Green GDP

Valuation of the water environment since 1990

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Outline

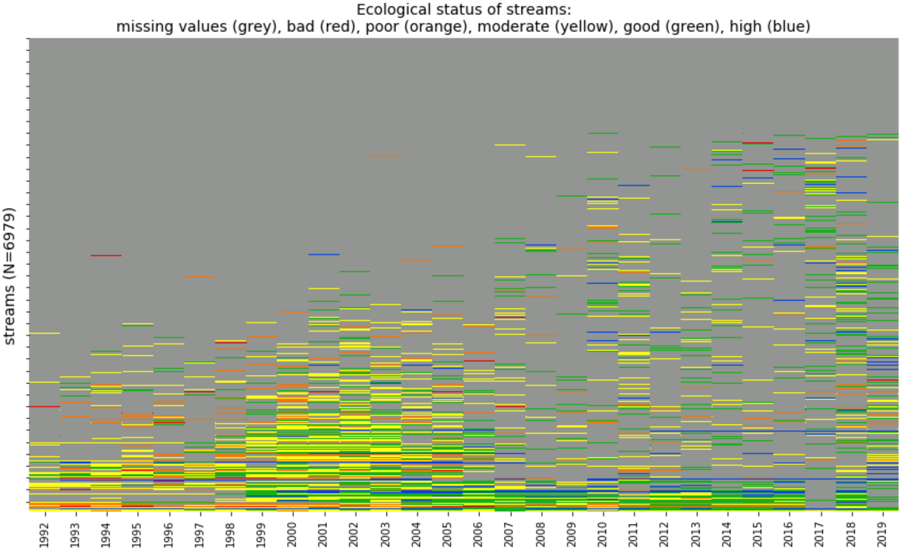
1. Assess ecological status from 1990-2020
2. Apply valuation from stated preferences
3. Growth decomposition
4. Takeaways

Assess ecological status from 1990-2020

Construct a complete panel dataset of ecological status for 1990-2020 comprising every Danish waterbody:

1. Biologists' field observations with GPS coordinates.
2. Assign point observations to matching water bodies.
3. Impute missing observations.
4. Translate biological indicators into ecological status being "Bad", "Poor", "Moderate", "Good", or "High".
    - Water quality $Q \in \{0, 1, 2, 3, 4\}$

Missing observations for streams




High
Good
Moderate
Poor
Bad
Unknown

Apply valuation from stated preferences

Marginal willingness to pay per year using stated preference studies:

- **Surface waters**: Meta regressions analysis of 32 nordic studies (Zandersen, M., S. B. Olsen, L. Martinsen, T. E. Panduro, K. H. Zemo, and B. Hasler, 2022, DCE Scientific Report no. 486).
- **Groundwater:** Choice experiment with 383 respondents around Limfjorden (Larsen, T. H., T. Lundhede, and S. B. Olsen, 2020, IFRO Working Paper). Questionnaire Example
  - Overrepresentation of women and higher educated.
  - Marginal WTP per year for improvement in groundwater quality from bad to good: 4,700 DKK (2019-prices).
- **Groundwater (old):** Choice experiment with 584 respondents (Hasler, B., T. Lundhede, L. Martinsen, S. Neye, and J. S. Schou, 2005, NERI Technical Report no. 543).
  - Exclusive focus on untreated vs treated drinking water.
  - WTP for untreated drinking water: 987 DKK (2005-prices).

Benefit transfer for surface water

Meta analysis function for benefit transfer of the marginal WTP per year for average water quality of the waterbodies of category j (streams, lakes, or coastal waters) in catchment area v in year t:

$$\ln \mu_{u,v,t}^{w,j} = \beta_0 + .55\overline{\ln Q}_{j,v,t} - .38D_j^{lake} - .01SL_{j,v} + .12\ln PSL_{j,v} - .07\ln PAL_v + 1.45\ln y_{v,t} + .5D_{v,t}^{age}, \quad \overline{\ln Q}_{j,v,t} = \frac{1}{\mathcal{I}_{j,v}} \sum_i^{\mathcal{I}_{j,v}} \mathbb{1}_{\mathbb{N}^+}(Q_{i,j,v,t}) \ln Q_{i,j,v,t}$$

$\overline{Q}_{jvt}$	mean water quality of category j in v at year t (deviation from "Bad")
D_j^{lake}	dummy for category j being lakes
SL_{jv}	shore length of category j (in 1,000 km) in catchment area v
PSL_{jv}	shore length of category j relative to total shore length in area v
PAL_v	proportion of agricultural land in catchment area v
y_{vt}	average household income in catchment area v at year t
D_{vt}^{age}	dummy for mean age of inhabitants $\geq$ 45 years in v at year t

Shadow value of groundwater

Use value of (clean) groundwater per household in catchment area v for year t:

$$\mu^{w,gw}_{u,v,t} = WTP^{gw}_t \frac{b^{good}_{v,t}}{B_{v,t}}, \qquad WTP^{gw}_t = \frac{WTP^{gw}_{2020}}{\prod_{k=1}^{2020-t}(1+\eta g_{2020-k})}$$

WTP^{gw}_t marginal WTP per household for “Good” groundwater quality

$b^{good}_{v,t}$ number of wells with “Good” groundwater quality

$B_{v,t}$ total number of well in catchment area v

η **income elasticity = 1 or 1.45 as for surface waters?**

g_t national average growth rate of household income over the last three years.

Time series and decomposition of use value of water

Aggregate use value of all water environmental services depends on the number of households N in catchment area v.

Sum over all categories $l \in \{\text{groundwater, streams, lakes, coastal waters}\}$:

$$\mu^{w}_{u,t} W_t = \sum_{v} \sum_{l} \mu^{w,l}_{u,v,t} N_{v,t}$$

Contributors to growth in the real value of consumption of water environmental services from 1990-2020:

- Water quality $\nearrow$
- Age $\nearrow$
- Household income $\nearrow$
- Family patterns $\nearrow$
- Urbanization $\searrow$

Main takeaways

1. Quality of the water environment improved from 1990-2020.
   - If ΔGNNI $>$ ΔNNI $\Rightarrow$ NNI and GDP underestimated growth.
2. Changes in sociodemographic factors affect the Green NNI.
3. The marginal WTP per year for a water quality of *good* as opposed to *bad* would add up to:
   - DKK 7 b (2020-prices) for all streams.
   - DKK 4 b (2020-prices) for all lakes.
   - DKK 6 b (2020-prices) for all coastal waters.
   - DKK 13 b (2020-prices) for all groundwater bodies.

Example 1: Characteristics of ground water quality

Three different ground water quality levels are distinguished: *Good, Moderate and Poor*. The differences between these levels are described below. The water can always be used for irrigation no matter the quality level.

Ground water quality	Description of water quality
Good	The water quality is not affected by pollution from human activity The water can be used for drinking following minimal treatment
Moderate	The water quality is slightly affected by pollution from human activity The water can be used for drinking following minimal treatment
Poor	The water quality is very affected by pollution from human activity The water can be used for drinking following more comprehensive treatment

Example 2: Choice set for ground water quality

Choice situation 1

	Current policy	Proposal 1	Proposal 2
Expected water quality	Poor	Moderate	Good
Risk of water quality not improving	No water quality improvement	40 % risk of not improving water quality	No risk (Water quality will improve as expected)
Water quality is achieved in	8 years	50 years	8 years
Tax increase for your household	$0 per year	$15 per year	$105 per year

I prefer *(If you find the proposals too expensive relative to the resulting improvements, you should choose the current policy)*

Current policy | Proposal 1 | Proposal 2

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