Green GDP

Valuation of the water environment since 1990

Thor Donsby Noe[1]   Jette Bredahl Jacobsen[2]

[1]AU/ECON

[2]UCPH/IFRO

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Outline

Limitations of GDP

"The welfare of a nation
can scarcely be inferred
from a measurement of
national income"

———————————————

Simon Kuznets, 1934

MOTIVATION (1)
While Simon Kuznets' was in charge of developing the concept of
GDP in the 1930s, he warned that **(...)**.

Limitations of GDP

> "The welfare of a nation
> can scarcely be inferred
> from a measurement of
> national income"
>
> *Simon Kuznets, 1934*

GDP has become synonymous with welfare despite not capturing:

1. The value of the consumption of ecosystem services.
2. The value of social factors.

MOTIVATION (2)

Nonetheless, GDP has largely become synonymous with welfare - which has led to criticism of its shortcomings in not capturing either (1) or (2).

Therefore, there is a widespread search for alternative measures

- e.g. the European Commission has launched a **Beyond GDP initiative**, motivated as being *"about developing indicators that are as clear and appealing as GDP, but more inclusive of environmental and social aspects of progress. Economic indicators such as GDP were never designed to be comprehensive measures of prosperity and well-being."*

Why calculate a Green GDP?

Our estimation of a **Danish Green GDP** serves a triple purpose:

TRIPLE PURPOSE
As a solution to the first shortcoming of GDP,
we estimate a Danish Green GDP with a triple purpose:

Why calculate a Green GDP?

Our estimation of a **Danish Green GDP** serves a triple purpose:

1. Valuation allows summation and comparison of ecosystems.

PURPOSE (1)

1. Beyond just describing the water quality in biological terms, monetary **(...)** and indicates the WTP for improvements in a given ecosystem relative to consumption of conventional goods and costs of measures to improve the environment.

Our estimation of a **Danish Green GDP** serves a triple purpose:

1. Valuation allows summation and comparison of ecosystems.
2. Analyze whether economic development from 1990-2020 meets the criterion of "strong" sustainability?

PURPOSE (2)

1.

2. Neither GDP nor the Green GDP should be interpreted as a measure for welfare, but the Green GDP is the attempt to **(...)** i.e. whether growth happened at the expense of the overall environment or allowed for a positive net growth in the environmental quality?

Why calculate a Green GDP?

Our estimation of a **Danish Green GDP** serves a triple purpose:

1. Valuation allows summation and comparison of ecosystems.
2. Analyze whether economic development from 1990-2020 meets the criterion of "strong" sustainability?
3. Provide a measure that is directly comparable to the GDP.

PURPOSE (3)

1.

2.

3. we do so using a measure that is directly comparable to the familiar concept of the GDP.

   – Alternatively, one could simply use **Genuine Saving** but it's a is less known concept which is already included as a component of the Green GDP - which moreover includes the **current benefit** of the environmental quality.

Research framework

Conventional Net National Income:

$$\textbf{NNI} = \text{GDP} - \text{depreciation of manufactured capital}$$
$$+ \text{ net foreign factor income}$$

FRAMEWORK (1)
In the literature, the Green NNI is the preferred measure, while one can deduct the Green GDP from it.

The **NNI** can be written as **(...)**:

i.e. the NNI captures the annual output of Danish citizens both domestically and abroad before accounting for the environment.

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Green GDP: The Water Environment
└─Motivation and framework

└─Research framework

Research framework

Conventional Net National Income:

NNI = GDP − depreciation of manufactured capital
+ net foreign factor income

Green Net National Income:

GNNI = NNI + benefit of the environmental quality
+ net growth in the environmental quality

Research framework

Conventional Net National Income:

$$\textbf{NNI} = \text{GDP} - \text{depreciation of manufactured capital}$$
$$+ \text{ net foreign factor income}$$

Green Net National Income:

$$\textbf{GNNI} = \text{NNI} + \text{benefit of the environmental quality}$$
$$+ \text{ net growth in the environmental quality}$$

FRAMEWORK (2)
The **Green NNI** is defined as:

NNI
+current marginal benefit of the environmental quality
+present value of net growth in environmental quality

[In more general terms - *only if asked*]
+value of consumption of environmental services
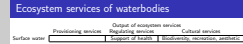+value of saving in environmental assets

Ecosystem services of waterbodies

	Output of ecosystem services		
	Provisioning services	Regulating services	Cultural services
Surface water		Support of health	Biodiversity, recreation, aesthetic

WTP for **surface water** quality:

- Regulating and supporting services wrt. human health.

- Existence and bequest values.

- Outdoor recreation and option value.

- Aesthetic value.

Ecosystem services of waterbodies

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Surface water		Support of health	Biodiversity, recreation, aesthetic
Groundwater	Drinking water*	Support of health	

Ecosystem services of waterbodies

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Green GDP: The Water Environment
└─Motivation and framework

　　└─Ecosystem services of waterbodies

	Output of ecosystem services		
	Provisioning services	Regulating services	Cultural services
Surface water		Support of health	Biodiversity, recreation, aesthetic
Groundwater	Drinking water*	Support of health	

WTP for **groundwater** quality:

- Regulating and supporting services wrt. human health.

- The market for drinking water is imperfect, so we use stated preferences to capture the full value.

- Use value (with minimal treatment).

- Bequest values.

Ecosystem services of waterbodies

	Output of ecosystem services		
	Provisioning services	Regulating services	Cultural services
Surface water		Support of health	Biodiversity, recreation, aesthetic
Groundwater	Drinking water*	Support of health	

Water quality can be damaged by:

- Physical modifications.

Physical conditions can be worsened by stream straightening or intensive dredging and cutting of water weeds.

Ecosystem services of waterbodies

	Output of ecosystem services		
	Provisioning services	Regulating services	Cultural services
Surface water		Support of health	Biodiversity, recreation, aesthetic
Groundwater	Drinking water*	Support of health	

Water quality can be damaged by:

- Physical modifications.
- Nutrient overenrichment $\rightarrow$ algae growth $\rightarrow$ oxygen depletion.

Nutrients, especially nitrate and phosphorus, are emitted from excessive use of fertilizers in agriculture and from point sources such as industry, cities, and sewage treatment plants.

Eutrophication i.e. **(...)**

Assess ecological status from 1990-2020

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

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Green GDP: The Water Environment
└─Assess ecological status from 1990-2020

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Assess ecological status from 1990-2020

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

This project consists of three parts.

1st part is to **(...)** i.e. for all streams, lakes, fjords, coastal waters and groundwater bodies. Process:

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

1. Biologists' field observations with GPS coordinates.

1. ... In the case of several observations in a year: apply the EU WFD's conservative approach of using the observation indicating the worst quality.

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.

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.

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Green GDP: The Water Environment
└─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.

└─Assess ecological status from 1990-2020

1.

2.

3. ... on the basis of observations of other waterbodies for the given year as well as observations from other years and a few physical characteristics. Issue: data isn't representative but has a systematic overrepresentation of larger waterbodies and those of special concern for the ecological quality.

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".

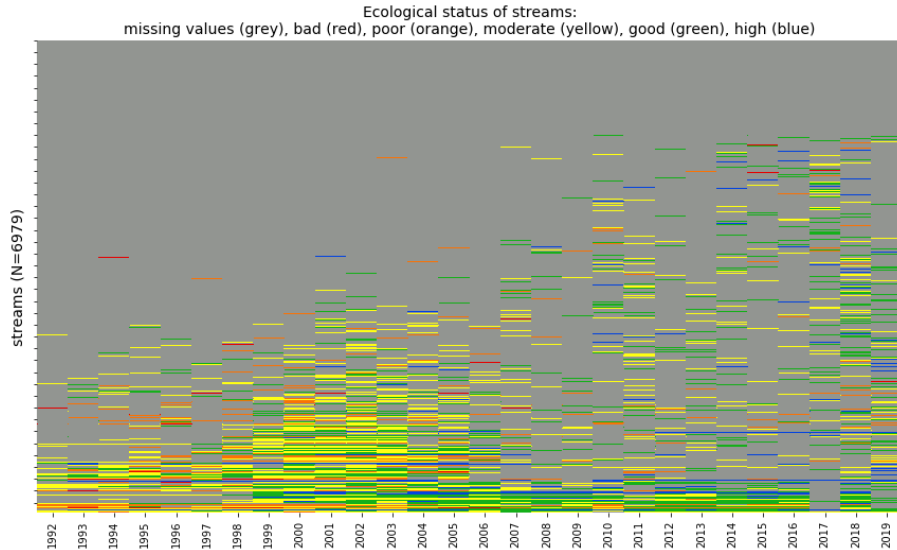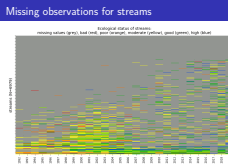Green GDP: The Water Environment
└─Assess ecological status from 1990-2020

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1.

2.

3.

4. ... based on certain thresholds given by the WFD.

Missing observations for streams

Ecological status of streams:
missing values (grey), bad (red), poor (orange), moderate (yellow), good (green), high (blue)

Heat map for each of the 7000 streams in VP2.

Grey indicates missing observations while a different color indicates the observed ecological status in a given year, i.e.

- Top: 9 % of streams that has never been observed but still has a goal of achieving 'good' ecological status in VP2.

- Bottom: Streams observed most years.

- Throughout the 90s, $\frac{2}{3}$ of observations were poor/moderate.

- From 2009, majority of observations were good/high quality.
  - Action Plan on the Aquatic Environment I (1987)
  - Action Plan on the Aquatic Environment II (1998)
  - Water Plan I (adopted by parliament 2009, municipal action plans 2010, measures came into effect 2012)
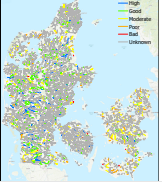
In 2019, water quality is still mostly poor/moderate in Eastern DK.

On average, a quarter of the total stream length is assessed each year; grey lines represent unobserved streams.

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).

Shadow prices express the marginal current benefits of improving the quality of the Danish water environment on a national level. Measured as **(...)**

- **(...)** comprising 124 estimates of marginal WTP for improvements in water quality.

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- **Groundwater:** Choice experiment with 383 respondents around Limfjorden (Larsen, T. H., T. Lundhede, and S. B. Olsen, 2020, IFRO Working Paper). `Questionnaire Example`

We have to rely on a single Danish study concerning the value of groundwater quality.

Apply valuation from stated preferences

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- **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).

They find a substantial WTP which, however, might be slightly biased by overrepresentation of groups that often show higher WTP.

Apply valuation from stated preferences

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- **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).

We acknowledge that there also exists an older study with a narrow focus on drinking water which we don't use.

Benefit transfer

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

$$\ln \mu_{j,q}^{w} = \beta_0 + .551 \ln WQ_{j,q} - .378 D_j^{lake} - .005 SL_{j,q} + .121 \ln PSL_{j,q}$$
$$- .072 \ln PAL_q + 1.453 \ln y_q + .496 D_q^{age}$$

$WQ_{j,q}$ quality of water bodies of category j in q (deviation from "bad")

D_j^{lake} dummy for category j being lakes

$SL_{j,q}$ shore length of category j in catchment area q (in 1,000 km)

$PSL_{j,q}$ shore length of category j relative to total shore length in q

PAL_q proportion of agricultural land in catchment area q

$\ln y_q$ average household income in catchment area q

D_q^{age} dummy for mean age of inhabitants in q $\geq$ 45 years

Growth decomposition

Aggregate value of waterbodies for a given year $= \sum\limits_{q} \sum\limits_{j} \mu_{j,q}^{w} N_q$

Growth decomposition

Aggregate value of waterbodies for a given year $= \sum_q \sum_j \mu_{j,q}^w N_q$

Contributors to growth in the real value of the Danish water quality from 1990-2020:

- Water quality ↗
- Age ↗
- Household income ↗
- Family patterns ↗
- Urbanization ↘

Main takeaways

1. Quality of the water environment improved from 1990-2020.
   - If ΔGNNI $> \Delta$NNI $\Rightarrow$ NNI and GDP underestimated growth.

PRELIMINARY RESULTS AND DISCUSSION
Overall, the quality of ecosystem services has improved since 1990. That is likely to be offset by the costs of GHG emissions and the depletion of exhaustible natural resources
- but if it should turn out that ΔGNNI $> \Delta$NNP,

$\Rightarrow$ then it would indicate that GDP growth has not been at the expense of the environment according to the definition of "strong" sustainability.

That is, with reservations that we don't fully live up to our international commitment such as the EU Water Framework Directive and the GHG reduction path implied by the Paris Agreement DESPITE outsourcing of our most polluting factories during the period.

Main takeaways

1. Quality of the water environment improved from 1990-2020.
   - If ΔGNNI $> \Delta$NNI $\Rightarrow$ NNI and GDP underestimated growth.
2. Changes in sociodemographic factors affect the Green NNI.

Main takeaways

1. Quality of the water environment improved from 1990-2020.
   - If ΔGNNI $> \Delta$NNI $\Rightarrow$ 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 <u>not</u> affected by pollution from human activity The water can be used for drinking following <u>minimal</u> treatment
Moderate	The water quality is <u>slightly</u> affected by pollution from human activity The water can be used for drinking following <u>minimal</u> treatment
Poor	The water quality is <u>very</u> affected by pollution from human activity The water can be used for drinking following more <u>comprehensive</u> treatment

EXAMPLE 1:

Description of the expected ground water quality following different policy proposals.

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

◂ Return

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Green GDP: The Water Environment
└─Examples of stated preferences

└─Example 2: Choice set for ground water quality

EXAMPLE 2:

Marginal WTP per household is deduced from elaborate question-naires such as the one containing this choice set regarding different proposed policies to improve ground water quality.