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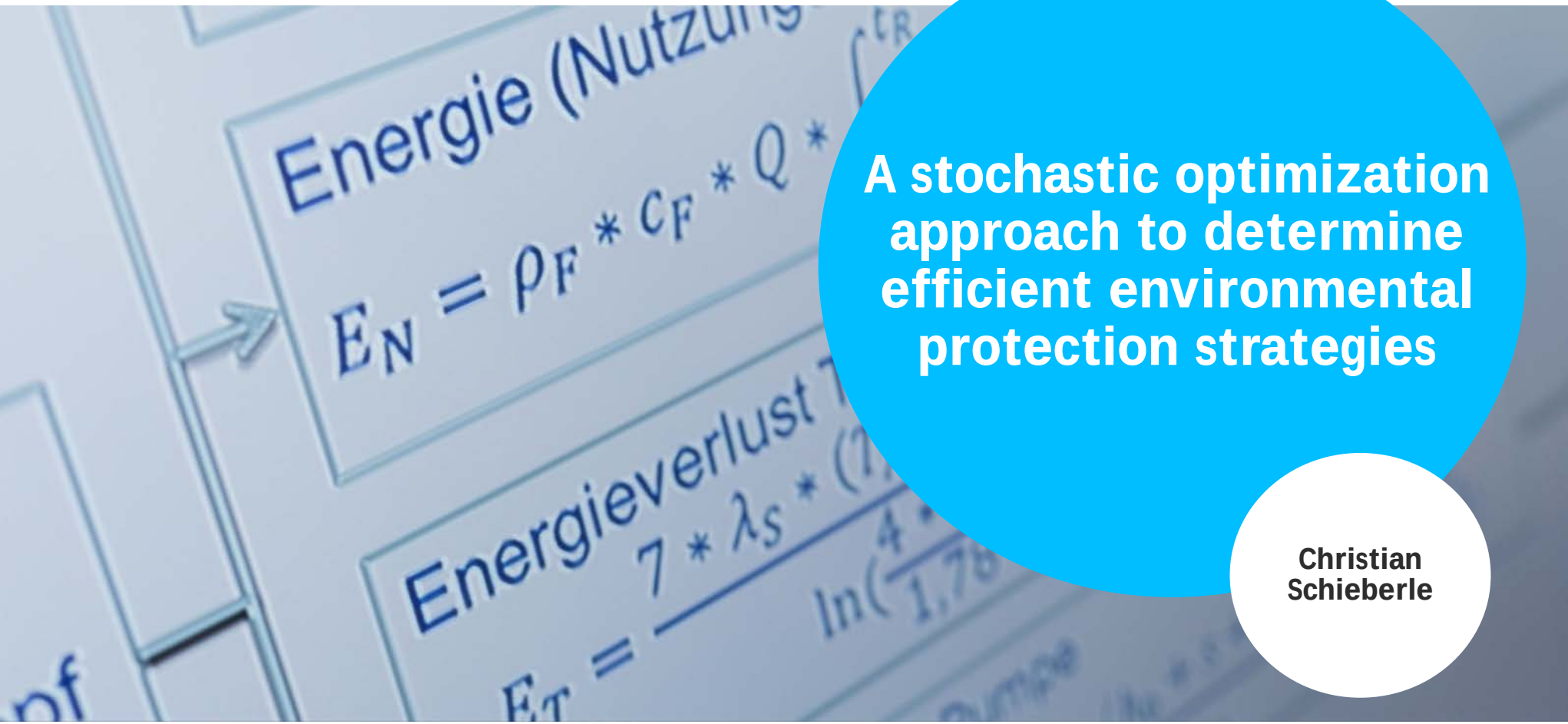

A stochastic optimization approach to determine efficient environmental protection strategies

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Overview

Approach to determine efficient environmental protection strategies

- Objectives
- ~~Methodology~~
- Meta-regression based evidence on travel demand elasticities
- Case study: Passenger transport in 2030 in EU28+2
- Conclusion and future work

Objectives

Approach to determine efficient environmental protection strategies

- **General objective:**
  Cost-efficient environmental protection strategies by trading-off the avoidance of impacts against cost and loss of surplus

- **Scope of this presentation:**
  - Passenger transport as a representative example for sectors in which considerable technical progress has already been achieved; necessity to **model behavioural change** (→ MRA)
  - Account for decision-maker's **risk attitude;**
    i.e. deal with **uncertainty of impact assessment** as well as **uncertainty of response** to policy implementation (→ stochastic CBA)

Methodology

Summary of main methodological aspects

- Cost-benefit analysis including avoided damages (assessed via IPA) and induced costs (including utility losses)
- Degrees of freedom (i.e. variables): policy implementation (fares, tolls, taxes, etc.)
- Objective: maximization of net benefit (EV, CVaR, weighted)

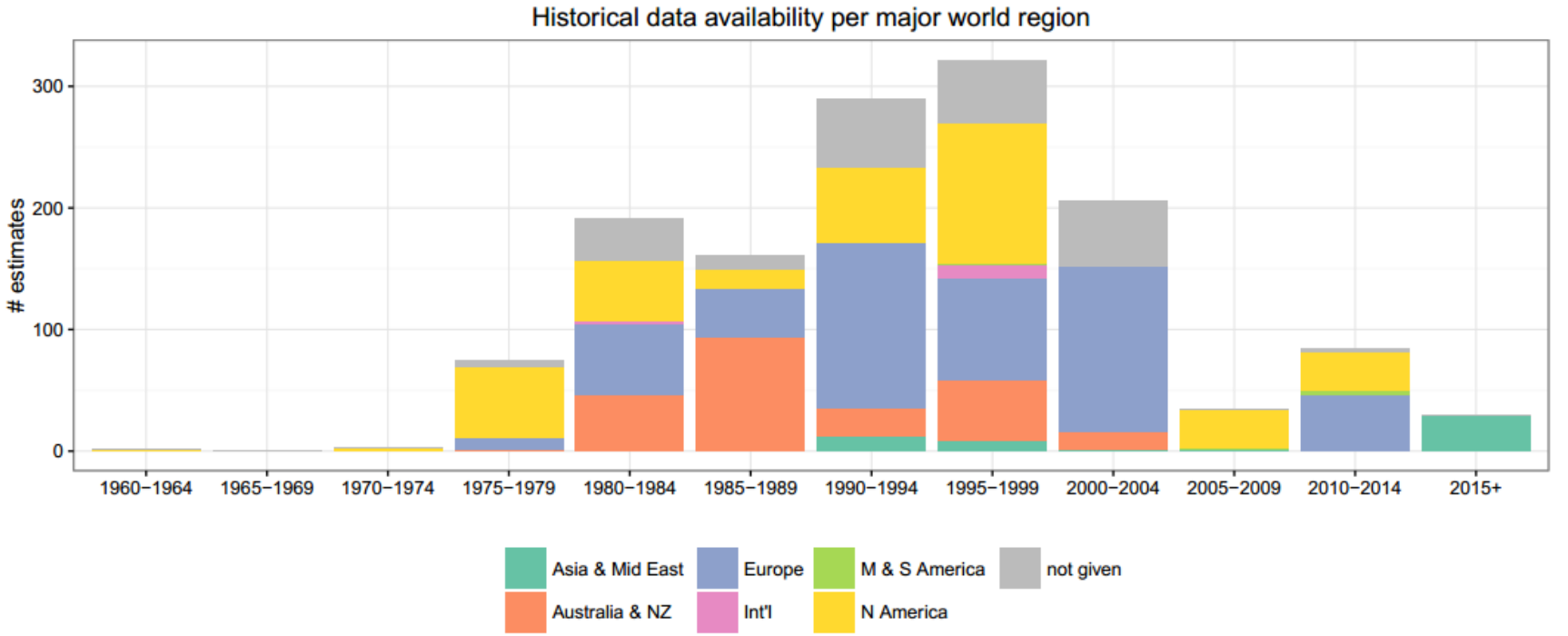
- Implementation:
  - Uncertainty of response estimated by meta-regression
  - Non-linear nature of response accounted for by piecewise-linear approx.
  - Uncertainty of individual IPA steps (from emission to monetized impacts)
  - Stochastic optimization: MIP formulated in GAMS EMP

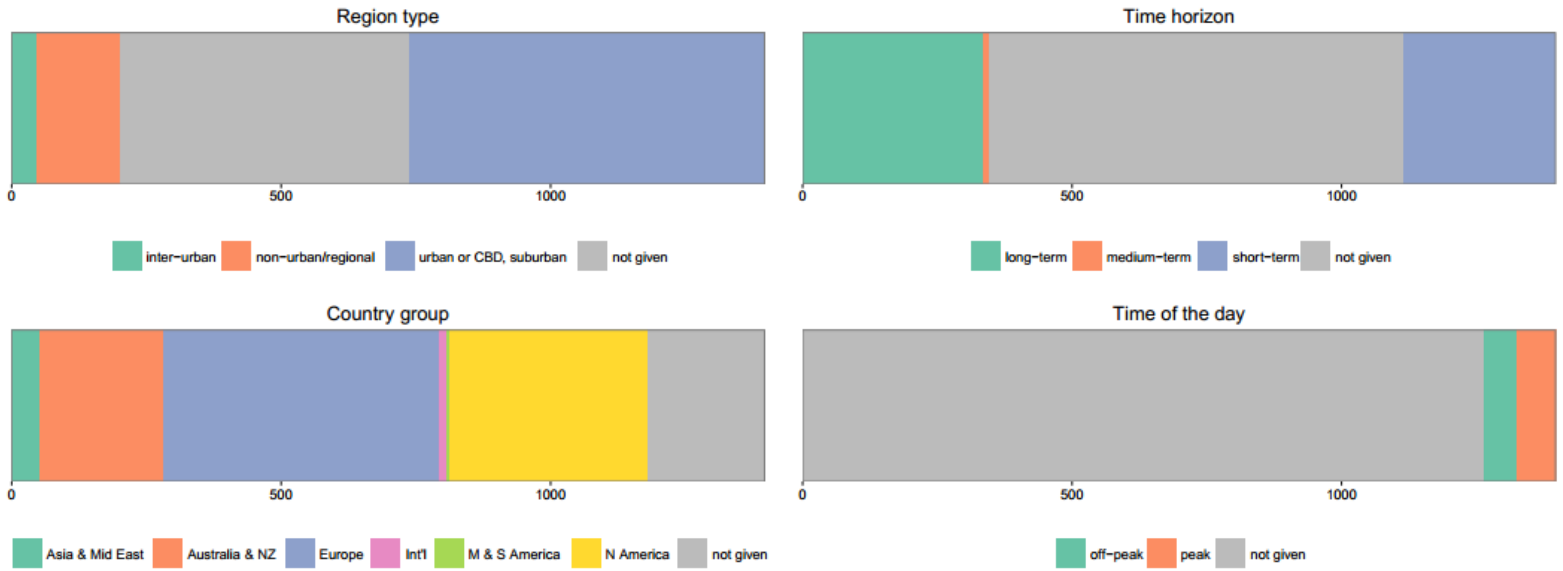
Meta-regression analysis (MRA)

Systematic literature review to determine meta-regression models

Query terms	Filter	Database	Studies
Any words: Fuel, Petrol, Diesel, Gasoline	-	BITRE	29
('fuel' OR 'petrol' OR 'diesel' OR 'gasoline') AND ('elasticity' OR 'elasticities')	English, 1950-2016	TRIS	24
('fuel' OR 'petrol' OR 'diesel' OR 'gasoline') AND ('elasticity' OR 'elasticities')	English, 1950-2016	ITRD	5
Any words: Bus, Coach, Train, Subway, Metro, Public	-	BITRE	51
('bus' OR 'coach' OR 'train' OR 'subway' OR 'metro' OR 'public') AND ('fare' OR 'price' OR 'time' OR 'ticket') AND ('elasticity' OR 'elasticities')	English, 1950-2016	TRIS	11
('bus' OR 'coach' OR 'train' OR 'subway' OR 'metro' OR 'public') AND ('fare' OR 'price' OR 'time' OR 'ticket') AND ('elasticity' OR 'elasticities')	English, 1950-2016	ITRD	7
Separate searches: Toll, Congestion, Road pricing	-	BITRE	9
('toll' OR 'congestion' OR 'road pricing') AND ('elasticity' OR 'elasticities')	English, 1950-2016	TRIS	9
('toll' OR 'congestion' OR 'road pricing') AND ('elasticity' OR 'elasticities')	English, 1950-2016	ITRD	9
Parking	-	BITRE	10
'parking' AND ('elasticity' OR 'elasticities')	English, 1950-2016	TRIS	6
'parking' AND ('elasticity' OR 'elasticities')	English, 1950-2016	ITRD	1
Total study records returned			172
Excluded due to duplication, non-accessibility or irrelevance			69
Total studies in database			**103**
Total elasticity estimates in database			**1397**

- Data sources:
  - TRID (TRB+OECD)
  - BITRE Elasticity database
  - TDM encyclopedia
- Focus:
  - PT wrt. fuel price
  - PT/IT wrt. bus fares
  - PT/IT wrt. city transit fares (rail-bound)
  - Toll / road pricing
  - IT / PT wrt. train fares
  - IT / PT wrt. coach fares


Historical data availability per major world region
estimates
300
200
100
0
1960–1964
1965–1969
1970–1974
1975–1979
1980–1984
1985–1989
1990–1994
1995–1999
2000–2004
2005–2009
2010–2014
2015+
Asia & Mid East
Europe
M & S America
not given
Australia & NZ
Int'l
N America


Region type
0
500
1000
inter−urban
non−urban/regional
urban or CBD, suburban
not given
Time horizon
0
500
1000
long−term
medium−term
short−term
not given
Country group
0
500
1000
Asia & Mid East
Australia & NZ
Europe
Int'l
M & S America
N America
not given
Time of the day
0
500
1000
off−peak
peak
not given

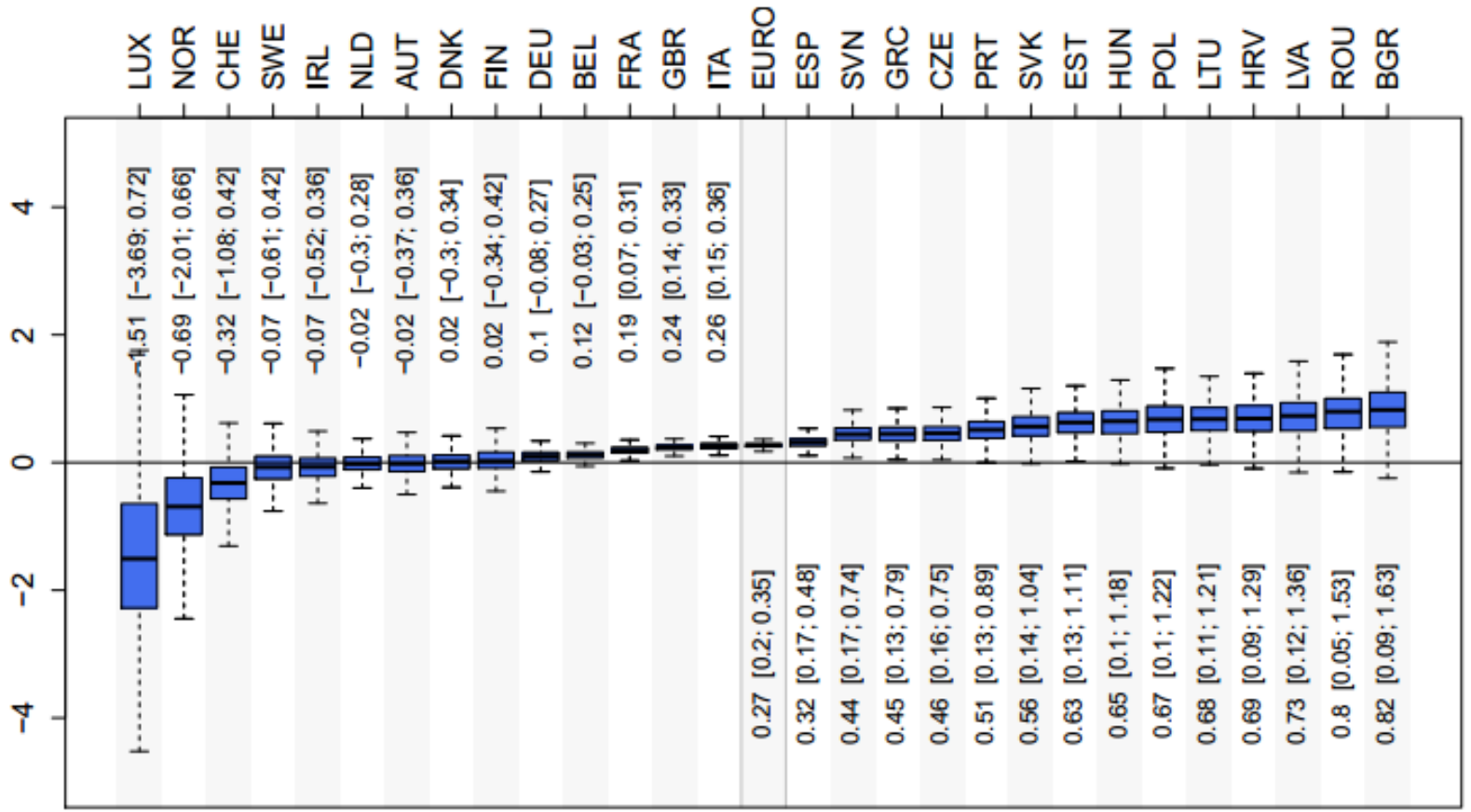
Meta-regression analysis (MRA)

Example: Country-specific short-/long-term PT cross-demand elasticity of fuel price

Variable	Coefficient (Std. Error)	t-value	p-value	
short-term (adj. R^2=0.90)				
GDP per cap., PPP [1000 Intl.-$\$_{2011}$]	-0.0501 (0.0135)	-3.711	0.0048	**
Population density [1000 ppl/km^2]	0.7673 (0.4422)	1.735	0.1168	
Rail track length per area of land [km], logarithm	0.0584 (0.0376)	1.552	0.1552	
Year of reference	0.0011 (0.0002)	4.708	0.0011	**
long-term (adj. R^2=0.96)				
GDP per cap., PPP [1000 Intl.-$\$_{2011}$]	-0.0705 (0.0366)	-1.927	0.0902	.
Population density [1000 ppl/km^2]	2.7601 (0.7464)	3.698	0.0061	**
Rail track length per area of land [km], logarithm	0.2877 (0.0350)	8.209	0.0000	***
Year of reference	0.0020 (0.0005)	3.776	0.0054	**

Meta-regression analysis (MRA)

Example: Country-specific short-term PT cross-demand elasticity of fuel price



Case study: Passenger transport in EU28+2

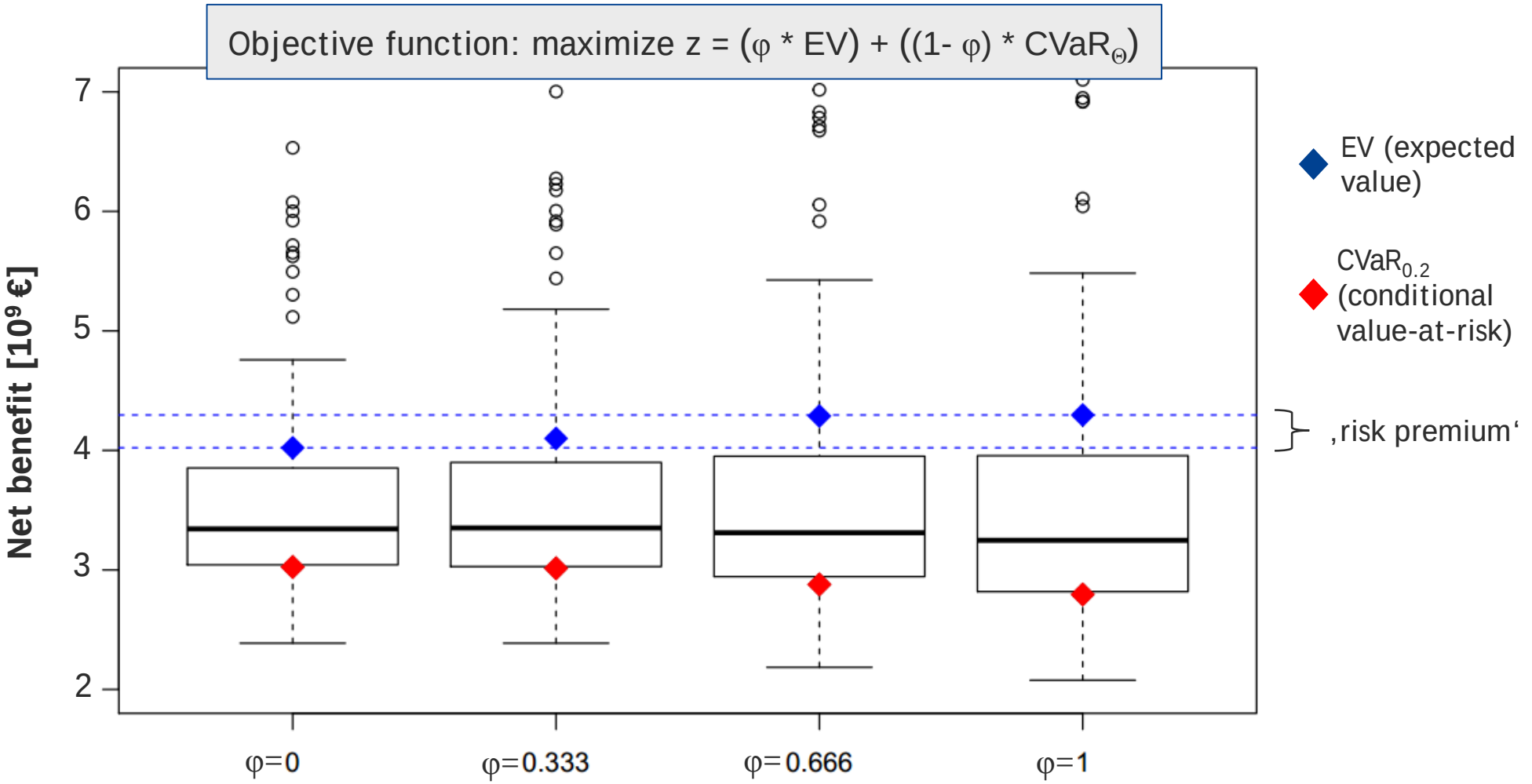
Model set-up

- 2030 reference demand levels – adjusted for income
- Selection and parametrization of policies (under constraints), e.g.
  - Fuel tax
  - Public transport fares (bus, metro, trains, …)
  - City toll
- Objective function
  - Risk-neutral case (EV)
  - Risk-averse case ($CVaR_{0.2}$ ~ EV of 20% worst cases)
  - Parametrized risk-attitude:

    $(\varphi * EV) + ((1- \varphi) * CVaR_{\Theta})$, φ in [0; 1] , Θ in {0.2, 0.1, 0.05, …}

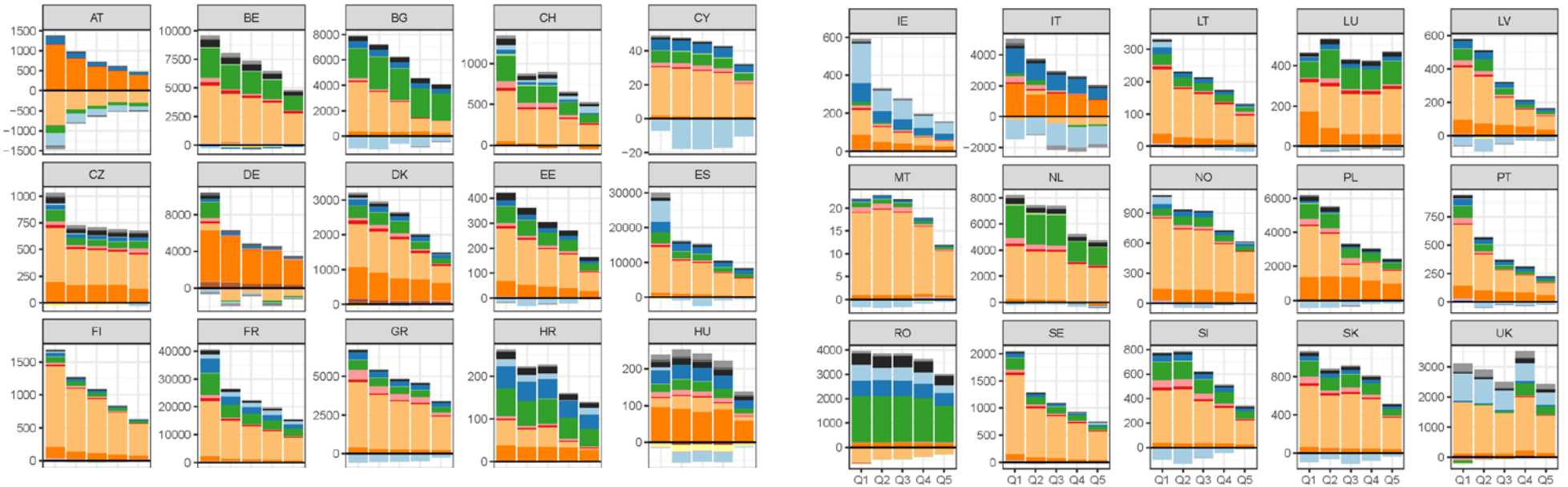
Case study: Passenger transport in EU28+2

Different risk attitudes



Case study: Passenger transport in EU28+2

Avoided damages in risk-neutral case (k-EUR per country per income group)



Conclusions

wrt. results of the case study

- Both scenarios yield net benefit; only **moderate risk premium**
- Summary of policies:
  - General tendency to lower fares to **‚pull' people towards public transport** in urban areas
  - Favourable to **implement city toll**, especially for vans
  - **Avoid to ‚push' people away from individual travel using a fuel tax** as people's response is highly uncertain; might even cause **rebound effects**
  - **Transport inequality** will even be **aggravated** – spend money on compensation payments for higher acceptance

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Vielen Dank!

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