Marine trade-offs: comparing the benefits of off-shore wind farms and marine protected areas

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Highlights

- We analyse the trade-offs between wind energy production and the designation of marine protected areas in Estonia
- Discrete choice modelling is used to estimate the relative welfare effects of 3 design options in two locations
- We use the latent class mixed logit model in willingness to pay space – the model shows distinct preference heterogeneity both within and between latent classes of respondents
- On average, people prefer “eco” windfarms or marine protected areas to conventional windfarms

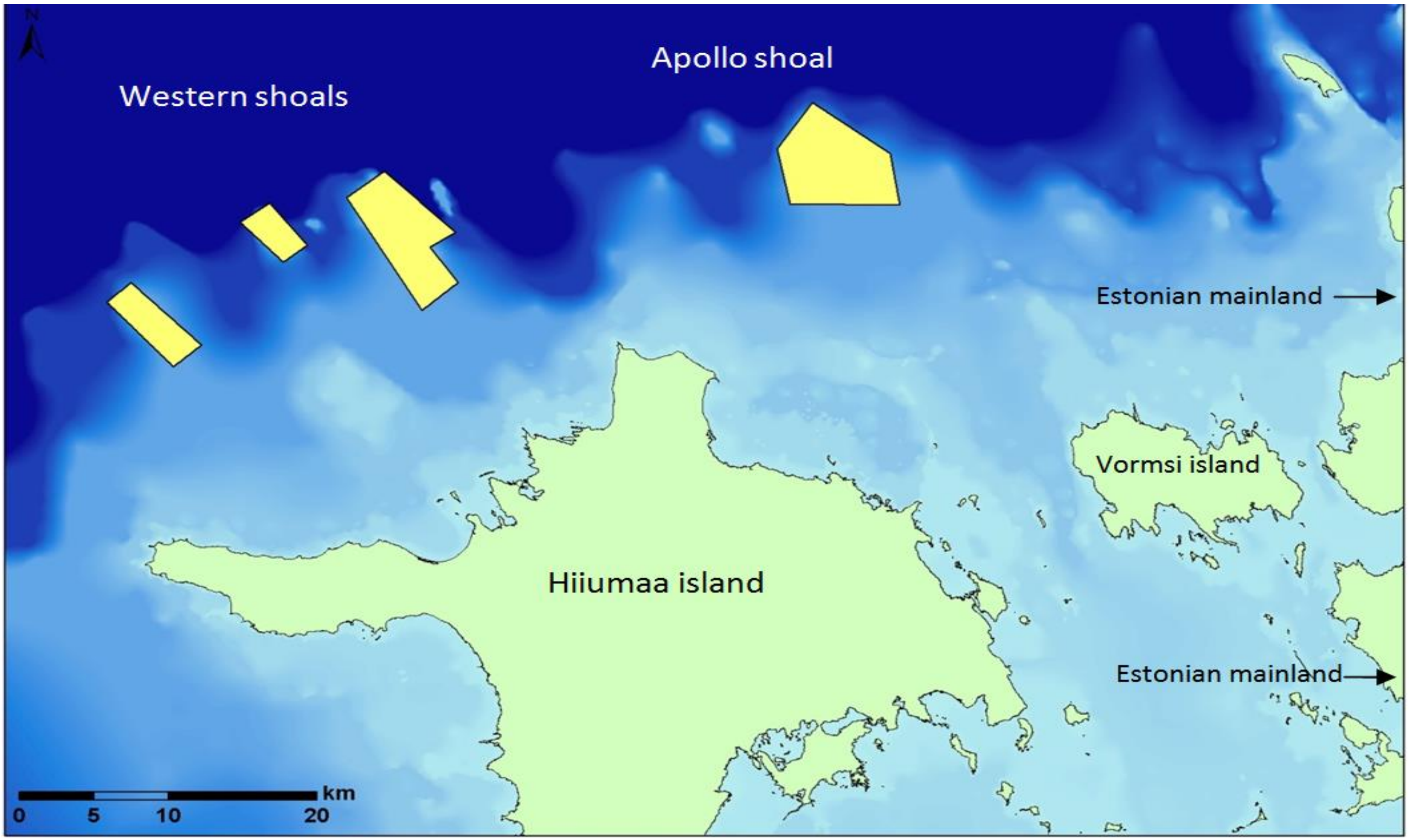
Policy context

- Climate and energy policies require the reduction of CO_2 emissions and an increase in the share of renewables in the energy mix
- Wind turbines require space and are often contested by local inhabitants
- Growing interest in locating new windfarms off-shore, away from inhabited areas
- Previous economic valuation studies show both support for and opposition towards off-shore renewable installations

Policy context cont.

- Any new investment in off-shore wind energy:
  - Economic benefits – those who support the expansion of renewables, the value of electricity produced and the savings in CO_2 and other emissions
  - Economic costs – those who oppose specific investments
- Competing use of marine shoals – Marine Protected Area:
  - Important tool of ecosystem-based marine spatial management – balance the increasing diversity and intensity of human activities with the sea's ability to provide ecosystem services
  - Empirical studies report positive WTP for establishing MPA, typically with preferences for more stringent restrictions on allowed uses of these areas

The study site:
shallow marine areas north-west of Hiiumaa island in Estonia



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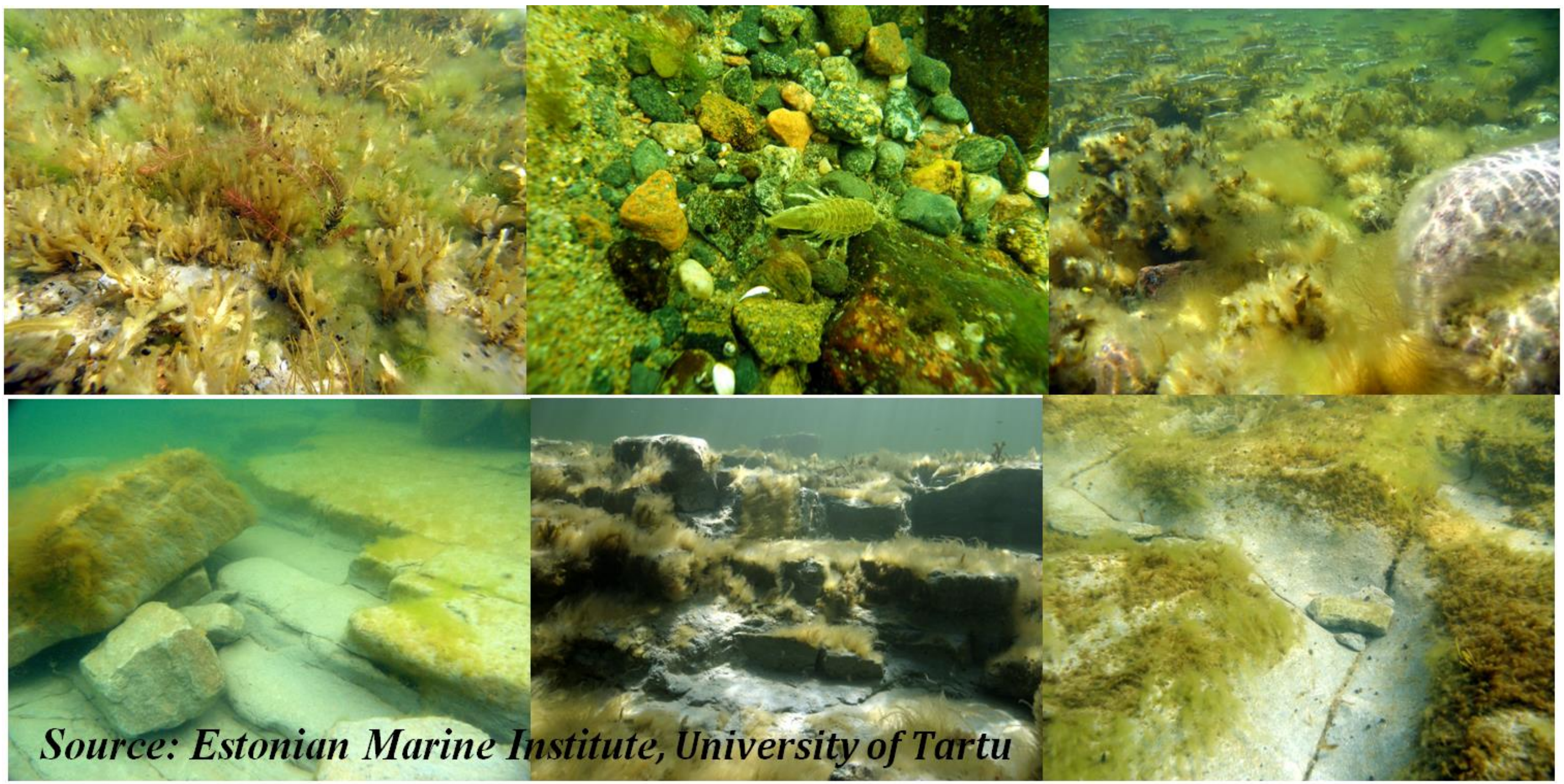
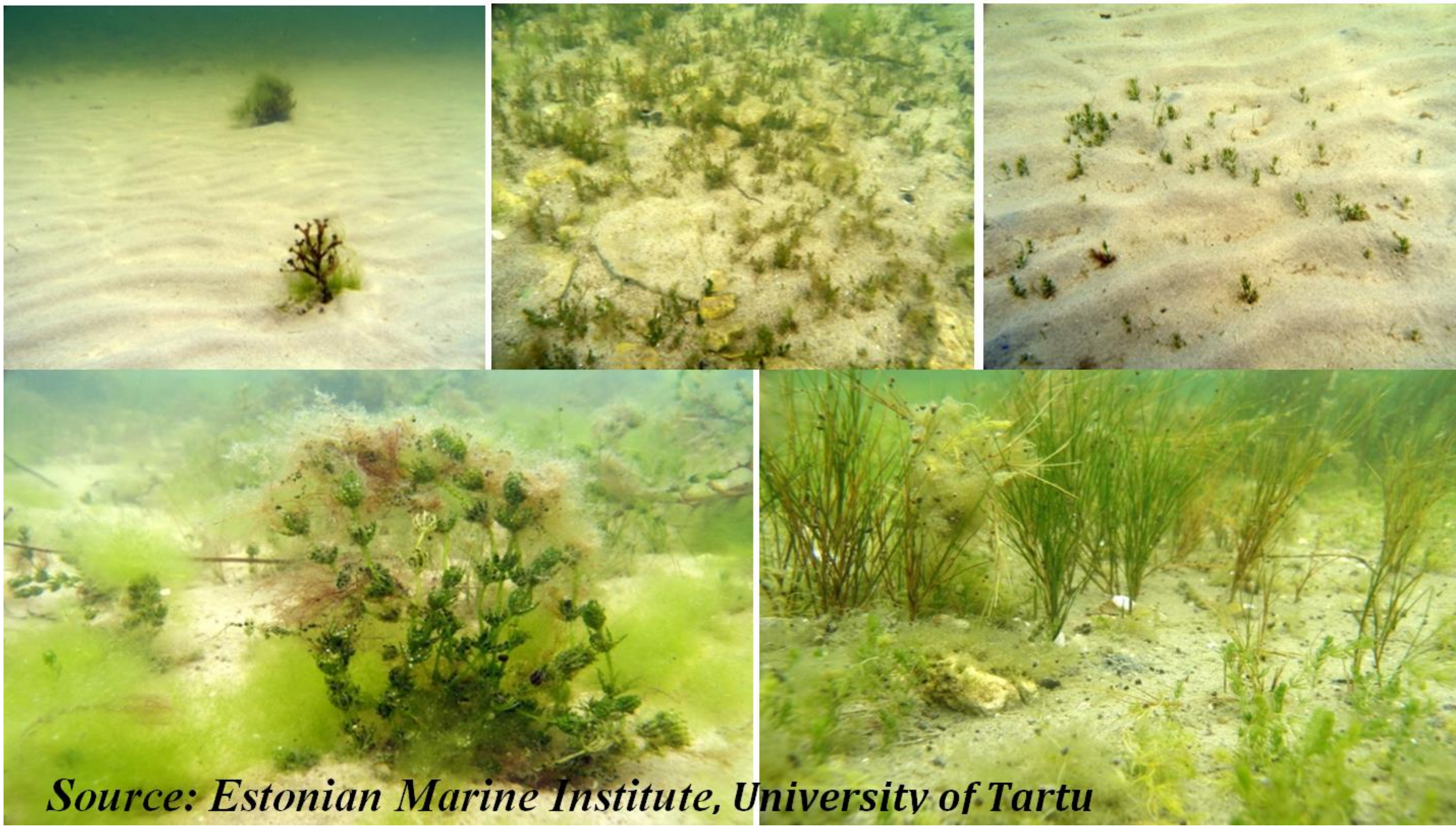
shallow marine areas north-west of Hiiumaa island in Estonia

- Marine shoals:
  - A good opportunity for installing wind turbines
  - Siting wind farms can damage their ecological quality
- Ecologically valuable reef and sandbank habitats
  - Rich spawning areas for fish and good habitat for birds and sea mammals
  - Relatively more sandbank habitats on the Apollo shoal (8% of the area)
    - It provides a habitat for many seabird species, including the long-tailed duck
  - Relatively more reef habitats on the Western shoals (30% of the area)
    - Reef habitats are relatively rare in the Baltic Sea and they are biodiversity hot spots

Reef habitats



Sandbank habitats



Seabirds on the shoals

Long-tailed Duck, Common Scoter, Common Eider, Herring Gull, Little Gull

Management options

- Currently – to a large extent undisturbed
- Plan A: constructing wind energy farms
  - Approximately 200 wind turbines
    - Up to 22% of Estonian total electricity production
    - Contribute to the energy security, increase the share of renewables, replace oil shale
  - Temporary but major pressures on the marine environment of Hiiumaa shoals:
    - Bottom habitats strongly affected during construction; marine mammals, fish and birds would all be disturbed
    - The impact on marine life during the operation phase is unclear; use of the shoals by birds would probably be limited

Management options cont.

- Plan B: constructing “eco wind farms”
  - Minimize environmental pressures
  - Wind turbines located where valuable bottom habitats are not present
  - Decreased number of wind turbines, increased power capacity of each turbine (the production of the same amount of electricity with reduced impacts on birds)
  - The use of the best available techniques in order to minimize the effects on the environment both during construction and operation phase
- Plan C: establishing marine protected areas
  - Currently about 27% of marine waters in Estonia are under some form of regulated use (i.e. no fishing, mining or installation of wind turbines allowed)

The discrete choice experiment setup

– An example of a choice card (translation):

	Status Quo	Alternative A	Alternative B
Apollo shoal	No change	ECO-WF	MPA
Western shoals	No change	WF	No change
Cost to your household (EUR per year)	0	20	10
YOUR CHOICE	☐	☐	☐

– CAWI

– The sample of 800 respondents quota-controlled for gender, age, nationality and place of residence

Econometric approach

- The latent class mixed logit model (LCMXL)
  - Segmentation of similar preference components into classes
  - Unobserved preference heterogeneity within these classes (via random parameters)
  - More flexibility in representing preference heterogeneity than the standard latent class model or the mixed logit model
    - Possibility of multi-modal preferences
  - In WTP-space

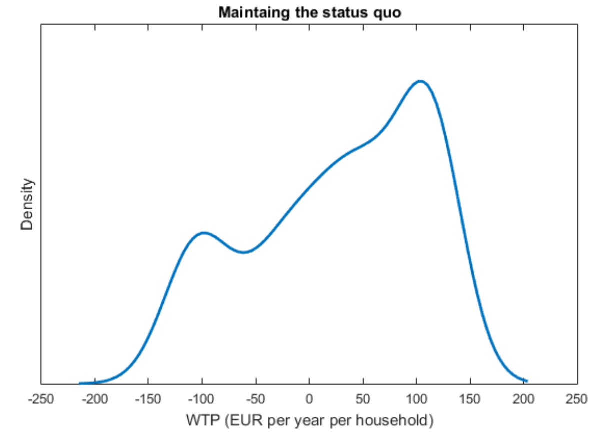
$$P(y_i \mid \mathbf{X}_i, \mathbf{Z_i}, \mathbf{\Omega}) = \sum_{c=1}^{C} \pi_c P\left(y_i \mid \mathbf{X}_i, \mathbf{\Omega}^c, class = c\right)$$

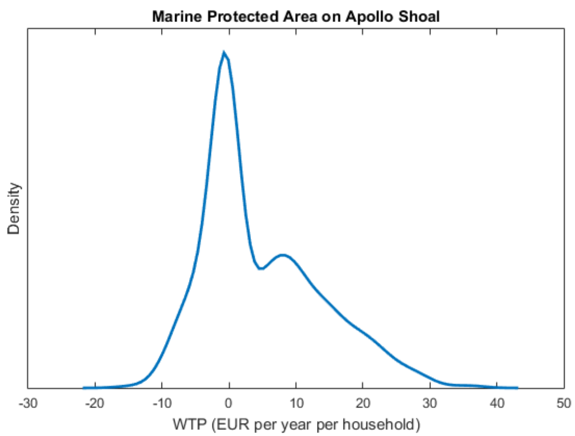
$$\pi_c = \frac{\exp\left(\boldsymbol{\theta}_c{}'\mathbf{Z_i}\right)}{1+\sum_{k=1}^{C-1}\exp\left(\boldsymbol{\theta}_k{}'\mathbf{Z_i}\right)} \qquad P(y_i \mid \mathbf{X}_i, \mathbf{\Omega}^c, class = c) = \int \prod_{t=1}^{T_i} \frac{\exp\left(\sigma_i^c a_i^c \left(p_{ijt} + \boldsymbol{\beta}_i^{c\prime}\mathbf{X}_{ijt}\right)\right)}{\sum_{k=1}^{C}\exp\left(\sigma_i^c a_i^c \left(p_{ikt} + \boldsymbol{\beta}_i^{c\prime}\mathbf{X}_{ikt}\right)\right)} d(a_i^c, \boldsymbol{\beta}_i^c)$$

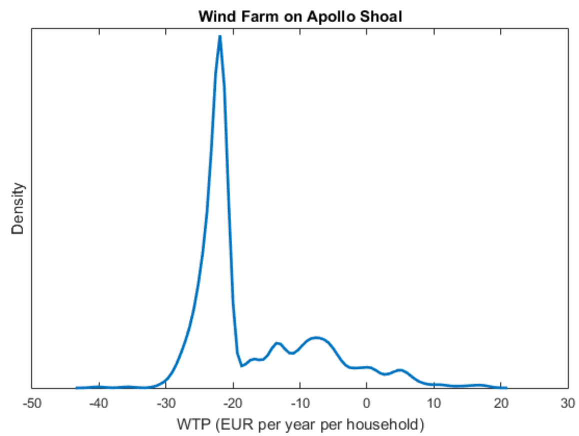
Results – marginal WTP (EUR / household / year)

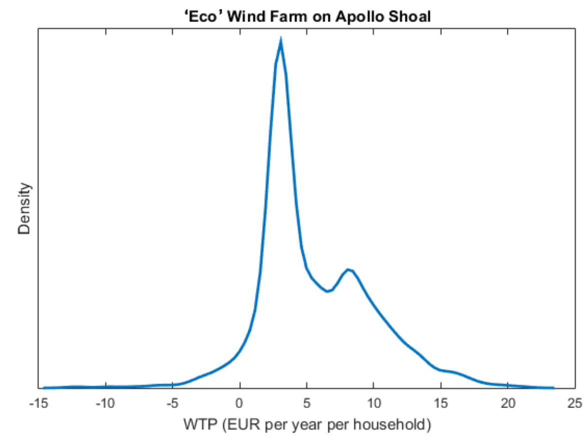
	Latent class 1		Latent class 2		Latent class 3	
Preference parameters						
	mean	st. dev.	mean	st. dev.	mean	st. dev.
Status quo (alternative specific constant)	-45.65 (23.69)	270.08*** (57.81)	-6.65** (2.77)	21.17*** (2.67)	11.26*** (0.77)	12.30*** (0.01)
Marine Protected Area on Apollo Shoal	29.87*** (4.32)	4.90 (10.25)	-17.78*** (3.63)	37.10*** (4.85)	0.34** (0.17)	0.75*** (0.45)
Wind Farm on Apollo Shoal	11.29*** (3.49)	11.15*** (4.72)	-73.00*** (9.72)	29.49*** (6.89)	0.49 (0.50)	0.08 (0.42)
'Eco' Wind Farm on Apollo Shoal	13.93*** (3.30)	1.33 (25.54)	7.13*** (2.42)	20.69*** (2.29)	-0.06 (0.79)	1.85*** (0.78)
Marine Protected Area on Western Shoals	32.83*** (4.74)	0.04 (78.38)	-3.26 (3.50)	32.98*** (4.10)	0.72 (0.69)	0.03 (1.07)
Wind Farm on Western Shoals	26.19*** (4.93)	1.71 (20.23)	-39.10*** (5.10)	41.15*** (5.51)	0.03 (0.75)	2.59*** (0.04)
'Eco' Wind Farm on Western Shoals	12.41*** (3.13)	6.46 (6.61)	-0.80 (2.54)	19.07*** (2.70)	-0.21 (0.57)	0.01 (0.47)
Annual cost per household (scale)	-13.77*** (1.73)	8.36*** (1.71)	-0.80 (1.10)	6.27*** (1.44)	57.59*** (15.44)	41.95*** (18.04)
Average class probabilities						
	0.34		0.34		0.32	

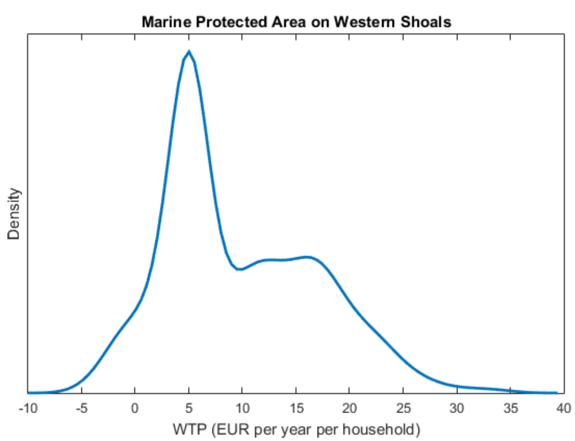
Results – the distribution of individual-specific (posterior) preferences (mean WTP)

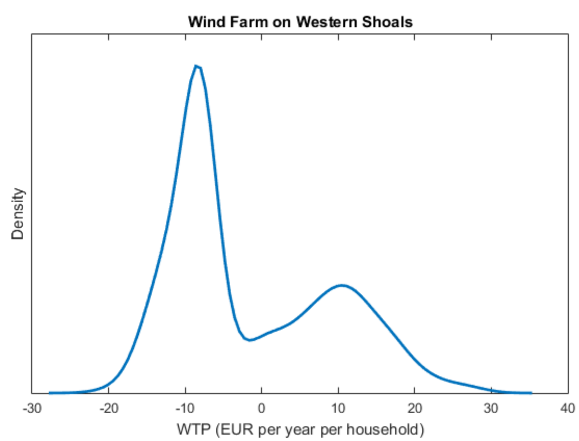


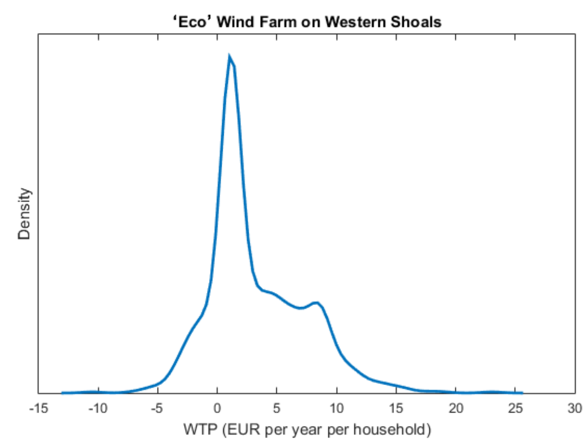












Results –
simulated welfare changes associated with the implementing a uniform policy on all of the shoals (EUR / year / household)

	Marine Protected Areas	Conventional Wind Farms	ECO-Wind Farms
Mean (st.error)	29.13 (8.9458)	-10.47 (9.8009)	25.46 (8.0011)
95% c.i.	(11.60 ; 46.71)	(-29.65 ; 8.79)	(9.77 ; 41.13)

Summary and conclusions

- Citizens willing to pay both for "environmentally-friendly" new windfarms, and the designation of new marine protected areas; willing to pay to avoid the siting of conventional windfarms (preference for the best available technology?)
- Considerable differences in the WTP for each of these options between the two areas (Apollo and Western Shoals)
- Substantial within-and between-class preference heterogeneity; LCMXL can provide its more sophisticated representation; estimation in WTP-space can make convergence more difficult

- The move to site new wind capacity off-shore changes and shifts economic costs (dis-amenity, effects on wildlife) spatially, but does not avoid them
- Such investments also create trade-off situations and it is still necessary to evaluate the relative environmental and economic benefits and costs