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**Working Paper**

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Economics Working Paper, No. 2017-03

**Provided in Cooperation with:**

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*Suggested Citation:* Meya, Jasper N.; Drupp, Moritz A.; Hanley, Nick (2018) : Income inequality and the international transfer of environmental values, Economics Working Paper, No. 2017-03, Kiel University, Department of Economics, Kiel

This Version is available at:

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Economics Working Paper  
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# Income Inequality and the International Transfer of Environmental Values

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issn 2193-2476



# Income Inequality and the International Transfer of Environmental Values

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August 1, 2018

How the valuation of environmental goods is related to income is a key question for economics, but the role of income inequality is often neglected. We study how income inequality affects the international transfer of the estimated value of environmental goods from a study to a policy site—a practice called value or benefit transfer. Specifically, we apply theory-driven, structural transfer factors to examine whether adjusting for income inequality affects errors made in benefit transfer, drawing on a multi-country valuation study on water quality improvement. Our convergent validity analysis shows that the structural income inequality adjustment reduces benefit transfer errors by more than 1.5 percentage points on average across all transfers. The adjustment for inequality is particularly important when income is distributed more unequally at the policy site relative to the study site, yielding reductions in transfer errors of up to 33 percentage points. Our results highlight the importance of taking the effects of economic inequality into account and are relevant for environmental valuation as well as public policy appraisal.

**JEL-Classification:** Q51, H43, D31, D61, D63, Q53, Q25

**Keywords:** environmental valuation, income inequality, benefit transfer, policy appraisal, transfer errors

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# 1 Introduction

There is a growing interest within economics and in society at large in the implications of income inequality.<sup>1</sup> A crucial question for economics concerns how the valuation of environmental goods is related to income. Numerous studies investigate this relationship by estimating how willingness to pay (WTP) for environmental goods depends on the level of income. They usually find that WTP increases with individual income, but at a lower than proportionate rate.<sup>2</sup> This implies that poorer households value these environmental benefits disproportionately and it suggests an important role of economic distribution for environmental valuation that has been largely neglected so far (Drupp et al. 2018). In a recent Science perspective, Frank and Schlenker (2016: 652) conjecture that “the income distribution might [...] be as important as overall economic growth” for the valuation of environmental goods. Related to this conjecture, Baumgärtner et al. (2017a) theoretically examine how mean WTP for environmental public goods within a society depends on the distribution of income. They find that mean WTP decreases (increases) with income inequality if the income elasticity of WTP is below (above) one, but that it—except for extreme cases—changes more elastically with mean income than with income inequality.

In this paper, we demonstrate that adjusting for income inequality in a structural, theory-driven fashion can improve one of the most frequently used methods for environmental valuation: benefit transfer. Benefit transfer—also often called value transfer—makes use of WTP estimates for an environmental good derived from a study site to estimate values for a policy site, where this information is to be used to inform decision-making for environmental management (Johnston et al. 2015). As sites and affected populations often differ in many ways, it is crucial to control for variations in key ex-

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<sup>1</sup>For example, Piketty’s (2014) work on economic inequality has received widespread attention, and while Google searches for “income inequality” have increased by more than 200 [110] percent in the USA [UK] from 2008 to 2016, searches for “income” only increased by 10 [19] percent (cf. Google Trends).

<sup>2</sup>Technically, these studies estimate the income elasticity of WTP for environmental goods, which is the percentage change in WTP relative to a percentage change in income. Almost all studies thus find that the income elasticity of WTP is positive and smaller than unity.

planatory variables, including income, as part of the transfer. This paper is the first to utilize theory-driven benefit transfer factors for income inequality, which have recently been developed by Baumgärtner et al. (2017a), to scrutinize whether controlling for differences in income inequality across sites improves the WTP estimates derived from benefit transfer in a multi-country convergent validity study.

Obtaining theoretically sound, empirically relevant and easy-to-use methods for benefit transfer is of first order importance as WTP-estimates from such transfers are increasingly used to inform policy decisions (Richardson et al. 2015). International and inter-regional benefit transfer have been frequently applied to inform environmental policy making in the European Union and the United States. For example, to inform the policy process on Natura 2000, the economic benefits from Natura 2000 sites were assessed for all of Europe (European Commission 2013).<sup>3</sup> As only limited primary valuations for ecosystem services from Natura 2000 sites were available (34 values from 20 studies), these were scaled up using the benefit transfer method. Consequently, the resulting value estimates entail scope for substantial benefit transfer errors. Furthermore, the U.S. EPA has been required to conduct benefit-cost analysis on environmental regulation for more than three decades (Griffiths et al. 2012). Benefit transfer has been applied, for instance, to estimate the recreational benefits of water quality improvements under the 2002 Combined Animal Feeding Operations rule (U.S. EPA 2014). WTP estimates from a national contingent valuation survey by Carson and Mitchell (1993) were used to value predicted water quality improvements across U.S. states.

As benefit transfer has become “the bedrock of practical policy analysis” to inform regulatory decision-making (Pearce et al. 2006: 266), improving its accuracy is an important research area. Kaul et al. (2013) review 20 years of studies that scrutinize the errors made by using benefit transfer. Their analysis suggests that benefit transfer should control for a range of covariates of WTP with their levels calibrated to policy-

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<sup>3</sup>Natura 2000 is Europe’s most important legislation to protect nature and biodiversity. The network of protected areas has the objective to conserve Europe’s unique biodiversity including endangered species, rare habitats and genetic diversity. Covering over 18 percent of the EU’s terrestrial area it is globally the largest coordinated network of protected areas (European Commission 2008, 2013).

case conditions. Other studies find that simple transfers adjusted for only purchasing power parity and income perform best (Czajkowski et al. 2017, Ready et al. 2004). A central finding of most studies is that accounting for income plays an important role for the accuracy of benefit transfer. Many policy applications of international benefit transfer, such as for Natura 2000, adjust WTP estimates exclusively for differences mean income, government guidance documents suggest the use of formulas for mean income correction (UBA 2012, Pearce et al. 2006, Defra 2007), and many academic studies on benefit transfer have employed this approach (e.g. Krupnick et al. 1996, Ready et al. 2004). However, while it is common practice to control for differences in mean income across sites, adjusting for differences in income inequality has, to our knowledge, not been considered in benefit transfer evaluations.<sup>4</sup>

The literature on benefit transfer has been mainly driven by empirical approaches such as using meta-regressions, with only very few exceptions of studies following a more structural utility theoretic approach.<sup>5</sup> Bateman et al. (2011) argue that parameters controlled for in benefit transfer should be based on economic theory rather than ad-hoc statistical approaches that may be over parametrized when applied out of the sample. As far as we know, Smith et al. (2002) first proposed a structural approach to benefit transfer, which requires specifying a utility function as well as all relevant additional conditions, such as the budget constraint, and then calibrating the function's parameters with information from the study site. Despite several advantages of such a theory-driven approach, its application has been limited among others due to the advanced micro-economic skills that may be required (Phaneuf and Requate 2017). Recently,

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<sup>4</sup>We surveyed a number of academics and practitioners working on benefit transfer and the general response was that 'no study ever controlled for differences in income inequality'. Furthermore, it is not mentioned as a potential control factor in the guidelines of i.a. Germany (UBA 2012), the OECD (Pearce et al. 2006), the UK (Defra 2007, HM Treasury 2011) as well as the USA (U.S. EPA 2014).

<sup>5</sup>Bergstrom and Taylor (2006) survey theory-based approaches to benefit transfer and distinguish three approaches: non-structural as well as weak and strong structural utility theoretic approaches. While the strong structural approach explicitly specifies the relationship between WTP and its explanatory variables, this is only loosely the case in the weak structural approach. We are only aware of very few strong structural approach studies (Baumgärtner et al. 2017a; Smith et al. 2002, 2006).

Baumgärtner et al. (2017a) have shown how aggregate WTP for an environmental public good depends on the distribution of income, based on a structural model with constant-elasticity-of-substitution preferences and an unequal distribution of income, and have derived theory-based and easy-to-apply benefit transfer factors, in particular for mean income and income inequality.

This paper builds on these theory-driven transfer factors to systematically examine the effects of a structural benefit transfer approach to income inequality adjustment using data from a valuation study on water quality improvement in all nine Baltic Sea countries (Ahtiainen et al. 2014). The unique feature of this study making it an ideal test-bed for our theory-driven approach to benefit transfer is that the contingent valuation study employed the same survey instrument across countries with substantial differences in income distributions for a well-defined change in environmental quality that has region-wide public good characteristics. It thereby offers the possibility to compare transferred WTPs across countries with actual primary valuations. Specifically, we calculate transfer factors to account for differences in mean income, income inequality and combinations of both, and evaluate transfer errors on a country-by-country basis.

By confronting theory-driven benefit transfer factors with a unique multi-country data set, this paper adds to the literature by providing a convergent validity exercise to test whether structural adjustment for income inequality can reduce errors made in benefit transfer. For the nine-country Baltic Sea study on water quality improvement, we find that (i) income inequality adjustment decreases transfer errors by more than 1.5 percentage points on average; (ii) Income inequality adjustment becomes particularly relevant when income is more unequally distributed at the policy relative to the study site. It decreases transfer errors by more than 5 percentage points on average when inequality at the study site is less than 80% of the policy site's income inequality; (iii) Even though adjustment for income inequality is of second-order compared to adjusting for the level of mean income, our study shows that accounting for income inequality can further improve benefit transfers and that its application is straightforward. We perform a number of robustness checks and find that our main conclusion is not affected by considering other transfer factors—for differences in the price level or the mean level

of the environmental goods accross countries—in addition. Finally, we show that a naive transfer adjustment for income inequality would increase benefit transfer errors, emphasizing the importance of employing structural theory-driven factors.

The remainder of the paper is organized as follows. We introduce the model framework and transfer factors derived from this in Section 2. In Section 3 we present data from the Baltic Sea study and describe in Section 4 our strategy to empirically test the proposed transfer factors. We report our main results in Section 5.1 and test their robustness in Section 5.2. Finally, we discuss limitations to our analysis in Section 6 and conclude in Section 7.

## 2 Theory-driven benefit transfer factors

This paper tests the effect of income inequality on the convergent validity of benefit transfer. For this, we draw on recent theoretical work by Baumgärtner et al. (2017a), who have derived a generic transfer function, which disentangles transfer factors for mean income and income inequality. In the following, we apply their modelling framework for our setting of benefit transfer, which seeks to transfer willingness to pay (WTP) estimates from a primary valuation study in one country or region  $s$  (the ‘study site’) to inform environmental policy making in another country or context  $p$  (the ‘policy site’):

Assume that in each country  $c$ , with  $c \in \{s, p\}$ , there are  $N^c$  individuals, denoted by  $i$ , who derive utility from the consumption of a market-traded private good,  $X_i^c$ , and a non-market-traded pure public environmental good,  $E^c$ . The consumption good  $X_i^c$  is traded at a given market price  $P^c > 0$ , while the consumption of the environmental good is fixed at level  $E^c > 0$ .<sup>6</sup> Individuals have identical preferences over the two goods represented by a constant elasticity of substitution (CES) utility function

$$U(X_i^c, E) = \left( \alpha X_i^c \frac{\theta-1}{\theta} + (1 - \alpha) E^c \frac{\theta-1}{\theta} \right)^{\frac{\theta}{\theta-1}}, \quad (1)$$

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<sup>6</sup>In Section 5.2, we discuss how this theory can be extended to the case of local public goods. We can show that if the consumption of a local environmental public good is uncorrelated with income, then the transfer factors for mean income and income inequality remain unchanged.



where  $\theta \in (0, +\infty)$  is the CES between market-traded consumption goods and non-market-traded public environmental goods, and  $\alpha \in (0, 1)$  is a preference parameter capturing the weight of market-traded consumption goods as part of overall utility.<sup>7</sup>

The decision problem of each individual  $i$  is then to maximize utility over the consumption of these two goods subject to the income constraint and the fixed level of  $E^c$ . While we assume that individuals have the same preferences, they differ in their individual incomes  $Y_i^c$ , which are given exogenously. Specifically, income is assumed to be distributed log-normally with mean,  $\mu_Y^c$ , and standard deviation,  $\sigma_Y^c$ .<sup>8</sup>

Individual  $i$ 's WTP for the environmental good  $E^c$  is then determined by the level of income  $Y_i^c$  and the parameters of the utility function and the level of  $E^c$

$$\text{WTP}(Y_i^c) = \kappa^c Y_i^{c\eta} \quad \text{with} \quad \kappa^c = \frac{1-\alpha}{\alpha} (P^c E^c)^{1-\eta}, \quad \eta = \frac{1}{\theta}, \quad (2)$$

where  $\eta$  is the income elasticity of WTP. The CES utility function implies that the income elasticity of WTP,  $\eta$ , is the inverse of the CES,  $\theta$ , between the market-traded consumption good,  $X_i^c$ , and non-market-traded public environmental good,  $E^c$ , and thus also a constant.<sup>9</sup> While this simple model of individual WTP explicitly captures some fundamental determinants of WTP, such as individual income, the level of the environmental good and the price level, the parameter  $\alpha$  can be thought of as a residual that may capture, for example, the effect of culture on WTP for environmental goods.

Based on this modelling set-up, mean WTP for a marginal change in  $E^c$  depends, inter alia, on mean income and income inequality as follows

$$\mu_{\text{WTP}}^c(\mu_Y^c, \text{CV}_Y^c, P^c, E^c) = \mu_Y^{c\eta} (1 + \text{CV}_Y^{c2})^{\frac{\eta(\eta-1)}{2}} \frac{1-\alpha}{\alpha} (P^c E^c)^{1-\eta}, \quad (3)$$

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<sup>7</sup>While the assumption of identical preferences may seem demanding, it is often implicitly made in the benefit transfer literature. We discuss how this assumption can be relaxed in Section 6.

<sup>8</sup>The assumption of log-normality allows for simple closed-form solutions (Baumgärtner et al. 2017a). While there may often be more complex distributions that yield better fits (McDonald 1984), the log-normal distribution provides a decent approximation for many income distributions at a national level, as well as for the world as a whole (Pinkovskiy and Sala-i-Martin 2009).

<sup>9</sup>While the assumption of a constant income elasticity of WTP has been challenged (Barbier et al. 2016), it is superior to other functional forms in benefit transfer for the Baltic Sea study that we use in this paper (Czajkowski et al. 2017), and it is typically applied by practitioners of benefit transfer.

where  $CV_Y^c := \sigma_Y^c/\mu_Y^c$  is the coefficient of variation of income, which measures the spread of the income distribution relative to the income level. Equation 3 implies that mean WTP increases with mean income in society, yet decreases (increases) with income inequality if the income elasticity of WTP is below (above) unity (cf. Baumgärtner et al. 2017a). The effect of income inequality on mean WTP can intuitively be explained as follows: For the case of an income elasticity of WTP smaller than unity, an increase in an individual's income results in an increase in WTP, but at a lower-than-proportional rate as compared to the increase in income (cf. Equation 2). Thus, individuals with a low income are willing to pay a larger share of their income than individuals with a higher income. Now, consider a society in which income is redistributed such that income inequality decreases but mean income remains constant, i.e. at least one individual with income below average has more and one individual with income above average has less income. As WTP increases at a lower-than-proportional rate than income, the increase in WTP of the poorer individual overcompensate the decrease in WTP of the richer individual, thus establishing the effect of changes in income inequality on mean WTP that we will make use of for our analysis of benefit transfers.<sup>10</sup>

The benefit transfer function,  $\mathcal{T}(\dots)$ , for transferring mean WTPs from the study site,  $\mu_{\text{WTP}}^s$ , to the policy site,  $\mu_{\text{WTP}}^p$ , while controlling for the variables that differ across sites in this theoretical equal-preference framework, is now defined as the ratio of the mean WTPs at the policy and the study sites:

$$\begin{aligned} \mathcal{T}(\mu_Y^p, CV_Y^p, P^p, E^p; \mu_Y^s, CV_Y^s, P^s, E^s) &:= \frac{\mu_{\text{WTP}}^p(\mu_Y^p, CV_Y^p, P^p, E^p)}{\mu_{\text{WTP}}^s(\mu_Y^s, CV_Y^s, P^s, E^s)} \\ \text{(Equ. 3)} &\underline{=} \frac{(\mu_Y^p)^\eta (1 + CV_Y^{p2})^{\frac{\eta(\eta-1)}{2}} (P^p E^p)^{1-\eta}}{(\mu_Y^s)^\eta (1 + CV_Y^{s2})^{\frac{\eta(\eta-1)}{2}} (P^s E^s)^{1-\eta}} \end{aligned}$$

This transfer function neatly disentangles into four individual transfer factors, with:

$$\begin{aligned} \mu_{\text{WTP}}^p &= f(\mu_{\text{WTP}}^s) \\ &= \mathcal{T}_\mu(\mu_Y^p, \mu_Y^s) \cdot \mathcal{T}_{\text{CV}}(CV_Y^p, CV_Y^s) \cdot \mathcal{T}_p(P^p, P^s) \cdot \mathcal{T}_E(E^p, E^s) \cdot \mu_{\text{WTP}}^s \cdot \end{aligned} \quad (4)$$

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<sup>10</sup>The rationale is reversed for an income elasticity of WTP larger than unity: In this case, an increase in income inequality would lower mean WTP.

In particular, this transfer function yields the transfer factors for differences in the level of mean income and income inequality that will be the main focus of our analysis:<sup>11</sup>

$$\mathcal{T}_\mu(\mu_Y^p, \mu_Y^s) = \left( \frac{\mu_Y^p}{\mu_Y^s} \right)^\eta, \quad (5)$$

$$\mathcal{T}_{CV}(\text{CV}_Y^p, \text{CV}_Y^s) = \left( \frac{1 + \text{CV}_Y^{p2}}{1 + \text{CV}_Y^{s2}} \right)^{\frac{\eta(\eta-1)}{2}}. \quad (6)$$

It is common practice in benefit transfer to adjust WTP-estimates for differences in mean income using  $\mathcal{T}_\mu(\mu_Y^p, \mu_Y^s)$ . For instance, Krupnick et al. (1996) adjusted estimates in this fashion for health impacts from Western Europe and the US to evaluate benefits from reductions in ambient air pollution in Central and Eastern European countries. Pearce (2000) stated this formula in policy advice used by the European Commission for international benefit transfer on health estimates. Moreover, policy guidance on benefit transfer, for instance for the UK (Defra 2007), Germany (UBA 2012) and from the OECD (Pearce et al. 2006), propose this formula to adjust WTP estimates for differences in mean income. Yet, none of these studies or guidelines on benefit transfer (UBA 2012, Defra 2007, Pearce et al. 2006, U.S. EPA 2014) mentions income inequality.

The income elasticity of WTP for environmental goods,  $\eta$ , plays a central role for the transfer factors. We therefore discuss different parameter values for  $\eta$ . First, we focus on the simplest case of  $\eta = 1$  that is most often assumed in the literature on benefit transfer (see, e.g., Barton (2002) and Czajkowski and Scasny (2010)) and in policy applications

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<sup>11</sup>The theory also yields transfer factors for the market price level  $\mathcal{T}_P(P^p, P^s) = \left( \frac{P^p}{P^s} \right)^{1-\eta}$  and the quantity of the environmental good  $\mathcal{T}_E(E^p, E^s) = \left( \frac{E^p}{E^s} \right)^{1-\eta}$ . As there is empirical evidence that the environmental good under study is a region-wide public good (see Section 3), we assume  $E^p = E^s$  for the main part of our analysis. We ease this assumption to a local public good in a sensitivity analysis in Section 5.2, where we apply  $\mathcal{T}_E(E^p, E^s)$ . We show that including this additional transfer factor does not alter our main result. Furthermore, we directly use the income and WTP data from the Baltic Sea study, which have already been made internationally comparable by using PPP-corrected currency exchange rates. As such our analysis starts out from a situation where differences in the market price levels between policy and study site are accounted for and hence we take  $P^p = P^s$ . To further establish the robustness of our main result for inequality, we also explicitly apply  $\mathcal{T}_P(P^p, P^s)$  in Section 5.2.

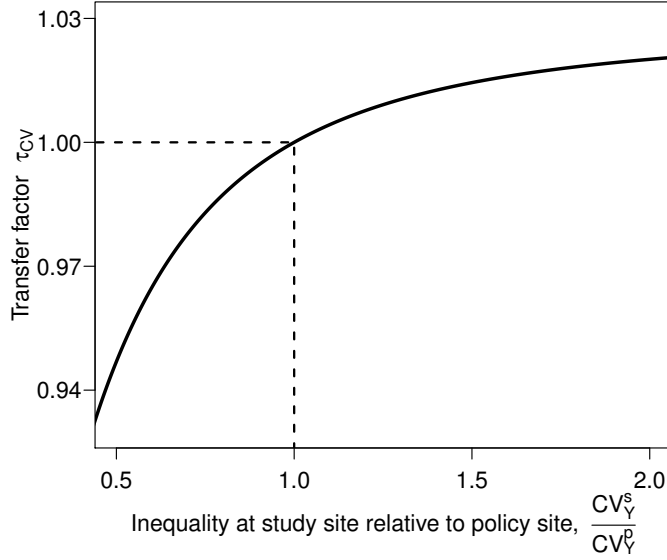


Figure 1: Relationship between the transfer factor for income inequality  $\mathcal{T}_{CV}(\cdot)$  and the ratio of income inequality in the study and policy country for  $\eta = 0.28$  and  $CV_Y^s = 0.56$ .

(see, e.g., ten Brink et al. (2011)). The theory-driven transfer factors suggest that controlling only for the difference in mean incomes is correct if and only if the income elasticity is equal to unity, which is often assumed for simplicity. However, as the income elasticity of WTP for environmental goods is in general not equal to unity, we also have to consider not only the transfer factor for mean income but also income inequality.

As there is only sparse empirical evidence for  $\eta > 1$ , we focus on the empirically most relevant case of  $\eta < 1$  (see Figure 1).<sup>12</sup> For income elasticities below unity,  $\eta < 1$ , WTP-estimates have to be adjusted by the ratio of mean income in the policy and study sites to the power of the income elasticity of WTP,  $\mathcal{T}_\mu(\mu_Y^p, \mu_Y^s)$ . A closer inspection of this theory-driven transfer factor from Baumgärtner et al. (2017a) for income inequality,  $\mathcal{T}_{CV}(CV_Y^p, CV_Y^s)$ , reveals that it increases in the ratio of income inequality at the study and the policy site,  $\frac{CV_Y^s}{CV_Y^p}$ , at a decreasing rate (Figure 1). This suggests that it is in particular relevant to control for income inequality when income inequality is higher at the policy site than on the study site (i.e. in the lower-left part of Figure 1).

<sup>12</sup>Most studies find an income elasticity of WTP between 0 and 1. This is also the case for the Baltic Sea study (Barbier et al. 2016). Surveying recent evidence on income elasticities, Drupp (2018) finds that only two of 18 considered studies imply mean income elasticities greater than unity.

### 3 Data

We investigate the empirical relevance of income inequality adjustment in benefit transfer using data from a multi-country contingent valuation study on the benefits of a water quality improvement in the Baltic Sea (Ahtiainen et al. 2014). Respondents were asked for their WTP for a nutrient reduction programme with associated consequences for water clarity, blue-green algal blooms, the abundance of sea grass beds, and fish species composition. Figure 2 shows a map of the Baltic sea and its neighboring countries, with levels of income inequality and mean WTP for water quality improvement.

The data is particularly suitable to study the performance of the theory-driven transfer factors as the same survey instrument was used to elicit the WTP for a common change in this environmental good across populations with substantially different mean income levels and income inequalities. Ahtiainen et al. (2014) designed the survey such that it is both comparable and meaningful to the population in each country bordering the Baltic Sea. Respondents were informed that the benefits of nutrient reductions would occur in open-sea areas across the whole Baltic Sea (Czajkowski et al. 2017), suggesting region-wide public good characteristics.<sup>13</sup>

The payment vehicle was framed as a 'Baltic Sea tax' for nutrient reduction levied in all countries bordering the Baltic Sea. A payment card with country specific bid vectors based on the WTP distributions in pilot studies was employed to elicit WTP. In the following we take individual maximum WTP to equal the mid point of the stated WTP interval, as previously done by Ahtiainen et al. (2014) and Barbier et al. (2016).

The survey was conducted from October to December 2011 in all nine countries bordering the Baltic Sea: Denmark (DEN), Estonia (EST), Finland (FIN), Germany

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<sup>13</sup>Respondents understanding was validated by the following survey questions: "Did you consider the whole Baltic Sea or a certain area of the Baltic Sea when answering how much you were willing to pay?", "To what extent did you consider open sea and coastal areas when answering how much you were willing to pay?" It shows that respondents indeed predominantly state that they considered the whole Baltic Sea opposed to the shore line when stating their WTP values. Moreover, Ahtiainen et al. (2014) find in their fully specified regression models a significant negative effect of respondents distance to the Baltic Sea on WTP for water quality improvement in only one out of nine countries.

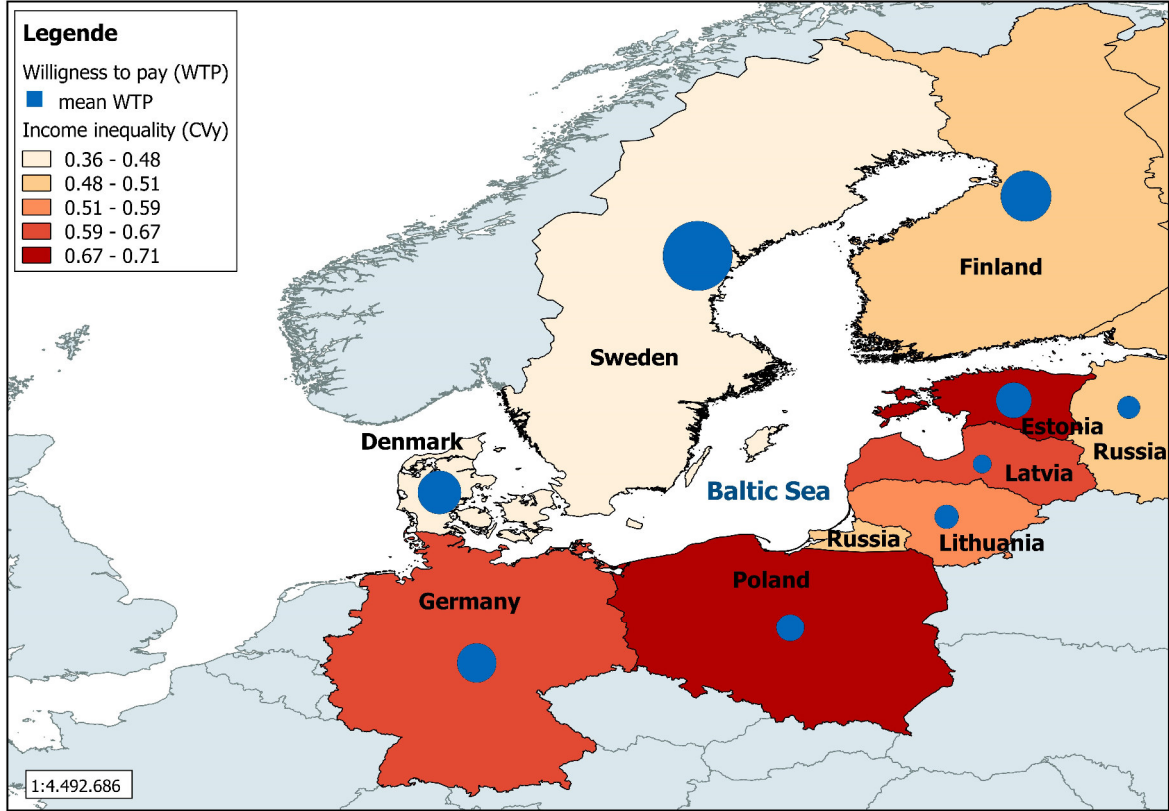


Figure 2: Countries neighboring the Baltic Sea with mean WTP for water quality improvement,  $\tilde{\mu}_{\text{WTP}}^c$ , and income inequality,  $\tilde{C}V_Y^c$ , of the surveyed population.

(GER), Latvia (LAT), Lithuania (LIT), Poland (POL), Russia (RUS) and Sweden (SWE). For comparison all WTP figures were converted to units of 2011-purchasing-power-converted-EUR [”2011-PPP-EUR”]. Country samples show substantially different estimated mean WTPs,  $\tilde{\mu}_{\text{WTP}}^c$  (Table 1).<sup>14</sup> These range from 5.74 [2011-PPP-EUR] elicited in Latvia to 80.64 [2011-PPP-EUR] in Sweden.

Respondents were asked to state their personal mean monthly net income by selecting the applicable interval. Income was then set to the interval mean, for all but the highest category, where it was set to the lower interval boundary.

Income distributions of the countries bordering the Baltic Sea differ substantially regarding both mean income and income inequality (Figure 2). Respondents mean monthly net income,  $\tilde{\mu}_Y^c$ , ranges from 343 [2011-PPP-EUR] in Lithuania up to 1,659

<sup>14</sup>We qualify estimates with a tilde to distinguish them from the true values in the population.

Table 1: Sample statistics by country

Country	$\tilde{N}^c$	$\tilde{\mu}_Y^c$	$\tilde{C}V_Y^c$	$Gini_Y^c$	$\tilde{\mu}_{WTP}^c$
Denmark (DEN)	1,061	1,659	0.46	0.26	31.50
Estonia (EST)	505	857	0.71	0.37	21.23
Finland (FIN)	1,645	1,585	0.51	0.28	42.84
Germany (GER)	1,495	1,559	0.60	0.33	25.59
Latvia (LAT)	701	483	0.66	0.36	5.74
Lithuania (LIT)	617	343	0.53	0.30	9.61
Poland (POL)	2,029	841	0.69	0.33	12.99
Russia (RUS)	1,508	666	0.50	0.28	8.57
Sweden (SWE)	1,003	1,431	0.36	0.20	80.64

*Note:* Monthly net income and WTP per year in 2011-PPP-EUR.

[2011-PPP-EUR] in Denmark. The surveyed income inequality is lowest in Sweden with a coefficient of variation,  $\tilde{C}V_Y^c$ , of 0.36 and highest in Estonia with a  $\tilde{C}V_Y^c$  of 0.71, corresponding to Gini-coefficients,  $Gini_Y^c$ , of 0.20 and 0.37, respectively.<sup>15</sup>

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<sup>15</sup> Compared to national statistics, sample mean income is below the national averages for most countries (exceptions are Poland and Estonia where sample mean income is slightly higher). The mean absolute deviation from the national income level is 14.48(±15.09)%. Concerning income inequality the picture is more mixed: Income inequality within the sample as measured with the  $Gini_Y^c$  is below official national figures for four countries (DEN, LIT, RUS, SWE), but higher for the other five countries (EST, FIN, GER, LAT, POL). The majority of differences are mostly below ten percentages points, with mean absolute deviation of 11.95(±8.92)%. Russia is an exception, where the surveyed income in the exclave Kaliningrad Oblast has shows a substantially lower  $Gini_Y^c$  than for the whole country.

## 4 Empirical strategy

For each pair of countries in our dataset we hypothetically transfer WTP-estimates from one country to the other and compare the transferred WTP with the actually surveyed WTP-estimates. This approach is often termed convergent validity, as it cross-validates the results of the benefit transfer with another estimate for the true WTP.<sup>16</sup>

The accuracy of benefit transfer is assessed by calculating transfer errors, which are a common measurement to study the convergent validity of benefit transfers (e.g. Kaul et al. 2013). Accordingly, the relative transfer error associated with a single benefit transfer is measured as the difference between the mean WTP estimate transferred from the study site  $f(\tilde{\mu}_{WTP}^s)$ , and the actually observed mean WTP-estimate at the policy site,  $\tilde{\mu}_{WTP}^p$ , expressed as a percentage (Kirchhoff et al. 1997):

$$|TE| = \frac{|WTP_{trans} - WTP_{obs}|}{WTP_{obs}} = \frac{|f(\tilde{\mu}_{WTP}^s) - \tilde{\mu}_{WTP}^p|}{\tilde{\mu}_{WTP}^p}. \quad (7)$$

Each transfer is conducted using unadjusted unit transfer, income inequality adjusted transfer, mean income adjusted transfer as well as mean income and income inequality adjusted transfer.

For simple unit transfer the transferred WTP-estimate,  $f(\tilde{\mu}_{WTP}^s)$ , equals the WTP surveyed at the study site,  $\tilde{\mu}_{WTP}^s$ , and this becomes:

$$|TE|_{unit} = \frac{|\tilde{\mu}_{WTP}^s - \tilde{\mu}_{WTP}^p|}{\tilde{\mu}_{WTP}^p}. \quad (8)$$

To adjust for differences in income inequality, the level of mean income between policy and study sites, or the combination of both we draw on the theory-driven benefit transfer factors for income inequality  $\mathcal{T}_{\tilde{C}V}(C\tilde{V}_Y^p, C\tilde{V}_Y^s) = \left(\frac{1+C\tilde{V}_Y^{p2}}{1+C\tilde{V}_Y^{s2}}\right)^{\frac{\tilde{\eta}(\tilde{\eta}-1)}{2}}$  (Equation 6), and for mean income  $\mathcal{T}_\mu(\tilde{\mu}_Y^p, \tilde{\mu}_Y^s) = \left(\frac{\tilde{\mu}_Y^p}{\tilde{\mu}_Y^s}\right)^{\tilde{\eta}}$  (Equation 5). The transfer errors after correcting for income inequality,  $|TE|_{\mathcal{T}_{CV}}$ , mean income,  $|TE|_{\mathcal{T}_\mu}$ , as well as both income inequality and mean income,  $|TE|_{\mathcal{T}_{CV,\mu}}$ , read:

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<sup>16</sup>Note that the estimate from the primary valuation at the policy site,  $\tilde{\mu}_{WTP}^s$ , might itself be a biased estimate of the 'true' WTP,  $\mu_{WTP}^s$ .



$$|TE|_{\mathcal{T}_{CV}} = \frac{|\mathcal{T}_{CV}(\tilde{C}V_Y^p, \tilde{C}V_Y^s, \tilde{\eta}) \cdot \tilde{\mu}_{WTP}^s - \tilde{\mu}_{WTP}^p|}{\tilde{\mu}_{WTP}^p}, \quad (9)$$

$$|TE|_{\mathcal{T}_\mu} = \frac{|\mathcal{T}_\mu(\tilde{\mu}_Y^p, \tilde{\mu}_Y^s, \tilde{\eta}) \cdot \tilde{\mu}_{WTP}^s - \tilde{\mu}_{WTP}^p|}{\tilde{\mu}_{WTP}^p}, \quad (10)$$

and

$$|TE|_{\mathcal{T}_{CV,\mu}} = \frac{|\mathcal{T}_{CV}(\tilde{C}V_Y^p, \tilde{C}V_Y^s, \tilde{\eta}) \cdot \mathcal{T}_\mu(\tilde{\mu}_Y^p, \tilde{\mu}_Y^s, \tilde{\eta}) \cdot \tilde{\mu}_{WTP}^s - \tilde{\mu}_{WTP}^p|}{\tilde{\mu}_{WTP}^p}. \quad (11)$$

The performances of benefit transfers after adjusting for income inequality, mean income and both,  $\mathcal{T}_{CV}$ ,  $\mathcal{T}_\mu$ ,  $\mathcal{T}_{CV,\mu}$ , are evaluated against unit transfer. Accordingly, reductions in mean transfer errors are measured (in percentage points) as

$$\Delta |TE|_{\mathcal{T}_{CV}} := |TE|_{\mathcal{T}_{CV}} - |TE|_{unit} \quad ,$$

$$\Delta |TE|_{\mathcal{T}_\mu} := |TE|_{\mathcal{T}_\mu} - |TE|_{unit} \quad ,$$

and

$$\Delta |TE|_{\mathcal{T}_{CV,\mu}} := |TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{unit} \quad .$$

To investigate whether income inequality adjustment increases the validity of benefit transfers, we are interested in the change in transfer errors when adjusting for income inequality and mean income compared to pure income-adjustment, and refer to this as additional income inequality adjustment,  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_\mu} = |TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{\mathcal{T}_\mu}$ .

The theory assumes that the income elasticity of WTP,  $\eta$ , is common to the population at the study and the policy site. In practical applications of benefit transfer this would be reflected in applying an estimate for the income elasticity,  $\tilde{\eta}$ , from a meta-study such as Jacobsen and Hanley (2009).<sup>17</sup> In the context of this Baltic Sea study, we assume that there is an income elasticity of the WTP for water quality improvements of the Baltic Sea common to all neighboring countries. We therefore rely on the estimate

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<sup>17</sup>We also explore the option of country-specific income elasticities and report the corresponding results in the discussion (Section 6).

for pooling income and WTP data across all countries in Barbier et al. (2016), who estimate a pooled income elasticity for a range of model specifications, and use the estimate of  $\tilde{\eta} = 0.28$  from the Box-Cox regression in the constant income elasticity specification with heteroskedascity and apply it throughout formulas (9) to (11).<sup>18</sup>

For nine countries this yields a set of  $9 \times 8 = 72$  possible transfers for each specification, based on which we calculate summary statistics (mean, standard deviation and median) for the transfer errors  $|TE|$ . We perform this analysis for the full set of benefit transfers as well as for sub-samples for different ratios in income inequality between study site and policy site in order to identify conditions under which income adjustment is likely to reduce transfer errors.

## 5 Results

### 5.1 Main result

Calculating transfer factors for mean income,  $\mathcal{T}_\mu(\cdot)$ , for income inequality,  $\mathcal{T}_{CV}(\cdot)$ , and for both together,  $\mathcal{T}_{CV,\mu} = \mathcal{T}_\mu(\cdot) \times \mathcal{T}_{CV}(\cdot)$ , is straightforward by plugging in countries' mean income, CV of income (from Table 1) and income elasticities of WTP for the environmental good,  $\tilde{\eta}$ , in Equations (5) and (6).

Transfer factors for income inequality,  $\mathcal{T}_{CV}(\cdot)$ , range from 0.97 (Sweden to Estonia) to 1.03 (Estonia to Sweden), which have the lowest (Sweden) and highest (Estonia) levels of income inequality. Populating the conceptual sketch from Figure 1 with data from our case study, Figure 3 now depicts the relationship between the transfer factor for income inequality  $\mathcal{T}_{CV}(\cdot)$  and the ratio of income inequality in the study and policy sites. In particular, we depict the two extreme cases, using Estonia (left panel) and Sweden (right panel) as the study sites and all countries as potential policy sites, respectively.

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<sup>18</sup>Alternatives to determine a pooled income elasticity of WTP could be to use an estimate from another global case study, such as Jacobsen and Hanley (2009), to use an average of individual country's income elasticities,  $\mu_{\tilde{\eta}_i}$ , or to construct a pooled estimates of the income elasticity that incorporates subjects from individual countries relative to the countries' population sizes.

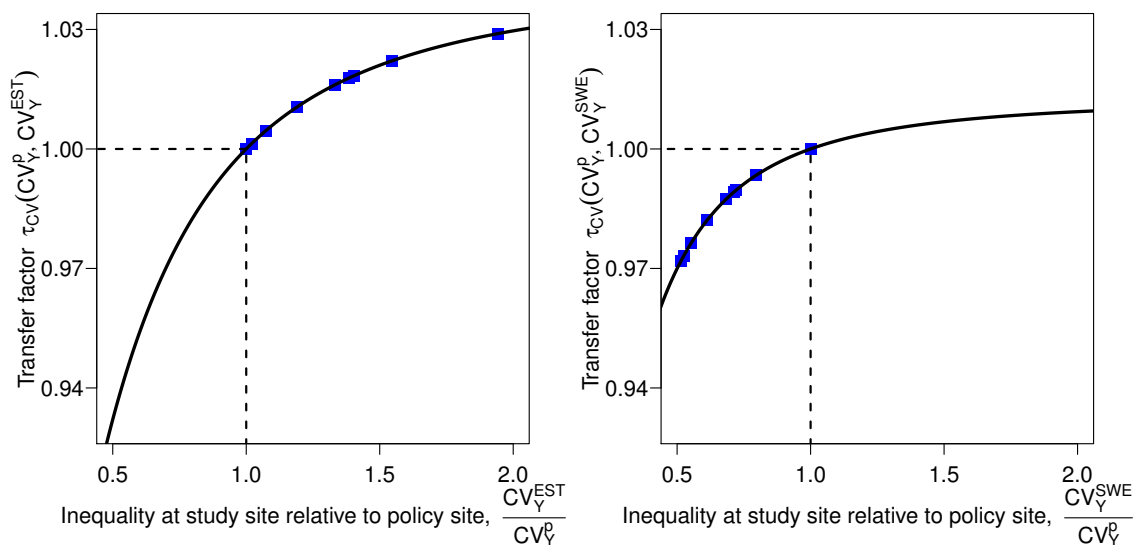


Figure 3: Relationship between the transfer factor for income inequality  $\mathcal{T}_{CV}(\cdot)$  and the ratio of income inequality in the study and policy sites, for Estonia (Sweden) as the study site in the left (right) panel. Each blue dot represents a possible benefit transfer.

Adjusting WTP-estimates for differences in mean income requires higher transfer factors,  $\mathcal{T}_\mu(\cdot)$ , ranging from 0.64 (Denmark to Lithuania) to 1.56 (Lithuania to Denmark), which have the highest and lowest mean income in our data set.

Simple unit transfers result in substantial transfer errors, with a mean absolute transfer error of 152.35%. This mean transfer error is reduced by  $\Delta |TE|_{\mathcal{T}_{CV}} = -1.80$  percentage points to  $|TE|_{\mathcal{T}_{CV}} = 150.55\%$  when WTP-estimates are adjusted for income inequality.<sup>19</sup> It is reduced by  $\Delta |TE|_{\mathcal{T}_\mu} = -36.88$  percentage points to  $|TE|_{\mathcal{T}_\mu} = 115.48\%$  when adjusting for mean income, underscoring that this is the more important adjustment in quantitative terms. Combining income inequality with mean income adjustment produces the best result ( $|TE|_{\mathcal{T}_{CV,\mu}} = 114.02\%$ ), where mean transfer errors are reduced by  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} = -38.33$  percentage points. Thus, additional income inequality adjustment reduces mean transfer errors by  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_\mu} = -1.46$  percentage points

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<sup>19</sup>The transfer errors associated with each individual benefit transfer are reported on a country-by-country basis in Tables 3 to 6 in the Appendix. Summary statistics on the absolute transfer errors for each specification of the benefit transfers are reported in Table 8.

Table 2: Mean differences in transfer errors (in percentage points) for pure and additional income inequality adjustment,  $\Delta |TE|_{\mathcal{T}_{CV}}$  and  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_{\mu}}$ .

	$\Delta  TE _{\mathcal{T}_{CV}}$	$\Delta  TE _{\mathcal{T}_{CV,\mu}} - \Delta  TE _{\mathcal{T}_{\mu}}$	$N_{transfer}$
all	-1.80	-1.46	72
$\frac{CV^s}{CV^p} < 1$	-3.82	-3.01	36
$\frac{CV^s}{CV^p} < 0.8$	-6.31	-4.96	20

(see Table 2, row 1). We find that changes in transfer errors from both income inequality adjustment,  $\Delta |TE|_{\mathcal{T}_{CV}}$ , and additional income inequality,  $\Delta |TE|_{\mathcal{T}_{CV,\mu}}$ , are significantly different from a zero transfer error reduction at  $p < 0.01$  for all 72 transfers.<sup>20</sup>

We now examine under which conditions (additional) income inequality adjustment particularly reduces benefit transfer errors.<sup>21</sup> Figure 4 depicts the relationship between reductions in absolute transfer errors through additional income inequality adjustment,  $\Delta |TE|_{\mathcal{T}_{CV,\mu}}$ , and the ratio of income inequality at study and policy site,  $\frac{CV^s}{CV^p}$ . We find that income inequality adjustment substantially reduces transfer errors in cases where income inequality is higher at the policy compared to the study site. For the 36 transfers where income inequality is higher at the policy site than at the study site, reduction in mean transfer errors roughly doubles compared to the whole set of transfers to  $\Delta |TE|_{\mathcal{T}_{CV}} = -3.82$  percentage points for pure income inequality adjustment and to  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_{\mu}} = -3.01$  percentage points for additional income inequality adjustment (see Table 2, row 2). The improvements in transfer accuracy due to income

<sup>20</sup>This also holds for non-parametric tests, such as the Wilcoxon signed-rank test. If we only consider uni-directional transfers, i.e. half the sample, we find that the results still hold at  $p < 0.05$  on average. Moreover, if we measure transfer errors as absolute changes instead of relative changes, i.e. define  $|TE'| := |WTP_{trans} - WTP_{obs}|$ , two-sided t-tests reveal that (additional) income inequality adjustment reduces transfer errors even at  $p < 0.001$ .

<sup>21</sup>Note that transfers for mean income as well as income inequality lead to some cases in which adjustments do not improve transfer errors. See Tables 4 to 6 in the Appendix, and Figure 4 for the case of additional income inequality adjustment.

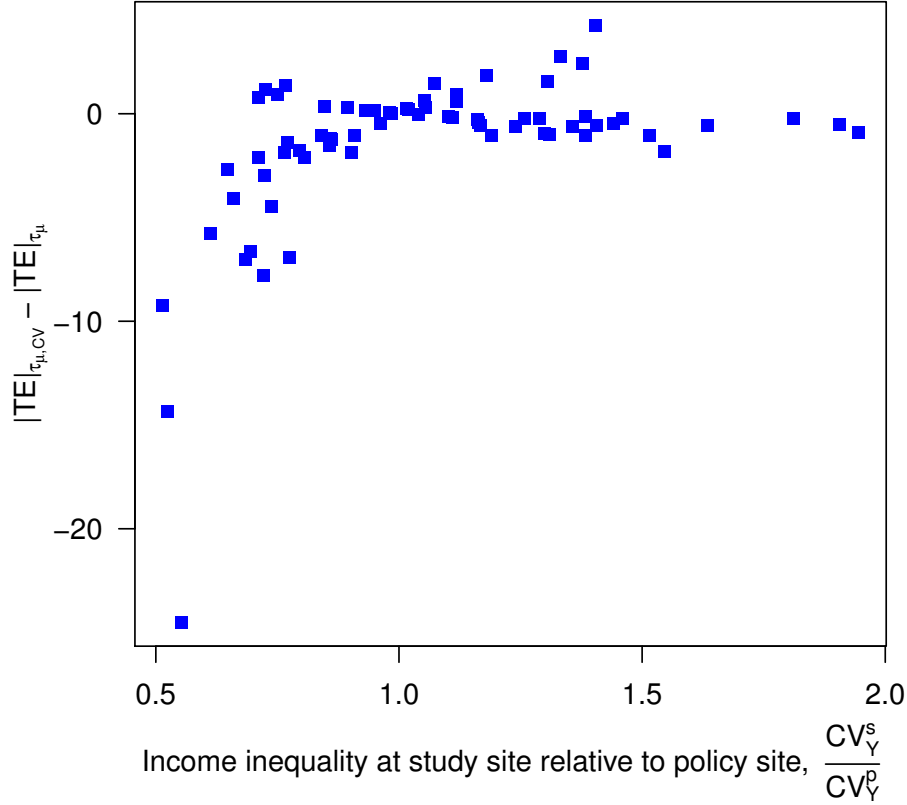


Figure 4: Relationship between reductions in transfer errors after additional income inequality adjustment,  $|TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{\mathcal{T}_\mu}$ , and the ratio of income inequality in the study and policy country for  $\tilde{\eta} = 0.28$ .

inequality adjustment are even more pronounced for the 20 transfers where inequality in the study sites is less than 80% of the policy site's estimate. Here, reductions in mean transfer errors are  $\Delta |TE|_{\mathcal{T}_{CV}} = -6.31$  and  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_\mu} = -4.96$  percentage points for pure and additional income inequality adjustment (see Table 2, row 3). The most substantial reduction of transfer errors is for a benefit transfer from Sweden to Latvia. Here, accounting for income inequality, over and above adjusting for differences in mean income, reduces the transfer error by 24.51 percentage points. Compared to the unit transfer, accounting for income inequality even reduces transfer errors by up to 33.31 percentage points. This is driven by both the large differences in mean WTP and income inequality between Sweden and Latvia.

## 5.2 Robustness checks

We perform a number of checks to examine the robustness of our main result—that theory-driven (additional) adjustment for income inequality improves benefit transfer. In particular, we extend our main analysis to consider (i) differences in level of the environmental good, (ii) differences in market prices as well as (iii) naive, non-structural adjustment for income inequality.

First, we test whether our main result still holds when we also consider differences in the level of the environmental good across countries. We thus depart from the simplifying assumption of a region-wide public good and allow  $\tilde{E}^p \neq \tilde{E}^s$ . We assume that a respondent’s level of consumption of the environmental good depends on her exposure to it, approximated by her distance to the shore. A respondent’s distance to the Baltic Sea,  $d_i$ , is measured from the geometrical centre point of the municipality or postal codes area they live in to the Baltic Sea (Ahtiainen et al. 2014). There are large country differences in respondents’ mean distance to the Baltic Sea reflecting that countries vary substantially in length of their coastline relative to their land area and geographical population density.<sup>22</sup> Since distance would give disutility, we take as an estimate for a country’s level of the environmental good,  $\tilde{E}^c$ , the average of respondent’s negative distance rescaled to the [0,1]-interval

$$\tilde{E}^c = \frac{1}{N^c} \sum_1^{N^c} \frac{\max(d) - d_i^c}{\max(d) - \min(d)}, \quad (12)$$

where the sample’s minimum and maximum distance to the Baltic Sea are  $\min(d) = 0$  and  $\max(d) = 9.300$  km.<sup>23</sup> Thus, to stay in line with the model, we consider differences in the level of the environmental good across countries, but not within a country.<sup>24</sup>

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<sup>22</sup>Denmark and Estonia have the shortest average distances to the Baltic Sea ( $d^{DEN} = 10$  km and  $d^{EST} = 30$  km), while Germany and Russia have the largest ( $d^{GER} = 360$  km and  $d^{RUS} = 880$  km).

<sup>23</sup>As an alternative proxy one could also use a country’s average inverse distance (restricting  $d_i$  to a minimum of 0.1 km to avoid infinite values of  $E_i$ ), with  $E_i = d_i^{-1}$  for  $d_i > 0.001$  and  $E_i = 0.001^{-1} = 1000$  for  $d_i < 0.001$ . While this approach would increase transfer errors compared to a unit transfer, adjusting for inequality still reduces transfer errors on a comparable magnitude.

<sup>24</sup>Meya (2018) extends the theory of Baumgärtner et al. (2017a) to local public goods. He shows that

We adjust WTP-estimates for differences in the closeness to the Baltic Sea in the hypothetical benefit transfers by using  $\tilde{E}^c$  in  $\mathcal{T}_E(\tilde{E}^p, \tilde{E}^s) = \left(\frac{\tilde{E}^p}{\tilde{E}^s}\right)^{1-\eta}$  and additionally adjusting for differences in mean income and income inequality. We find that the adjustment for the level of the environmental good,  $\Delta |TE|_{\mathcal{T}_E}$ , reduces the average transfer error compared to the unit transfer by 2.87 percentage points.<sup>25</sup> However, this does not much affect our main results on how adjusting for income inequality affects transfer errors: We find that accounting for income inequality over and above for differences in the level of the environmental good,  $\Delta |TE|_{\mathcal{T}_E} - \Delta |TE|_{\mathcal{T}_{E,CV}}$ , reduces transfer errors on average by 1.78 percentage points. This is almost the same effect size as if we had not controlled for differences in the level of the environmental good, which leads to a reduction of 1.80 percentage points. When adjusting for income inequality additionally to both transfers for the environmental good and mean income differences,  $\Delta |TE|_{\mathcal{T}_{E,CV,\mu}} - \Delta |TE|_{\mathcal{T}_{E,\mu}}$ , we find that it further reduces average transfer errors by 1.45 percentage points. Recall that the effect size without controlling for differences in the level of the environmental good was 1.46. Thus the effect sizes presented in the main results section remain largely unchanged.

Second, we test whether our main result still holds when we explicitly adjust for difference in the market price level, that is allowing  $\tilde{P}^p \neq \tilde{P}^s$ . For this we take the annual average exchange rates of the national currency in Euro for 2011 from OECD.Stat. Dividing countries PPP-estimates used in Czajkowski et al. (2017) by their exchange rates yields their market price level,  $\tilde{P}^c$ .<sup>26</sup> In contrast to our previous approach of

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the transfer factors for income inequality employed here also hold for environmental local public goods if their consumption is uncorrelated with income. Otherwise, one also needs to account for environmental inequality and the correlation between the environmental good and income when adjusting for income inequality. Yet, in this case, one cannot neatly disentangle transfer factors. For the Baltic Sea dataset correlating a possibly differential level of the environmental good, approximated as respondents' closeness to the Baltic Sea, and income produces mixed results, As there is no significant correlation (at  $p < 0.05$ ) in the majority of cases, we refrained from further extending our analysis in this direction.

<sup>25</sup>Summary statistics on the absolute transfer errors for the closeness-adjusted benefit transfers are depicted in Table 9 in the Appendix.

<sup>26</sup>The estimated market price level is only  $\tilde{P}^{LAT} = 0.48$  in Latvia but  $\tilde{P}^{DEN} = 1.37$  in Denmark.

starting off with PPP-corrected WTP-estimates, we now first convert WTP-estimates to 2011-EUR and then explicitly adjust for differences in the market price level in benefit transfers by applying  $\mathcal{T}_P(\tilde{P}^p, \tilde{P}^s) = \left(\frac{\tilde{P}^p}{\tilde{P}^s}\right)^{1-\eta}$ . Simple unit transfer to a single currency converted WTP-estimates results in a mean transfer error of 302.01%, which is substantially reduced when adjusting for the market price level,  $|TE|_{\mathcal{T}_P} = 179.91\%$ . Thus, this approach yields higher transfer errors than in our main results specification (compare it to the mean transfer error of 152.35 for unit transfer of the PPP-adjusted WTP-estimates). However, additional income inequality adjustments continue to reduce transfer errors: Adjusting for income inequality in addition to the market price level reduces mean transfer errors by  $\Delta |TE|_{\mathcal{T}_{CV,P}} - \Delta |TE|_{\mathcal{T}_P} = -2.28$  percentage points. When also adjusting for mean income or for mean income and the level of the environmental good the reduction are still  $\Delta |TE|_{\mathcal{T}_{CV,P,\mu}} - \Delta |TE|_{\mathcal{T}_{P,\mu}} = -1.85$  and  $\Delta |TE|_{\mathcal{T}_{CV,P,\mu,E}} - \Delta |TE|_{\mathcal{T}_{P,\mu,E}} = -1.84$  percentage points, respectively.

Finally, we test whether adjusting WTP-estimates for income inequality in a naive, non-theory driven fashion also reduces transfer errors. Without being informed by economic theory, a natural ‘naive’ approach to adjust for income inequality in benefit transfer would most likely be to follow common practice in mean income adjustment using income ratios and thus to adjust WTP-estimates from the study site by the ratio of income inequality at policy and study site, i.e. applying  $\mathcal{T}'_{CV}(CV_Y^p, CV_Y^s) = \frac{CV_Y^p}{CV_Y^s} = \frac{\sigma_Y^p}{\sigma_Y^s}$ . All other things equal to Section 5.1, using such a naive income inequality adjustment increases transfer errors compared to unadjusted unit transfer by  $\Delta |TE|_{\mathcal{T}'_{CV}} = 57.55$  percentage points instead of reducing them and results in mean transfer errors of  $|TE|_{\mathcal{T}'_{CV}} = 209.90\%$ . Compared with mean income adjustment additional inequality adjustment in such a naive way worsens the accuracy of benefit transfer by  $\Delta |TE|_{\mathcal{T}'_{CV,\mu}} - \Delta |TE|_{\mathcal{T}'_{\mu}} = 47.54$  percentage points. This finding highlights the important role of theory for specifying functional forms.



## 6 Discussion

This section provides a discussion of crucial assumptions and major limitations of our analysis. These include (i) the public good characteristics of the environmental quality improvement employed in the contingent valuation survey, (ii) the quality of the income data, (iii) alternative measures of income inequality, (iv) the potential for non-constant income elasticities, as well as (v) the assumption of identical preferences.

First, our theoretical basis for the benefit transfer factors relies on the assumption of a pure public good character of the environmental good in question. Yet, water quality improvement is not always a pure public good and may entail a number of benefits that have a mixed-use character. As such it may also be classified as a local public good, in which exposure to the good differs depending on one's distance to it. In our case, however, respondents were informed that the benefits of nutrient reductions would occur in open-sea areas across the whole Baltic Sea. Indeed, respondents predominantly stated that they considered the whole Baltic Sea, as opposed to only their country's shore line when stating their WTP values (Czajkowski et al. 2017). This is also reflected in the finding by Ahtiainen et al. (2014) that respondents' distance to the Baltic Sea negatively affects their WTP in only one out of nine countries. It thus seems a reasonable assumption that the environmental good in question matches the pure (region-wide) public good characteristics in the theoretical model used to derive the transfer factors. Nevertheless, we eased this assumption in Section 5.2 finding that the effect of (additional) income inequality adjustment remains unchanged.

Second, the quality of the income data is not ideal, as income was only elicited on a limited interval scale (Ahtiainen et al. 2014). As such this is a typical initial situation for benefit transfer, since income data elicited in valuation studies is usually coarsely-grained. We followed Ahtiainen et al. (2014) in setting individual income estimates to the interval mean for all but the highest category, where it was set to the lower interval boundary. This provides conservative estimates of both mean income and income inequality and implies that the reported effect of inequality adjustment is likely a conservative estimate of the actual effect of inequality. This limited information on income

data also does not allow for a proper test of the assumption of a log-normal distribution of income. As there is mixed evidence on how well the log-normal distribution fits actual income data within countries and for the world as a whole (e.g. McDonald 1984, Pinkovskiy and Sala-i-Martin 2009), our results only hold in approximation.

Third, there are a number of different measures for income inequality that one could use to develop transfer functions (see, e.g., Cowell 2009). In particular, one can distinguish notions of absolute and relative income inequality. Measures of absolute income inequality include the standard deviation of income,  $\sigma_Y^e$ , as well as the  $Gini_Y$ -coefficient. It is possible to derive transfer factors for benefit transfer for differences in these measures of absolute income inequality (Baumgärtner et al. 2017a). However, as transfer factors for mean income and income inequality cannot be disentangled for these two absolute measures of income inequality, we have restricted our analysis to the coefficient of variation,  $CV_Y^e$ , as a measure of relative income inequality to isolate the effects. As country-level  $Gini_Y$ -coefficient data may be more widely accessible, we also conduct a simple check on whether it is particularly worthwhile to adjust for income inequality in benefit transfer, based on the  $Gini_Y$  for data from the Baltic Sea study. For this, we consider those 16 cases for which a  $Gini_Y$ -coefficient ratio between the study and the policy site is smaller than 0.8 and compute mean reductions in transfer errors by including the transfer factors. For these cases, we find that as compared to unit transfer or mean income adjustment, respectively, additionally considering income inequality adjustment reduces transfer errors by 7.73 percentage points for  $\Delta |TE|_{\mathcal{T}_{CV}}$  and by 6.15 percentage points for  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_\mu}$ . This suggests that our rule-of-thumb—that income inequality adjustment is particularly relevant for cases in which inequality at the study site is below 80 percent of the policy site’s level of inequality—might even be more pronounced when considering the  $Gini_Y$ -coefficient.

Fourth, the theory-driven transfer factors employed in our analysis rest on the assumption of a constant elasticity of substitution utility function and an associated constant income elasticity of WTP. This assumption is most often adopted in the practice of benefit transfer (e.g. ten Brink et al. 2011), is supported by some primary valuation studies (e.g. Jacobsen and Hanley 2009, Broberg 2010) and has been shown to produce

the best fit in terms of reducing transfer errors in the benefit transfer analysis of the Baltic Sea study by Czajkowski et al. (2017). Despite these encouraging results and the attractiveness of a constant elasticity approach for tractability reasons, it is unlikely that the elasticity is constant in general. Recently, Barbier et al. (2016) have provided evidence that suggests a non-constant income elasticity of WTP, varying with the level of mean income, based on a different analysis of the Baltic Sea study. Additionally, some theoretical studies have provided arguments for non-constant income elasticities, for example, by taking into account a subsistence consumption level of environmental goods (Baumgärtner et al. 2017b, Drupp 2018), or environmental risk and individual risk-aversion (Baumgärtner et al. 2017c). While this paper provides a theory-driven analysis of income inequality adjustment in benefit transfer that rests on the most widely used framework, further theoretical research on benefit transfer functions is required.

Finally, the theory-driven transfer factors rely on the assumption of homogeneous preferences within and across countries. Specifically, we assumed (a) that the utility weight individuals put on the environmental good relative to consumption good,  $\alpha$ , is the same, and (b) that the elasticity of substitution and thus the income elasticity of WTP,  $\eta$ , is the same for all individuals. However, it is possible to introduce heterogeneities. First, we address assumption (a), i.e. the share parameter  $\alpha$ . For simplicity consider a case where the mean weight parameters differ across countries, perhaps due to cultural differences or education leading to a higher or lower weight put on environmental goods (think, for example, of Sweden versus Latvia).<sup>27</sup> The transfer function would then need to be extended by a factor for the weight parameter:  $\mathcal{T}_\alpha(\alpha^p, \alpha^s) = \frac{\alpha^s}{\alpha^p} \left( \frac{1 - \alpha^p}{1 - \alpha^s} \right)$ .

Assumption (b) has implicitly been made also by benefit transfer approaches that assume a single, constant income elasticity of WTP. It is, however, possible to relax this assumption. For example, Baumgärtner et al. (2017a) consider heterogenous preferences for the case where individual-specific income elasticities are normally distributed and uncorrelated with income. Different distributions of  $\eta$ -types in two countries would then lead to mean income elasticities that differ across countries. Detailed data on  $\eta$ -

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<sup>27</sup>Hynes et al. (2013) study how international benefit transfer may be adjusting for cultural differences.

estimates in both countries is usually not available in the context of benefit transfer and often times no pertinent meta-study is available. The more relevant case in practice is to only consider the income elasticity from the study country. We therefore also estimated the income elasticity of WTP,  $\tilde{\eta}_i$ , for all nine countries individually and applied the study sites estimate in the transfer factors given in formulas (9) to (11).<sup>28</sup> We find that income elasticities of WTP of seven out of nine countries fall within the usual range of 0.1 to 0.6. Yet, the estimates vary substantially. Employing the country specific income elasticities,  $\tilde{\eta}_i$ , in the benefit transfers further reduces transfer errors over the case of a common income elasticity,  $\tilde{\eta}$ . It shows that mean transfer errors decrease by  $\Delta |TE|_{\mathcal{T}_{CV}} = -2.26$  and  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_{\mu}} = -1.69$  percentage points for pure and additional income inequality adjustment down to a total average transfer errors of  $|TE|_{\mathcal{T}_{CV,\mu}} = 108.28$  percent when controlling for mean income and income inequality. This shows that our main results also hold when the income elasticity from the study site is applied, and that this might even be more accurate than using the pooled estimate.<sup>29</sup>

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<sup>28</sup>We assume that the income elasticity is constant within each country, estimated with an OLS regression in log-log specification without control variables. The assumption of a log-log WTP-income relation seems to outperform other functional forms in benefit transfer (Czajkowski et al. 2017).

<sup>29</sup>Country-specific income elasticities, aggregate statistics on transfer errors and transfer errors for all country-to-country benefit transfers are available from the authors upon request.

## 7 Conclusion

This paper has shown how benefit transfer can account for differences in income inequality in a theory-driven fashion and has scrutinized the applicability of this approach drawing on a multi-country study on water quality improvement in the Baltic Sea.

Improving benefit transfer is of tremendous importance for public and in particular environmental policy appraisal, as it has perhaps become the most important method of non-market valuation (Richardson et al. 2015). A number of different approaches to benefit transfer have been developed over the past decades, ranging from simple unit transfer to sophisticated individual study based calibrations. Kaul et al. (2013) review studies including more than 1000 benefit transfers and find substantial mean (median) transfer errors of 172 (39) percent. Based on the same Baltic Sea data employed in the present paper, Czajkowski et al. (2017) analyze which functional form should be chosen for international benefit transfer. They find that a constant income elasticity function that controls for differences in the level of mean income between the study and the policy site performs best. As many previous approaches to benefit transfer have been somewhat ad-hoc, Bateman et al. (2011) among others have called for benefit transfer parameters to be more firmly grounded in economic theory and underlying preferences. Responding to these calls, we build on theory-driven transfer factors for mean income and income inequality that were recently developed by Baumgärtner et al. (2017a) to scrutinize whether and to what degree income inequality adjustments can improve benefit transfer.

We find that income inequality adjustment reduces benefit transfer errors by more than 1.5 percentage points on average for the Baltic sea data. We show that this main finding is robust to considering a number of model variations. While our main finding may seem as a rather small effect, it will often be economically substantial. Furthermore, income inequality adjustment becomes particularly relevant when income at the policy site is more unequally distributed than at the study site. On average the reduction in transfer errors amounts to more than 5 percentage points when income inequality at the study site is more than 20 percent lower than the level of inequality

at the policy site. We perform a number of checks and show that our main result is robust to additionally considering other possible transfer factors for differences in the price level or the mean level of the environmental goods across countries. Finally, we show that a naive a-theoretic transfer adjustment for income inequality would increase benefit transfer errors. This emphasizes the importance of employing the structural theory-driven factors that we draw on in our convergent validity exercise.

Our findings are relevant in several respects: First, practitioners of benefit transfers should consider employing transfer factors for differences in income inequality, in particular when income is distributed more unequally at the policy site compared to the study site. Our study has shown how this can be undertaken easily by drawing on simple, theory-driven transfer factors. This would be, for example, particularly relevant for transferring values from European countries to applications in the USA, where income is distributed considerably more unequally. Moreover, inter-country differences in income inequality are considerable for many pairs of European countries. Thus, studies assessing EU-wide benefits by scaling up a small number of WTP-estimates from a subset of member states, should take into account income inequality effects on value transfer. For instance, the benefit streams from ecosystems services from all Natura 2000 sites have been estimated to be 314 billion Euros per year using benefit transfer (ten Brink et al. 2011: 59-64, European Commission 2013). A simple, conservative extension of this analysis—additionally applying benefit transfer factors for income inequality—would increase benefits by only 0.13 percent on average, which would however translate into a sizable economic effect size of 446 million Euros per year.<sup>30</sup> This simple application high-

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<sup>30</sup>Our simple extended analysis follows the Natura 2000 steps, except that we additionally account for income inequality assuming that the income elasticity of WTP of 0.38 is given by the mean estimate from most comprehensive global meta-study on WTP for biodiversity conservation (Jacobsen and Hanley 2009). Data on the income distribution of European countries was taken from the European Survey on Income and Living Conditions provided by eurostat. The survey contains upper limits of percentiles for disposable household income in 2011 per capita (equivalised). Decentiles and 95th, 96th, 97th, 98th, 99th percentiles were taken to construct national income distributions (taking the interval values as means of lower and upper limits) and estimate mean income and relative income inequality. This approach yields only a conservative estimate for the reduction in transfer errors from additional income

lights that although adjustments for income inequality may seem of minor importance in percentage terms, they can imply substantial effects in absolute economic terms.

Second, theory-driven transfer factors reveal that the frequent use of an income elasticity of one in benefit transfers neglects income inequality, as the transfer factor for income inequality becomes one for different income inequalities if and only if the income elasticity of WTP is unity. Our analysis shows that this shortcut might perform well if income at the policy site is distributed more equally and is relatively similar to the study site. However this shortcut can result in serious transfer errors when income is distributed substantially more unequally at the policy site. Thus, our study underscores once more the importance of conducting theory-driven benefit transfer as proposed, among others, by Bateman et al. (2011).

Thirdly, the collection of value estimates for different environmental goods in benefits transfer databases is often hailed to be the “holy grail of benefits transfer” (Pearce et al. 2006: 267). There are several attempts in this direction, such as the *The Environmental Valuation Reference Inventory* (EVRI 2017), a database including information on over 4,000 international valuation studies, that is also mentioned in several guidelines on benefit transfer (e.g. UBA 2012, Pearce et al. 2006). For instance, the UK sees a further increasing scope of benefit transfer as value databases expand (HM Treasury 2011: 21) and actively supports their development (Defra 2007). One of such future applications might be the use of benefit transfer to inform government project appraisal by drawing on information gathered in environmental impact assessments, e.g. for economic analysis in the context of the EU Water Framework Directive (Droste and Meya 2017). The increasing availability of WTP-estimates for different environmental goods should be accompanied by methodological developments to increase the accuracy of benefit transfer (Pearce et al. 2006) that are sufficiently easy to apply—as the theory-driven benefit transfer factors tested in this study—such as to be used widely in practice.

Fourth and relatedly, there are several efforts underway to link ecosystem services to economic activities in national accounts. Recently, the UN, EU, OECD, FAO and World  

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inequality adjustment, as in Natura 2000 WTPs are transferred to the European average rather than on a country-by- country basis, where differences in relative income inequality are much higher.

Bank (2014) proposed the *system of environmental economic accounting - experimental ecosystem accounting* to facilitate further explorations on a country's ecosystem accounting. This is accompanied by a discussion of the conceptual foundations and appropriate valuation methods to integrate ecosystem services in accounting standards (e.g. Droste and Bartkowski 2017, Obst et al. 2016). One approach is to make changes in ecosystem services directly comparable to market activities through monetary valuation. As primary valuations are usually site-specific, this will regularly involve scaling-up estimates to the national level. The UN et al. (2014: 127) thus call for “efforts aimed at improving benefit transfer methods”. Our analysis suggests that this should include accounting for the effects of income inequality when conducting benefit transfer.

Finally, primary non-market valuation studies should report measures on income elasticities and on income inequality to facilitate the application of more sophisticated and accurate benefit transfers. Ideally, studies would always state standard deviations of respondent's income besides relevant means, or even make the full income distribution available in supplementary online material.

Overall, our findings add empirical evidence to the debate on the importance of economic growth and changes in inequality for the valuation of non-market environmental goods. They suggest that while accounting for differences in mean income is relatively more important, taking into account income inequality results in considerable improvements in the performance of benefits transfers.



## Acknowledgments

We are indebted to Stefan Baumgärtner and Mikolaj Czajkowski for their valuable feedback and are very grateful for comments from Nils Droste, Klaus Eisenack, Roger von Haefen, Frikk Nesje, Martin Quaas, Arnaud Reynaud as well as seminar participants at Basel, BIOECON 2017, EAERE 2017, EnvEcon 2017, HU Berlin, Kiel, UFZ Leipzig and WCERE 2018. We thank all collectors of the dataset, including researchers from nine countries and the BalticSTERN Secretariat, as well as the funders (Finnish Ministry of Agriculture and Forestry, Finnish Ministry of Environment, Finnish Ministry of Transport and Communications and Finnish Ministry of Finance, Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas); Danish Strategic Research Council; German Federal Environment Agency (UBA); Swedish Environmental Protection Agency) for their willingness to share the data for our research purposes. Drupp gratefully acknowledges financial support from the German Ministry of Education and Research under grant 01UT1410. Meya gratefully acknowledges financial support from the Ministry for Science and Culture of Lower Saxony (Germany) and the Volkswagen Foundation within the program Science for Sustainable Development under grant VWZN3045.

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# Appendix

Table 3: Transfer errors  $|TE|$  (in percent) for unit transfer

to: from:	DEN	EST	FIN	GER	LAT	LIT	POL	RUS	SWE
DEN	0	48.35	26.47	23.12	448.65	227.82	142.52	267.59	60.93
EST	32.59	0	50.44	17.01	269.83	120.97	63.47	147.78	73.67
FIN	36.00	101.76	0	67.45	646.19	345.84	229.83	399.94	46.87
GER	18.78	20.49	40.28	0	345.63	166.26	96.98	198.56	68.27
LAT	81.77	72.96	86.60	77.56	0	40.25	55.80	33.00	92.88
LIT	69.50	54.75	77.57	62.44	67.37	0	26.02	12.13	88.08
POL	58.77	38.83	69.68	49.23	126.23	35.17	0	51.57	83.89
RUS	72.80	59.64	80.00	66.51	49.26	10.82	34.03	0	89.37
SWE	155.98	279.75	88.22	215.16	1,304.44	739.15	520.80	840.96	0

Table 4:  $\Delta |TE|_{\mathcal{T}_{CV}} = |TE|_{\mathcal{T}_{CV}} - |TE|_{unit}$  (in percentage points)

to: from:	DEN	EST	FIN	GER	LAT	LIT	POL	RUS	SWE
DEN	0	-3.21	0.31	-1.40	-9.43	-1.94	-4.94	-1.34	-0.26
EST	-1.49	0	-0.88	-0.87	1.69	3.55	0.22	4.56	-0.76
FIN	0.58	-3.52	0	-1.19	-9.68	-0.75	-5.33	0.31	-0.59
GER	-0.93	-1.26	-0.43	0	-2.63	1.46	-1.79	2.32	-0.58
LAT	-0.32	0.12	-0.18	-0.13	0	-0.68	0.14	-0.92	-0.17
LIT	-0.18	0.72	-0.04	0.20	-1.89	0	1.07	0.26	-0.15
POL	-0.86	0.08	-0.50	-0.47	0.73	1.99	0	2.58	-0.44
RUS	-0.10	0.73	0.01	0.26	-2.03	0.20	1.11	0	-0.11
SWE	-1.70	-10.69	-2.05	-5.65	-33.31	-10.53	-16.68	-9.67	0



Table 5:  $\Delta |TE|_{\mathcal{T}_\mu} = |TE|_{\mathcal{T}_\mu} - |TE|_{unit}$  (in percentage points)

to: from:	DEN	EST	FIN	GER	LAT	LIT	POL	RUS	SWE
DEN	0	-25.24	0.94	-2.13	-161.45	-117.84	-42.33	-83.48	1.59
EST	-13.82	0	-9.40	-15.28	-55.32	-50.42	-0.87	-17.01	-4.10
FIN	1.76	-32.16	0	-0.77	-212.77	-156.58	-54.05	-108.55	1.51
GER	-1.43	-18.74	-0.28	0	-125.60	-92.71	-31.52	-63.74	0.76
LAT	-7.60	-4.76	-5.35	-8.81	0	5.52	-7.50	-6.38	-2.56
LIT	-17.12	-13.38	-12.14	-20.06	17.04	0	-21.36	23.17	-5.93
POL	-8.72	-0.33	-5.94	-9.67	-32.81	-30.28	0	-9.65	-2.61
RUS	-7.99	-2.98	-5.55	-9.09	-12.97	15.27	-4.49	0	-2.56
SWE	10.88	-51.21	5.50	7.72	-371.13	-278.81	-86.57	-182.78	0

Table 6:  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} = |TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{unit}$  (in percentage points)

to: from:	DEN	EST	FIN	GER	LAT	LIT	POL	RUS	SWE
DEN	0	-27.90	1.25	-3.50	-168.10	-119.09	-46.40	-84.52	1.34
EST	-15.62	0	-10.45	-16.32	-53.88	-47.68	-0.65	-12.77	-4.99
FIN	2.35	-35.12	0	-1.96	-219.69	-157.07	-58.51	-108.30	0.94
GER	-2.38	-19.80	-0.71	0	-127.48	-91.76	-33.03	-61.92	0.19
LAT	-8.05	-4.61	-5.59	-8.99	0	4.90	-7.33	-7.39	-2.79
LIT	-17.40	-12.45	-12.20	-19.75	14.96	0	-19.98	23.49	-6.16
POL	-9.76	-0.25	-6.54	-10.23	-32.18	-28.74	0	-7.23	-3.13
RUS	-8.12	-2.19	-5.53	-8.76	-14.82	15.44	-3.31	0	-2.70
SWE	9.11	-60.46	3.39	1.93	-395.64	-285.84	-100.92	-190.57	0

Table 7: Transfer error changes for additional income inequality adjustment  $\Delta |TE|_{\mathcal{T}_{CV,\mu}} - \Delta |TE|_{\mathcal{T}_\mu}$  (in percentage points)

to: from:	DEN	EST	FIN	GER	LAT	LIT	POL	RUS	SWE
DEN	0	-2.67	0.31	-1.37	-6.65	-1.25	-4.07	-1.04	-0.25
EST	-1.80	0	-1.05	-1.04	1.44	2.74	0.22	4.25	-0.88
FIN	0.59	-2.96	0	-1.19	-6.92	-0.48	-4.46	0.24	-0.57
GER	-0.95	-1.06	-0.43	0	-1.89	0.95	-1.51	1.83	-0.57
LAT	-0.45	0.14	-0.25	-0.19	0	-0.62	0.17	-1.01	-0.24
LIT	-0.28	0.93	-0.06	0.31	-2.09	0	1.38	0.31	-0.23
POL	-1.04	0.08	-0.60	-0.56	0.63	1.54	0	2.42	-0.52
RUS	-0.13	0.78	0.02	0.33	-1.85	0.17	1.18	0	-0.14
SWE	-1.78	-9.25	-2.11	-5.79	-24.51	-7.03	-14.36	-7.79	0

Table 8: Transfer errors  $|TE|$  summary statistics (in percent)

	$ TE _{unit}$	$ TE _{\mathcal{T}_{CV}}$	$ TE _{\mathcal{T}_\mu}$	$ TE _{\mathcal{T}_{CV,\mu}}$
mean	152.35	150.55	115.48	114.02
median	72.88	72.80	67.44	66.07
sd	215.57	211.27	152.70	149.43

Table 9: Transfer errors  $|TE|$  summary statistics (in percent) when also adjusting for differences in the level of the environmental good,  $\tilde{E}^c$ .

	$ TE _{\mathcal{T}_E}$	$ TE _{\mathcal{T}_{E,CV_Y}}$	$ TE _{\mathcal{T}_{E,\mu_Y}}$	$ TE _{\mathcal{T}_{E,\mu_Y,CV_Y}}$
mean	149.48	147.70	113.05	111.60
median	71.86	71.82	67.21	66.04
sd	211.56	207.26	149.24	145.96