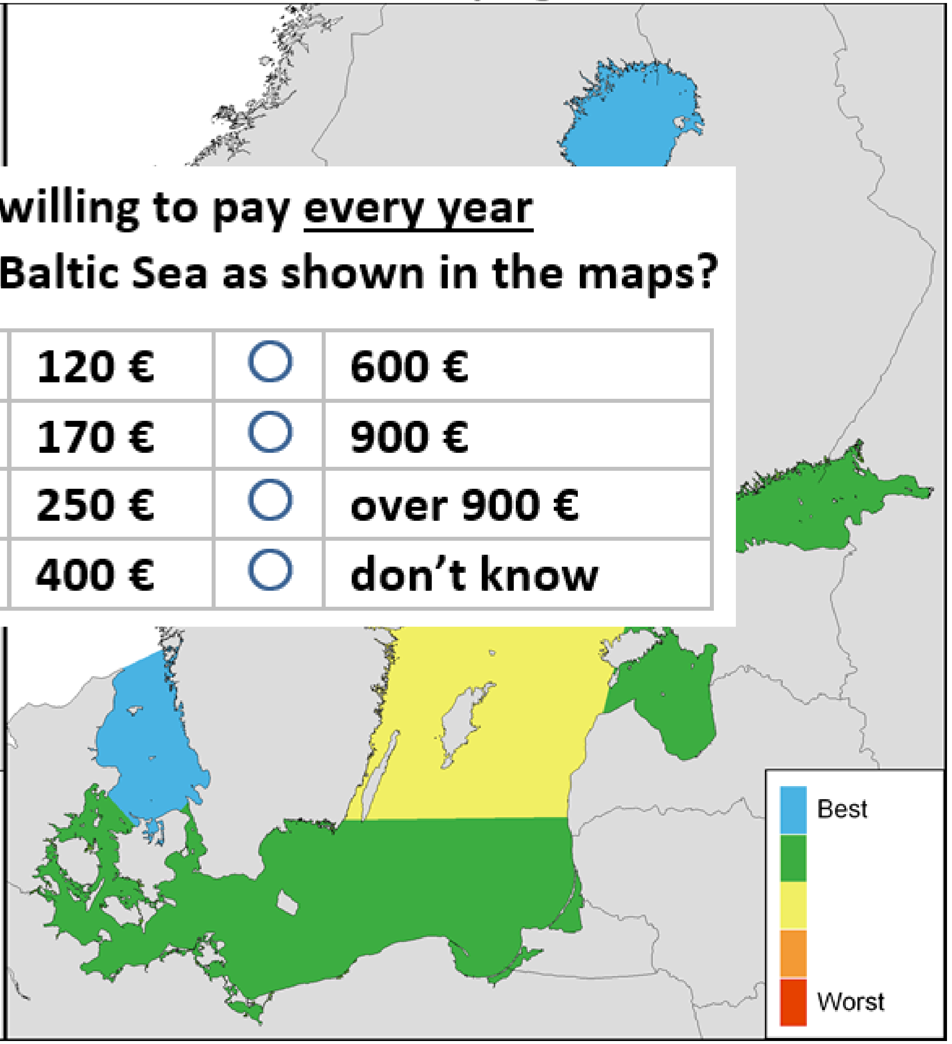

Payment card

What is the most you would be willing to pay every year to reduce eutrophication in the Baltic Sea as shown in the maps?

○	0 €	○	25 €	○	120 €	○	600 €
○	5 €	○	35 €	○	170 €	○	900 €
○	10 €	○	50 €	○	250 €	○	over 900 €
○	15 €	○	75 €	○	400 €	○	don't know

Survey for the Deepwater Horizon

The only way to prevent the effects of the next spill would be to put a second pipe in place at the same time that the first pipe is drilled. That way, a well can be closed in just 2 days after the leak starts, rather than in 3 months.

The "prevention program": the government paying to put a second pipe in each of the 400 new wells that will be drilled in the Gulf of Mexico during the next 15 years.

Do you vote for or against the prevention program, which will cost you and your family living with you the one-time tax of $135?

- Possible tax amounts: $15, $65, $135, $265, $435
- One cost randomly displayed
- Single binary choice format

Results: Baltic Sea

Poland (Computer-Assisted Web Interviews)

Distribution	Spike	Log-L	Param.	AIC/n	BIC/n	WTP (mean)	WTP (s.e.)
Lewbel-Watanabe						16.07	1.9
Exponential	yes	-2385.31	2	5.09	5.1	18.92	1.05
Generalized Pareto	yes	-2379.19	4	5.08	5.1	18.94	1.23
Birnbaum Saunders	yes	-2385.64	3	5.09	5.11	18.03	1.07
Lognormal	yes	-2385.95	3	5.09	5.11	17.98	1.29
Inverse Gaussian	yes	-2391.31	3	5.11	5.12	18.32	1.33
Loglogistic	yes	-2393.07	3	5.11	5.12	21.2	4.03
Negative Binomial	yes	-2396.16	3	5.12	5.13	18.16	1.06
Generalized Extreme Value	yes	-2393.02	4	5.11	5.13	20.4	2.75
Negative Binomial	no	-2462.02	2	5.25	5.26	18.11	1.45
t Location Scale	yes	-2547.9	4	5.44	5.46	14.61	3.06
Logistic	yes	-2637.57	3	5.63	5.65	16.79	0.8
Normal	yes	-2720.83	3	5.81	5.82	19.95	0.89
Exponential	no	-2740.43	1	5.85	5.85	18.04	0.81
Rayleigh	yes	-2766.54	2	5.9	5.91	22.31	0.63
Rician	yes	-2766.54	3	5.91	5.92	22.89	0.79
Extreme Value	yes	-2962.49	3	6.32	6.34	21.99	1.15
t Location Scale	no	-3199.83	3	6.83	6.84	13.55	2.72
Logistic	no	-3332.17	2	7.11	7.12	16.45	0.73
Normal	no	-3470.45	2	7.4	7.41	21.42	0.95
Extreme Value	no	-3848.45	2	8.21	8.22	25.52	1.2

Note: WTP in EUR

Results: Baltic Sea

Poland (Computer-Assisted Web Interviews)

For each country, we calculate:

$$\frac{\text{standard deviation of } n \text{ best-fitting distributions}}{\text{WTP from the best-fitting model}} \cdot 100\%$$

where n = {2, 3, …, 10, all}

We call it **relative variation**

Distribution	Spike	Log-L	Param.	AIC/n	BIC/n	WTP (mean)	WTP (s.e.)
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Exponential	yes	[illegible]	[illegible]	[illegible]	[illegible]	18.92	1.05
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Extreme Value	no	[illegible]	[illegible]	[illegible]	[illegible]	25.52	1.2

Note: WTP in EUR

standard deviation = 0.01

standard deviation = 0.52

standard deviation = 2.86

Results: Baltic Sea

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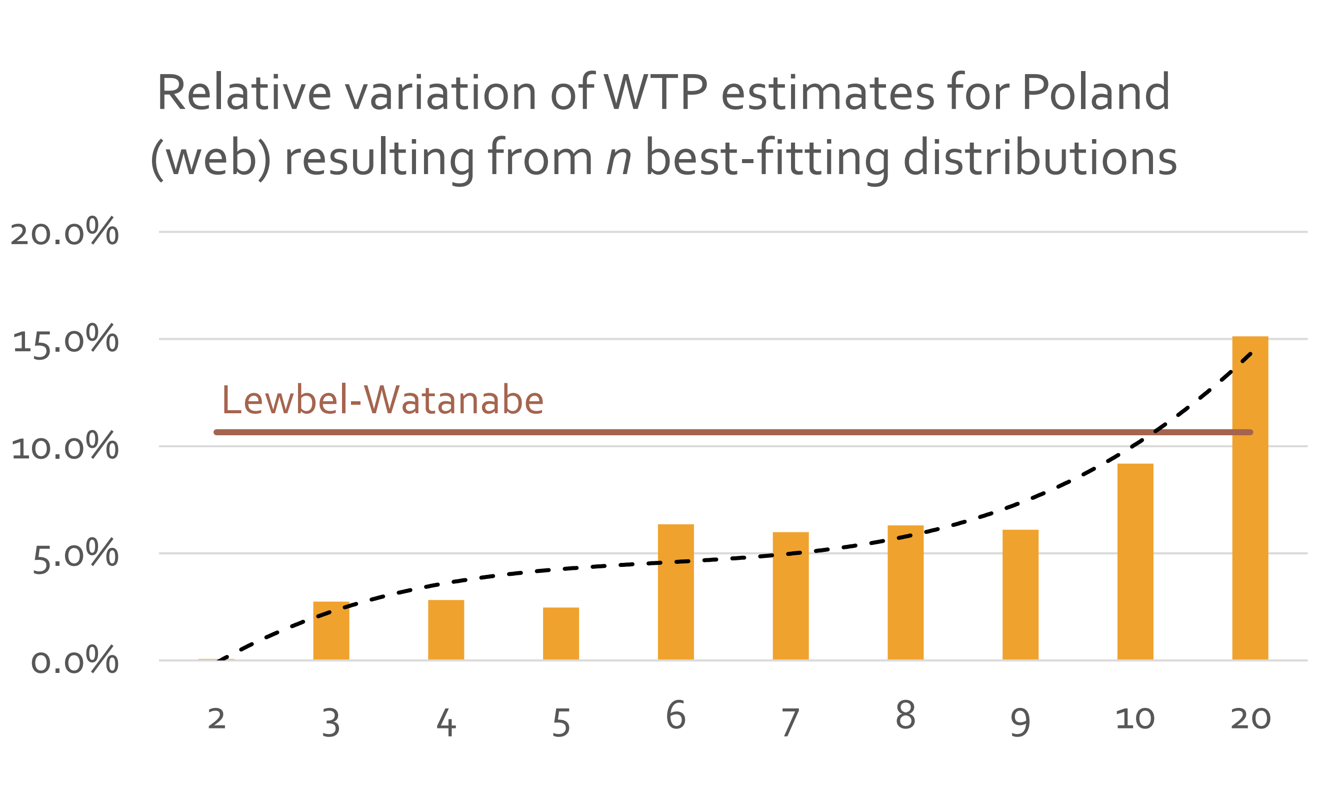

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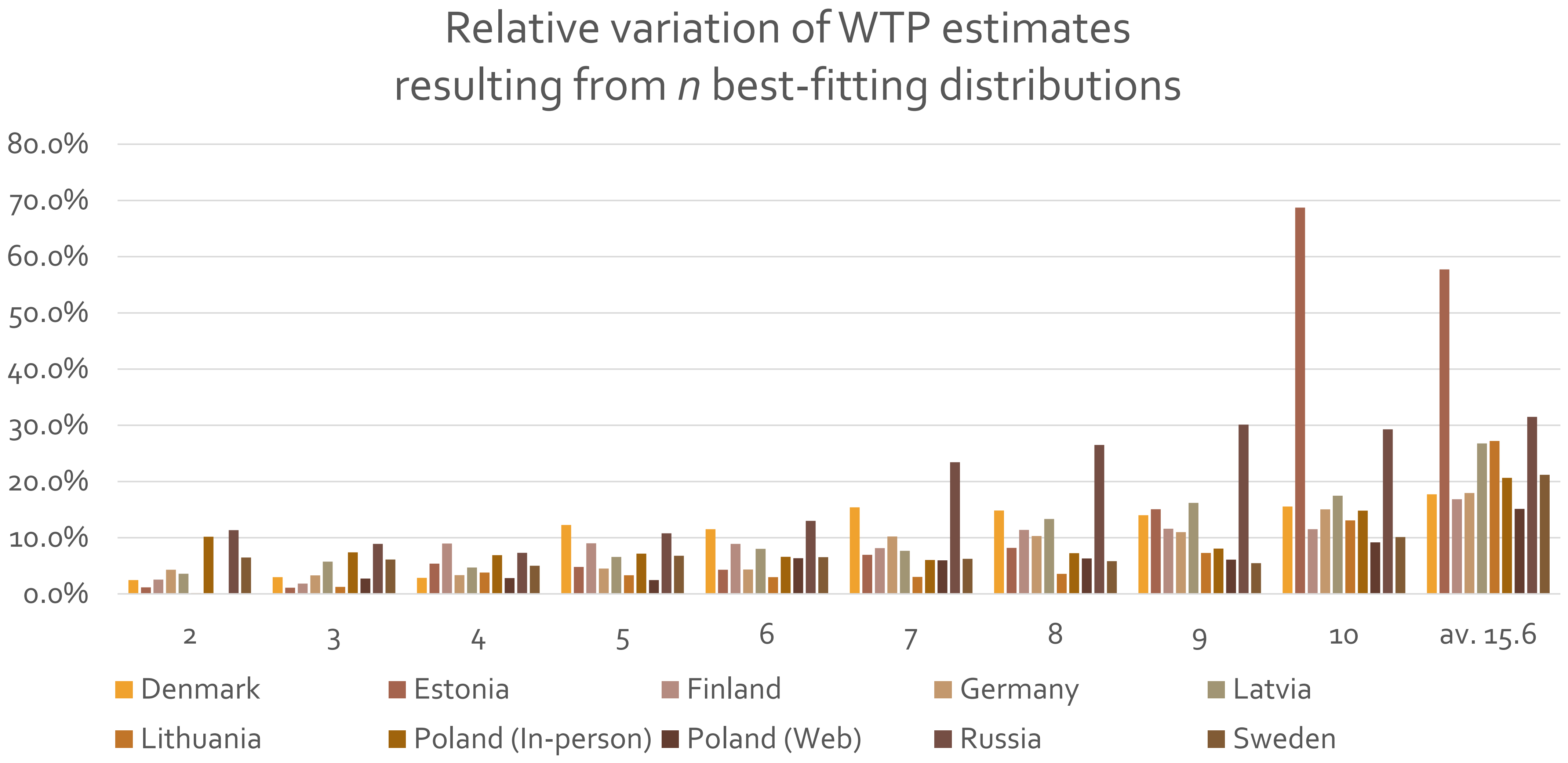
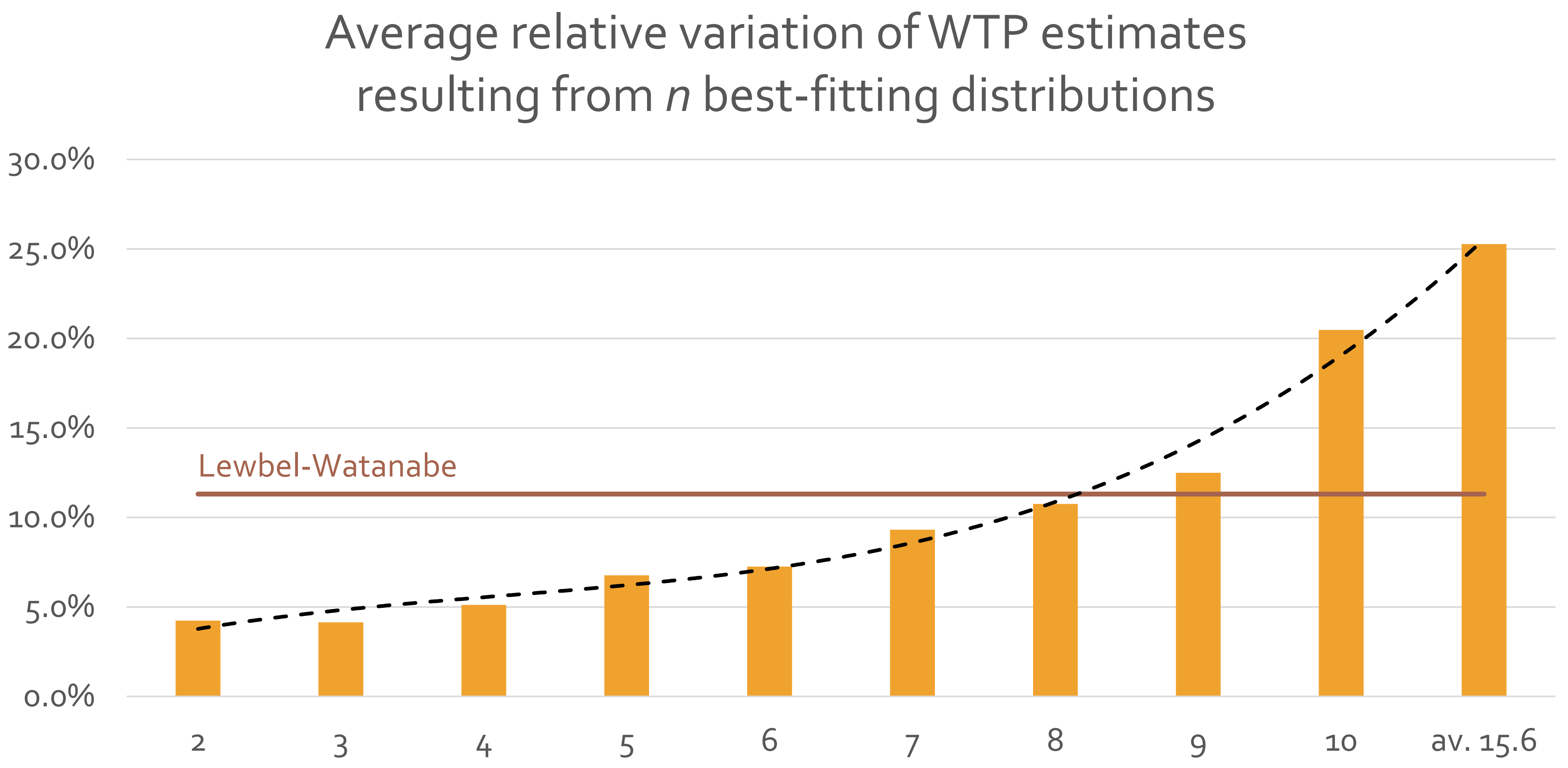
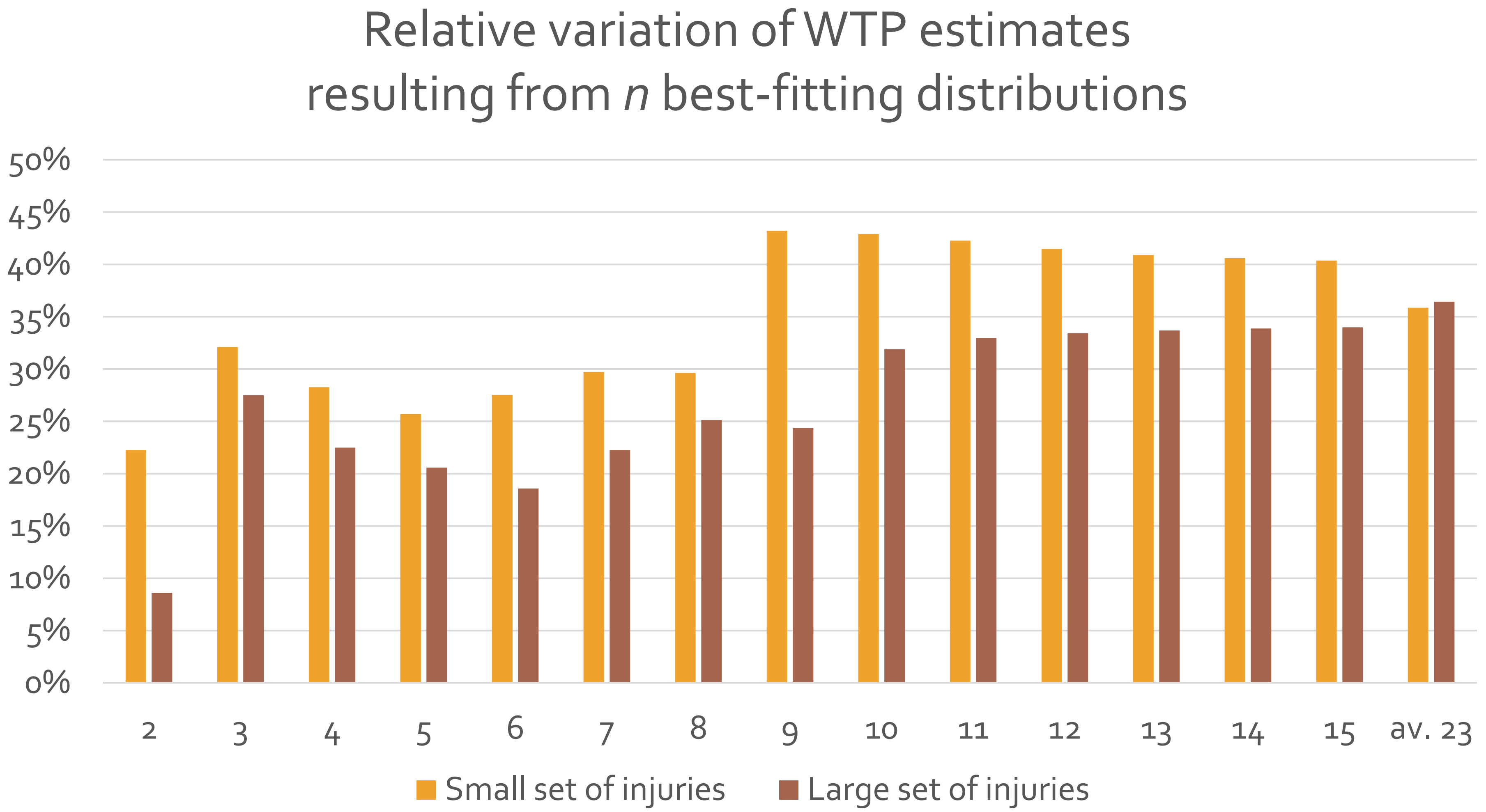


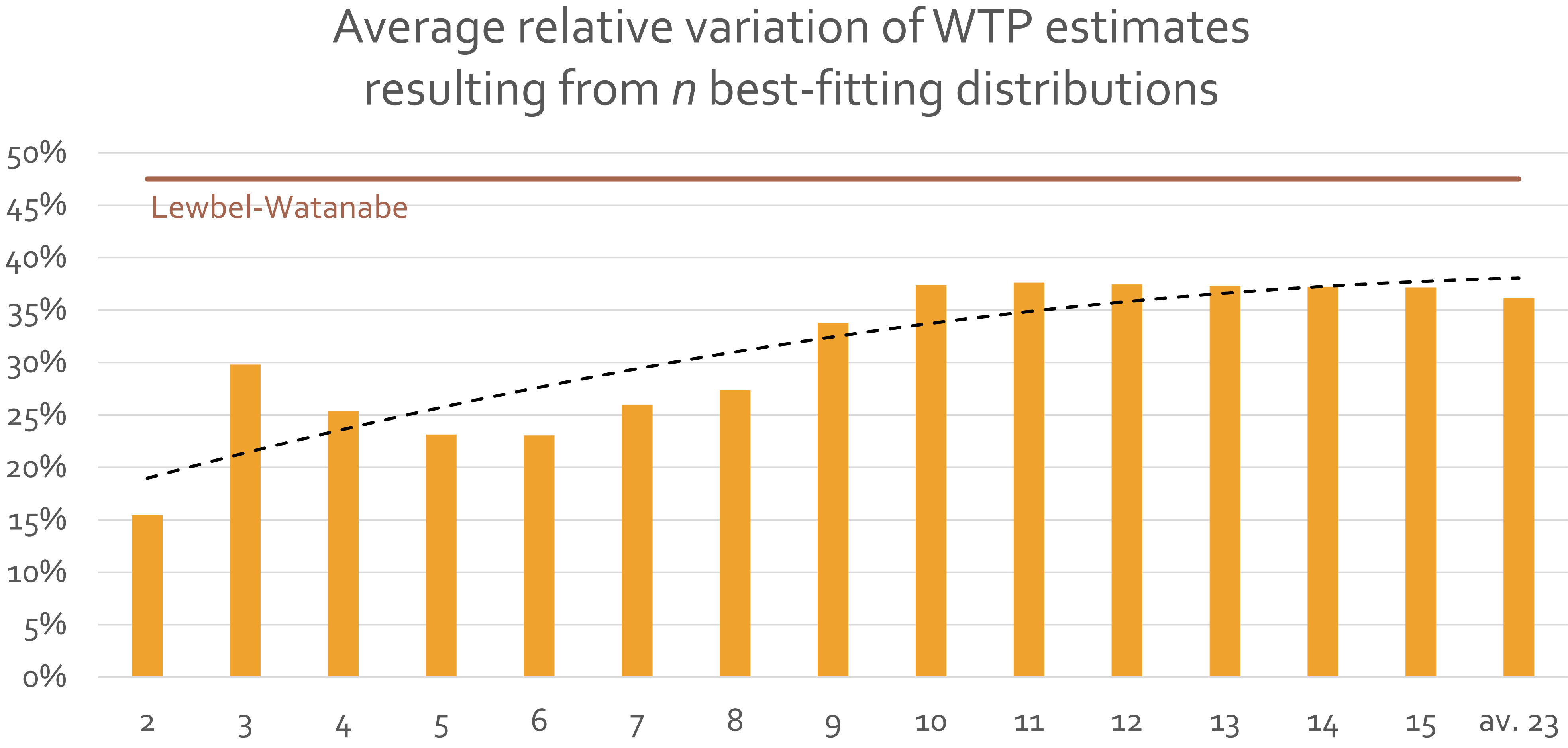
Results: Baltic Sea



Results: Deepwater Horizon



Results: Deepwater Horizon



Conclusions

- Our findings suggest considering many parametric distributions in modelling contingent valuation responses to select the one that fits best to the data
- Choosing a model specification ad hoc can reduce the model fit to the data and may lead to imprecise value estimates
- Non-negligible differences emerge in value estimates across different model specifications (different assumed parametric distributions)
- Variation in WTP values is smaller when only better-fitting models are considered
- Improving estimation methods delivers more precise value estimates, which can lead to more economically-efficient policy decisions

THANK YOU

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