Contributions from ValuGaps:

“Valuation of biodiversity and ecosystem services: Methods and approaches to deal with limited information and uncertainty”

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Introduction

- As primary valuation is time-intensive and costly, mainstreaming non-market values requires methods to transfer and scale values of different types from primary valuation studies across time and space to estimate values for policy appraisal or accounting
- Benefit transfer is the "bedrock of practical policy analysis" (OECD), yet most approaches are theoretically weak in how they deal with heterogeneities in study & policy contexts
- We propose ready-to-implement formulas to transfer and scale non-market values across valuation contexts based on microeconomic theory of the value of ecosystem services with public-good characteristics (i.a./ Baumgärtner/Drupp/Meya/Munz/Quaas, 2017 *JEEM*)
- We test empirically how these theory-driven transfer factors for benefit transfer can help to reduce benefit transfer errors (i.a./ Meya/Drupp/Hanley 2021 *REE*)
- We also propose and calibrate approaches to "benefit transfer in time"

Basic Model

- two regions i: s ('study site') and p ('policy site')
- infinitely many individuals N_{j}
- two (composite) goods:
  - private consumption good X^{i}, traded on a market at exogenously given price P^{i}
  - pure public environmental good E^{i}, exogenously fixed at uniform level E^{i}
- all individuals have identical preferences over $(X_{\mathrm{j}}^{\mathrm{i}}, E^{\mathrm{i}})$, represented by utility function

$$U(X_{\mathrm{j}}^{\mathrm{i}}, E^{\mathrm{i}}) = \left(\alpha X_{\mathrm{j}}^{\mathrm{i}\,\frac{\theta-1}{\theta}} + (1-\alpha)\, E^{\mathrm{i}\,\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}},$$

  with constant elasticity of substitution $0 < \theta < +\infty$
- individuals differ in exogenously given income Y_j^{i}

Basic Model

Individual j's WTP for the environmental good at level E^{i} in region i depends on income Y^{i} as follows (Ebert, 2003 *EARE*):

$$\mathsf{WTP}(Y_{\mathsf{j}}^{\mathsf{i}}) = \kappa^{\mathsf{i}}\, {Y_{\mathsf{j}}^{\mathsf{i}}}^{\eta} \quad \text{with} \quad \kappa^{\mathsf{i}} = \frac{1-\alpha}{\alpha}(P^{\mathsf{i}}E^{\mathsf{i}})^{1-\eta}, \quad \eta = \frac{1}{\theta}\ ,$$

Baumgärtner/Drupp/Meya/Munz/Quaas (2017, *JEEM*) assume that income Y^{i} is distributed log-normally, with mean μ_Y^{i} and coefficient of variation $CV_Y^{\mathsf{i}} = \sigma_Y^{\mathsf{i}}/\mu_Y^{\mathsf{i}}$ of income

- good empirical approximation (e.g. Pinkovskiy and Sala-i-Martin, 2009)

$\Rightarrow$ In each region i, societal **mean WTP** for a change in E^{i} is given by

$$\mu_{\mathsf{WTP}}^{\mathsf{i}}(\mu_Y^{\mathsf{i}}, \mathsf{CV}_Y^{\mathsf{i}}) = \kappa^{\mathsf{i}}\, {\mu_Y^{\mathsf{i}}}^{\eta} \left(1 + {\mathsf{CV}_Y^{\mathsf{i}}}^2\right)^{\frac{\eta(\eta-1)}{2}}$$

Benefit transfer factors (Baumgärtner et al., 2017 JEEM)

from: study site (μ_Y^{s},CV_Y^{s}, ...) **to:** policy site (μ_Y^{p},CV_Y^{p}, ...)

Benefit transfer function

$$\mu_{\mathsf{WTP}}^{\mathsf{p}} = \mathcal{T}_{(\ldots)}(\ldots) \cdot \mu_{\mathsf{WTP}}^{\mathsf{s}}$$

Benefit transfer factors (Baumgärtner et al., 2017 JEEM)

from: study site (μ_Y^{s},CV_Y^{s}, ...) **to:** policy site (μ_Y^{p},CV_Y^{p}, ...)

Benefit transfer function

$$\mu_{\mathsf{WTP}}^{\mathsf{p}} = \mathcal{T}_{(\ldots)}(\ldots) \cdot \mu_{\mathsf{WTP}}^{\mathsf{s}}$$

with theory-driven **benefit transfer factors**:

$$\mathcal{T}_{\mu}(\mu_Y^{\mathsf{p}}, \mu_Y^{\mathsf{s}}) = \left(\frac{\mu_Y^{\mathsf{p}}}{\mu_Y^{\mathsf{s}}}\right)^{\eta}$$

$$\mathcal{T}_{CV}(CV_Y^{\mathsf{p}}, CV_Y^{\mathsf{s}}) = \left(\frac{1 + {CV_Y^{\mathsf{p}}}^2}{1 + {CV_Y^{\mathsf{s}}}^2}\right)^{\frac{\eta(\eta-1)}{2}}$$

$$\mathcal{T}_{E}(E^{p}, E^{s}) = \left(\frac{E^{\mathsf{p}}}{E^{\mathsf{s}}}\right)^{1-\eta}$$

Benefit transfer factors

from: study site (μ_Y^{s},CV_Y^{s}, ...) **to:** policy site (μ_Y^{p},CV_Y^{p}, ...)

Benefit transfer function

$$\mu_{\mathsf{WTP}}^{\mathsf{p}} = \mathcal{T}_{(\dots)}(\dots) \cdot \mu_{\mathsf{WTP}}^{\mathsf{s}}$$

with theory driven **transfer factors**:

$$\mathcal{T}_\mu(\mu_Y^{\mathsf{p}}, \mu_Y^{\mathsf{s}}) = \left(\frac{\mu_Y^{\mathsf{p}}}{\mu_Y^{\mathsf{s}}}\right)^\eta$$

Defra 2007, UBA 2012, OECD 2006

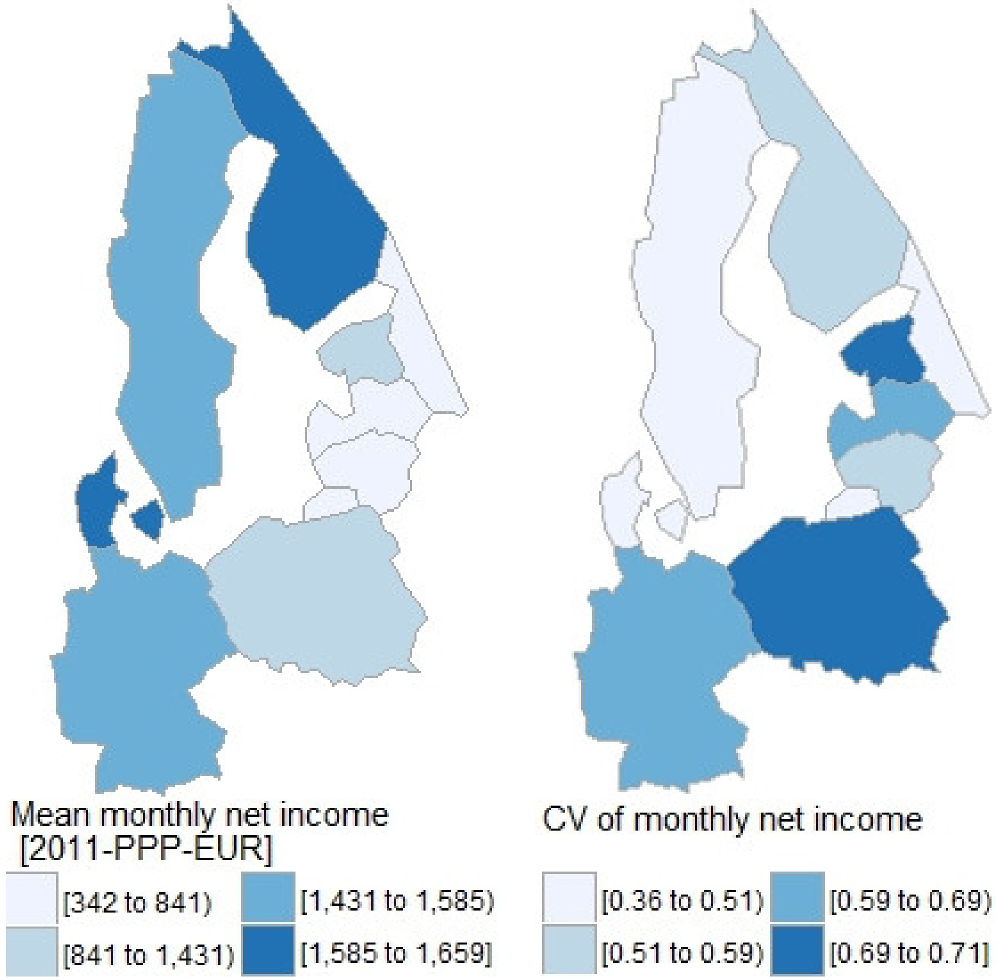
$$\mathcal{T}_{CV}(CV_Y^{\mathsf{p}}, CV_Y^{\mathsf{s}}) = \left(\frac{1 + CV_Y^{\mathsf{p}\,2}}{1 + CV_Y^{\mathsf{s}\,2}}\right)^{\frac{\eta(\eta-1)}{2}}$$

$$\mathcal{T}_E(E^p, E^s) = \left(\frac{E^{\mathsf{p}}}{E^{\mathsf{s}}}\right)^{1-\eta}$$

Empirical test: Case study

We test these theory-driven transfer factors using a multi-country contingent valuation study (Athinainen et al. 2014 *JEEP*):

- WTP for the same environmental good (nutrient reduction in the Baltic Sea),
- with public good properties ('open sea areas'),
- elicited with the same survey instrument,
- across 9 countries with substantially different income distribution!
- Income elasticity for pooled dataset $\tilde{\eta} = 0.28$ (Barbier/Czajkowski/Hanley 2016 *EARE*).



Empirical strategy

For each pair of countries (72 in total) we hypothetically transfer WTP-estimates from one country to the other and compare the transferred WTP with the surveyed WTP-estimates.

Transfer errors (e.g. Kirchhoff et al. 1997 *JEEM*)

$$|TE| = \frac{|WTP_{trans} - WTP_{obs}|}{WTP_{obs}} \cdot 100 = \frac{|f(\tilde{\mu}^{\mathsf{s}}_{WTP}) - \tilde{\mu}^{\mathsf{p}}_{WTP}|}{\tilde{\mu}^{\mathsf{p}}_{WTP}} \cdot 100$$

Comparison case: (Unadjusted) unit transfer

$$|TE|_{unit} = \frac{|\tilde{\mu}^{\mathsf{s}}_{WTP} - \tilde{\mu}^{\mathsf{p}}_{WTP}|}{\tilde{\mu}^{\mathsf{p}}_{WTP}} \cdot 100.$$

Empirical strategy

We estimate transfer errors after correcting for...

- ... **income inequality**

$$|TE|_{\mathcal{T}_{CV}} = \frac{\left|\mathcal{T}_{CV}(\tilde{CV}^{\mathsf{p}}_{Y}, \tilde{CV}^{\mathsf{s}}_{Y}, \tilde{\eta}) \cdot \ \tilde{\mu}^{\mathsf{s}}_{WTP} - \tilde{\mu}^{\mathsf{p}}_{WTP}\right|}{\tilde{\mu}^{\mathsf{p}}_{WTP}} \cdot 100,$$

- ... **mean income**

$$|TE|_{\mathcal{T}_{\mu}} = \frac{|\mathcal{T}_{\mu}(\tilde{\mu}^{\mathsf{p}}_{Y}, \tilde{\mu}^{\mathsf{s}}_{Y}, \tilde{\eta}) \cdot \ \tilde{\mu}^{\mathsf{s}}_{WTP} - \tilde{\mu}^{\mathsf{p}}_{WTP}|}{\tilde{\mu}^{\mathsf{p}}_{WTP}} \cdot 100,$$

- ... and both **income inequality and mean income**

$$|TE|_{\mathcal{T}_{CV,\mu}} = \frac{\left|\mathcal{T}_{CV}(\tilde{CV}^{\mathsf{p}}_{Y}, \tilde{CV}^{\mathsf{s}}_{Y}, \tilde{\eta}) \cdot \ \mathcal{T}_{\mu}(\tilde{\mu}^{\mathsf{p}}_{Y}, \tilde{\mu}^{\mathsf{s}}_{Y}, \tilde{\eta}) \cdot \ \tilde{\mu}^{\mathsf{s}}_{WTP} - \tilde{\mu}^{\mathsf{p}}_{WTP}\right|}{\tilde{\mu}^{\mathsf{p}}_{WTP}} \cdot 100.$$

Results

	$\lvert TE\rvert_{unit}$	$\lvert TE\rvert_{\mathcal{T}_{CV}}$	$\lvert TE\rvert_{\mathcal{T}_E}$	$\lvert TE\rvert_{\mathcal{T}_\mu}$	$\lvert TE\rvert_{\mathcal{T}_{E,\mu_Y,\text{CV}_Y}}$
mean	152.4	150.6	149.48	115.5	111.60

$\Rightarrow$ Income inequality and environmental goods level adjustment reduces transfer errors, but substantially less so that mean income adjustment

$\Rightarrow$ Applying all transfer tors reduces the mean transfers error by $\approx$27%

Summary and extensions

Summary

- We develop (Baumgärtner et al. 2017 *JEEM*) theory-driven benefit transfer factors and test them empirically (Meya et al. 2021 *REE*)

⇒ Theory-driven transfer factors are easy to apply and can help to reduce transfer errors

Extensions

- We're extending the theory-based transfer function approach
  - dynamic aspects, such as growth and interest rates (Meya et al., 2020 R&R *JAERE*)
  - preference heterogeneity (Drupp and Meya 2022, in prep)
  - local public goods and environmental substitutes (in progress)
  - ...
- As part of ValuGaps, we will carry out a multi-site valuation study specifically designed to test theory-based benefit transfer (and to compare it with meta-regression approaches)

“Benefit transfer in time” (relative price adjustment)

- We typically have to rely on somewhat outdated WTP studies and for valuing natural capital we need to consider all (discounted) future streams of ecosystem service values derived from the natural capital stock as well

- Example from the World Bank’s Changing Wealth of Nations:

  Forest ecosystem service values estimated via meta-regression analysis (Siikamäki et al. 2021) using 498 studies of non-wood forest benefits in 3 categories:
  (1) recreation, hunting, fishing, (2) watershed protection, (3) non-wood forest products.

- The capitalized value of ecosystem services is taken as the present value of annual services, discounted over 100 years, with a 4% SDR.
  - *“per-hectare monetary values estimated for 2018 are assumed to be constant over time and are adjusted for inflation using country specific GDP deflators.”*

Benefit transfer in time: Motivation

Structural change of inclusive capital and consumption:

Continuous growth of global economy and human-made goods, but parallel loss of non-market environmental goods (IPBES, 2019; IPCC, 2021; UNEP, 2021)

Research question:

How to value changes in the flow of ecosystem services when relative scarcities of ecosystem services vis-a-vis human-made consumption goods change over time?

Relevance:

Relative price changes already feature in policy guidance, e.g. in The Netherlands, while other countries use lower discount rates for environmental goods (Groom et al., 2022 *ARRE*)

⇒ Adjust WTPs for ecosystem services by relative price changes in policy appraisal and extended environmental-economic accounting

Background

Some non-market ecosystem services are a direct source of utility $U(C, E)$. Within the $STPR$ approach ($STPR_t = r_{C_t} = \rho + \mu_{CC} \times g_{C_t}$), we can accomodate this theoretically by (e.g. Baumgärtner et al. 2015 *EARE*; Gollier 2010 *JET*; Guesnerie 2004 *Rev.Eco.*; Heal 2005, 2009 *CC*; Hoel/Sterner 2007 *CC*; Malinvaud 1953 *Econometrica*; Traeger 2011 *JEEM*; Weikard/Zhu 2005 *Eco.Mod.*; ...)

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Some non-market ecosystem services are a direct source of utility $U(C, E)$. Within the $STPR$ approach ($STPR_t = r_{C_t} = \rho + \mu_{CC} \times g_{C_t}$), we can accomodate this theoretically by

A allowing for **differentiated discount rates**

$$r_{C_t} = \rho + \mu_{CC} \times g_{C_t} + \mu_{CE} \times g_{E_t} \tag{1}$$

$$r_{E_t} = \rho + \mu_{EE} \times g_{E_t} + \mu_{EC} \times g_{C_t} \tag{2}$$

where

- μ_{CC} (μ_{EE}): elasticities of *same-good* marginal utility of consumption
- μ_{CE} (μ_{EC}): elasticities of *cross-good* marginal utility of consumption

Background

Some non-market ecosystem services are a direct source of utility $U(C, E)$. Within the $STPR$ approach ($STPR_t = r_{C_t} = \rho + \mu_{CC} \times g_{C_t}$), we can accomodate this theoretically by

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B or accounting for **relative price changes** of ecosystem services vis-a-vis manufactured consumption goods

$$RPE_t = \frac{p_{Et}}{p_{Ct}} = \tfrac{d}{dt}\left(\tfrac{U_E}{U_C}\right) / \left(\tfrac{U_E}{U_C}\right) \tag{3}$$

With standard constant-elasticity-of-substitution (CES, σ) preferences:

$$U(C_t, E_t) = \left(\alpha C_t^{\frac{\sigma-1}{\sigma}} + (1-\alpha) E_t^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{4}$$

$$\implies r_{C_t} - r_{E_t} \;=\; RPE_t \;=\; 1/\sigma \times \left[g_{C_t} - g_{E_t}\right] \quad \text{if } \sigma > 0 \;\; \text{(e.g. Weikard/Zhu 2005)} \tag{5}$$

Background

- A single discount rate $STPR = r_C$, as currently used in CWON, is appropriate if
  - the two goods are considered perfect substitutes ($\sigma \to \infty$)
    $\Rightarrow$ very unlikely
  - relative scarcities do not change over time ($g_{C_t} = g_{E_t}$ for all t)
    $\Rightarrow$ very unlikely
  - relative price changes are already appropriately captured in (primary) valuation studies, or explicitly taken care of
    $\Rightarrow$ (very) unlikely or not the case

$\Rightarrow$ A single discount rate $STPR = r_C$ can very likely lead to considerable inefficiencies in allocating ecosystem service flows over time (if ecosystem service scarcity doesn't drag down g_C due to limited substitutability in production, see Zhu et al. 2019 *JEEM*)

$\Rightarrow$ Accounting for changing relative prices of ecosystem services is likely a good idea
(e.g. Bastien-Olvera/Moore 2021 *Nat.Sust.*; Drupp/Hänsel 2021 *AEJ:Policy*; Sterner/Persson 2008 *REEP*)

Policy background: The Netherlands

- The Netherlands use a SDR of 2.25%

  ⇒ A consumption good unit in 100 years weighs only 11% relative to today's unit

- They use a general relative price adjustment of environmental goods of 1%

  ⇒ Relative value of a unit of environmental goods increases by 170% over 100 years
  - based on indirect estimates (Baumgärtner et al., 2015 *EARE*; Drupp, 2018 *EARE*)

- This can be re-adjusted depending on the specific project under evaluation.
  - *"for project effects on easily substitutable ecosystem services and/or ecosystem services whose growth does not lag behind the growth rate of consumption, no relative price increase needs to be used"*. Exemplary case: agricultural production.
  - Relative price changes of more than 1% can be considered *"if there are hardly any substitution possibilities and/or the growth rate lags far behind consumption growth"*. Exemplary case: local recreational opportunities.

Estimating relative price changes

- Baumgärtner et al. (2015 *EARE*)
  - estimate relative price changes for the global level and for selected countries.
  - apply national growth rates for the country-level results, yet assume that the elasticity of substitution is constant across all countries and ecosystem service types.
  - derive the elasticity of substitution via the inverse relation to the income elasticity of WTP, ξ (i.e.: $\sigma = 1/\eta$), based on a meta-analysis by Jacobsen/Hanley (2009), who estimate the income elasticity of WTP for global biodiversity conservation.
  - estimate a constant yearly relative price increase of 0.91$\pm$0.35% globally
- Heckenhahn and Drupp (2022 R&R *EARE*) estimate relative price changes for Germany and find a yearly relative price increase of ecosystem services of $>$4 percent, with largest adjustments for regulating ecosystem services
- Drupp et al. (in prep) extend this to a global level and various ecosystem services

Implications for environmental-economic accounting

- In the World Bank's CWON, forest ecosystem service values estimated via meta-regression analysis (Siikamäki et al. 2021)
- The capitalized value of ecosystem services is taken as the present value of annual services, discounted over 100 years, with a 4% SDR.
  - *"per-hectare monetary values estimated for 2018 are assumed to be constant over time and are adjusted for inflation using country specific GDP deflators."*

    $\Rightarrow$ No relative price change adjustment even though GDP elasticity of WTP is estimated to be non-zero by Siikamäki et al. (2015)

    $\rightarrow$ Conservative adjustment by 1% p.a. would raise per-hectare value by $\approx$30%

    $\rightarrow$ Adjustment by 2% (4%) p.a. would raise per-hectare value by $\approx$75% ($\approx$300%)

$\Rightarrow$ Adjustments for relative price changes of non-market environmental goods can substantially change how their value is reflected in environmental-economic accounting

Conclusions for environmental-economic accounting

- Theory-driven benefit transfer in space and time can help to improve how non-market environmental values are reflected in environmental-economic accounting
- A first suite of easy-to-apply (static) transfer factors is available
- "Benefit transfer in time" (relative price adjustment) is now considered by a few countries in project appraisal guidelines
  - Environmental-economic accounting should consider following suit
- ValuGaps will provide
  - further theoretical developments of transfer factors & functions
  - experimental elicitations of income elasticities and substitutability
  - multi-site valuation study that will enable better testing benefit transfer approaches

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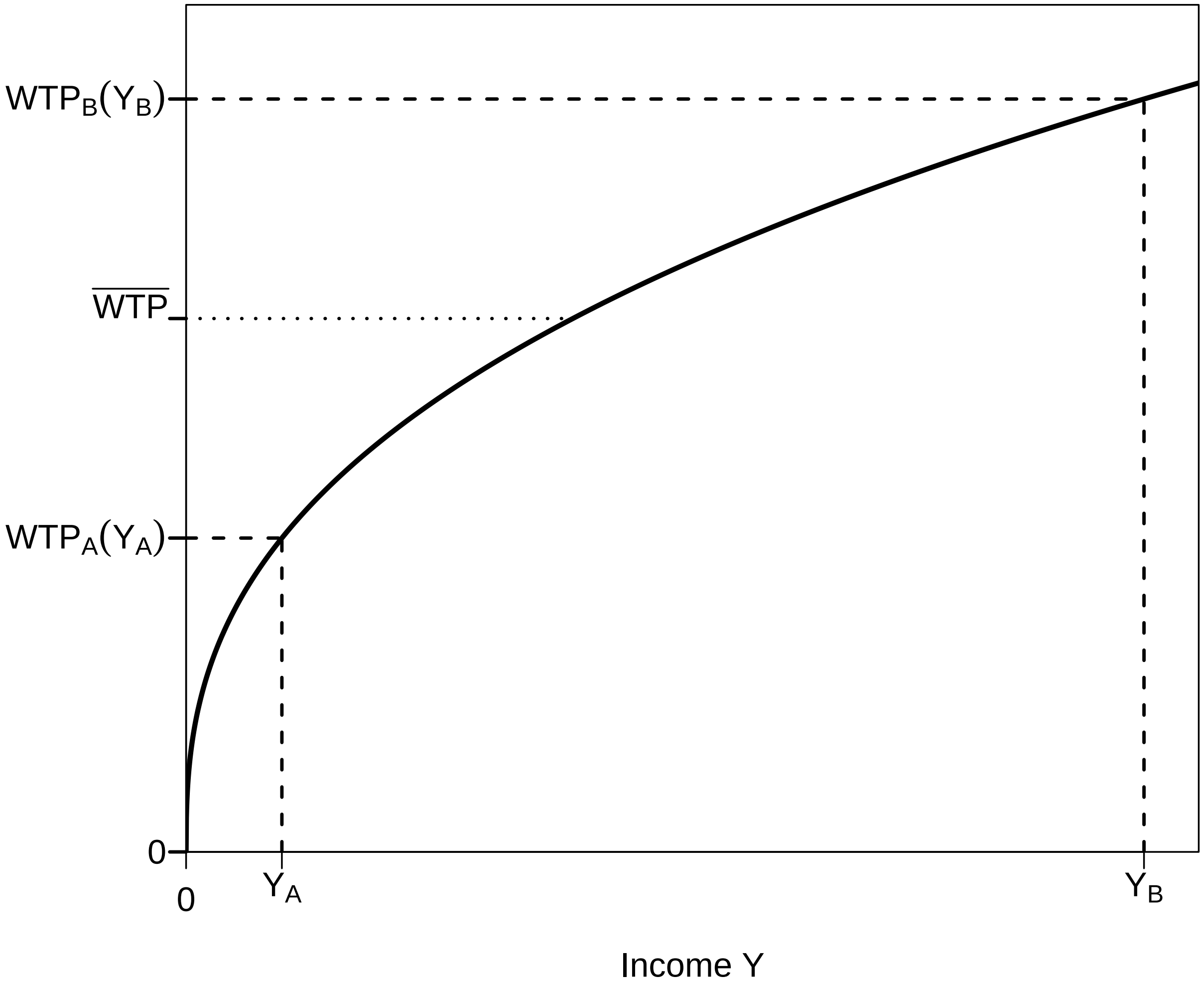
Backup

The effect of income inequality on WTP

If $\eta < 1$, a decrease in income inequality will increase mean WTP



From Drupp/Meya/Baumgärtner/Quaas (2018, *EcolEcon*).

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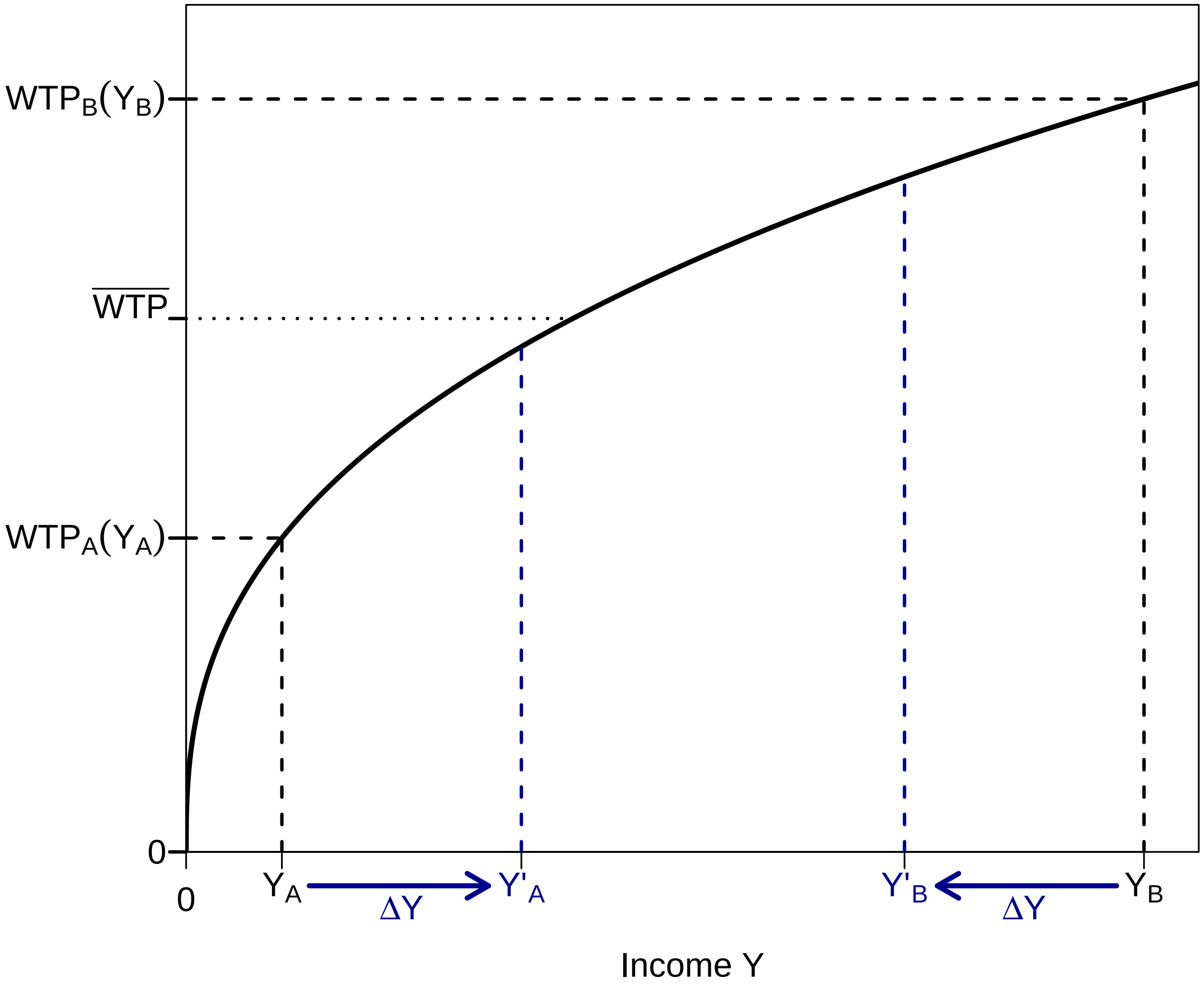

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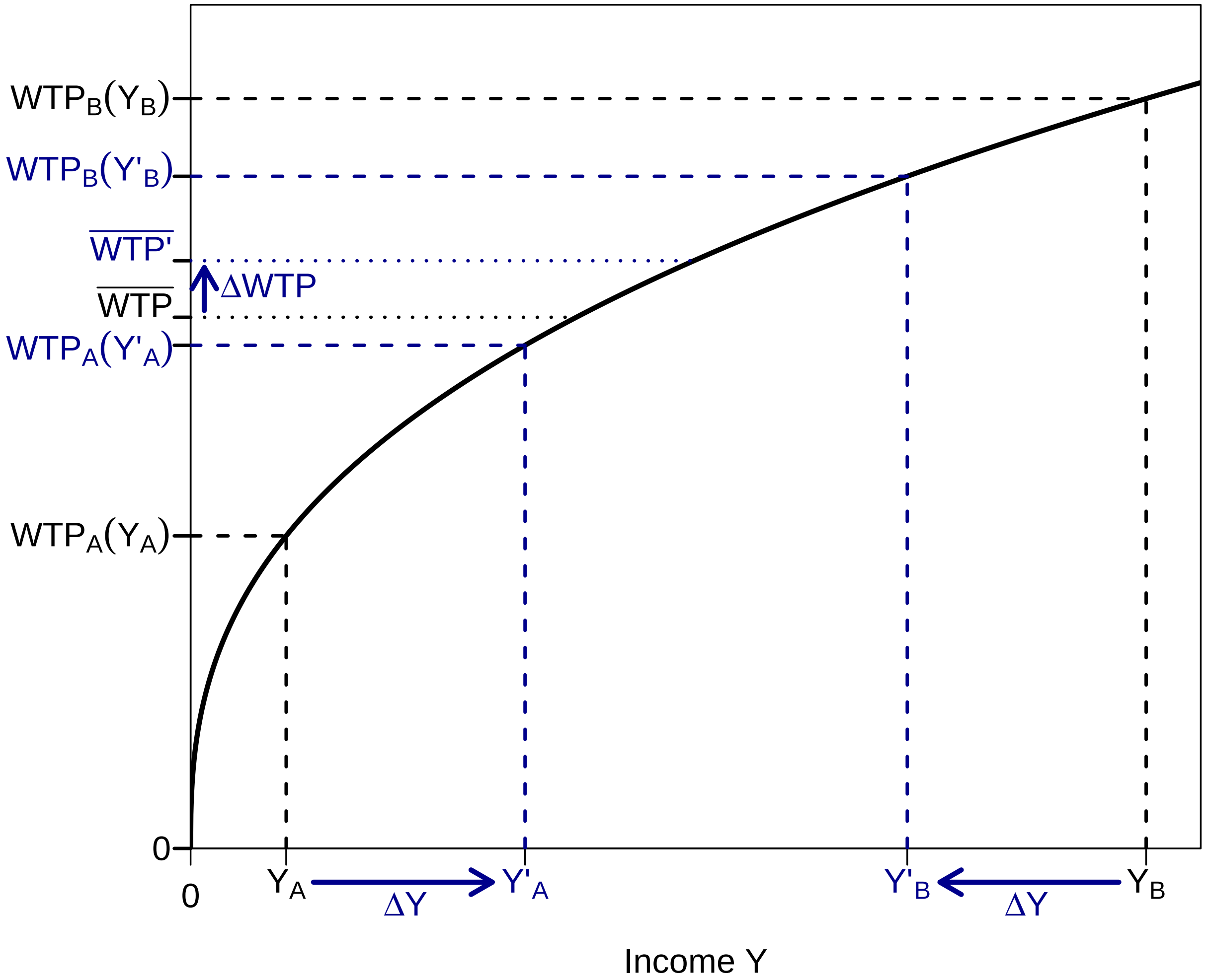

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