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# Income Inequality and the International Transfer of Environmental Values

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How income and the valuation of environmental goods are related is a key question for science and policy, but the role of income inequality is often neglected. This paper studies how income inequality impacts the international transfer of environmental values—a practice called value or benefit transfer. Specifically, we apply theory-driven transfer factors to examine whether adjusting for income inequality can improve benefit transfer, drawing on a multi-country case study on water quality improvement. We find that income inequality adjustment reduces benefit transfer errors significantly, and by 1.5 percentage points on average. Adjusting for income 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 25 percentage points. Our results are relevant for the practice of policy appraisal and environmental accounting, and more generally for the role of income inequality in non-market valuation.

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

**Keywords:** benefit transfer, income, inequality, stated preference, transfer errors

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# 1 Introduction

How income is related to the valuation of environmental goods is a central topic for environmental economics. Numerous valuation studies investigate this relationship by estimating how willingness to pay (WTP) for environmental goods depends on the level of income (e.g Jacobsen and Hanley 2009). Almost all find that WTP increases with individual income, but at a lower than proportionate rate.[1] This implies that poorer households value these environmental benefits over-proportionately, already suggesting a potentially important role for considering issues of economic distribution.

There is a growing interest in society at large as well as in the economics literature in the effects of income inequality.[2] 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. (2016) examine how mean WTP for environmental goods depends on the distribution of income in society. They find that WTP increases with income inequality for constant income elasticities below unity, but changes more elastically with mean income than with income inequality for large parts of the parameter space.

To shed light on the empirical relationship between income, income inequality and the valuation of environmental goods, we study the effects of income inequality in one of the most frequently used valuation methods: benefit transfer (Czajkowski et al. 2017, Johnston et al. 2015). Benefit transfer—also often called value transfer—makes use of WTP estimates for an environmental good derived from a study site for another policy site, where this information is to be used to inform decision-making for environmental

[1]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.

[2]For example, 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" have only increased by 10 (19) percent (own calculation based on Google Trends). Piketty's (2014) work on economic inequality has received widespread attention and the 2015 Sveriges Riksbank Prize in Economic Sciences has been awarded to Deaton for "his analysis of consumption, poverty, and welfare".

management. As sites may differ in many ways, it is crucial to control for variations in key explanatory variables, including income, as part of the transfer. This paper builds on theory-driven benefit transfer factors for income and income inequality to scrutinize whether controlling for differences in income inequality across sites improves the WTP estimates derived from benefit transfer.

Obtaining theoretically sound, empirically relevant and easy-to-use approaches 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), as primary valuation studies are costly and time intensive. International and inter-regional benefit transfer has been frequently applied to inform environmental policy making in the European Union and the United States. For illustration we briefly highlight two cases of environmental policy making where benefit transfer was applied.

First, Natura 2000 is Europe's most important legislation to protect nature and biodiversity (Brouwer and Navrud 2015). 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 European Union's terrestrial area and including more than 26.000 sites it is globally the largest coordinated network of protected areas (European Commission 2008, 2013). To inform the policy process on Natura 2000, the economic benefits from Natura 2000 sites were assessed for all of Europe (European Commission 2013). As only limited primary valuation for ecosystem services from Natura 2000 sites were available (34 values from 20 different studies),[3] these were scaled up, i.e. 'transferred', entailing scope for substantial transfer errors.

Second, the U.S. Environmental Protection Agency (EPA) has been required to conduct benefit-cost analysis on environmental regulation for more than three decades (Griffiths et al. 2012). Despite its drawbacks, benefit transfer has thereby been "one of the most common approaches" to estimate the value of changes in environmental quality (U.S. EPA 2014: 45). For instance, benefit transfer was applied to estimate the recreational benefits of water quality improvements under the 2002 Combined Animal

[3]These estimates derive mainly from sites in the UK (15 values) and the Netherlands (6 values).

Feeding Operations rule (U.S. EPA 2014). WTP estimates of the national contingent valuation survey by Carson and Mitchell (1993) were used to value predicted water quality improvements across U.S. states.

Due to this widespread demand for environmental valuation by governmental agencies to inform project appraisal, benefit transfer has become "the bedrock of practical policy analysis" to inform regulatory decision-making (Pearce et al. 2006: 266). Accordingly, studying the reliability of benefit transfer has become an important research focus in environmental economics. While ideal conditions for benefit transfer—complete equivalence of the study and policy site across all relevant variables affecting WTP—are almost always violated, which makes the simple so-called unit transfer of values inadmissible, the literature has focused on developing adequate ways of adjusting benefit transfer for key variables. Kaul et al. (2013) review 20 years of published studies that scrutinize the validity of benefit transfer. Their analysis suggests that comprehensive benefit function transfer is more accurate, i.e. benefit transfer should control for a range of covariates of WTP with their levels calibrated to policy-case conditions. Other studies find that simple transfers adjusted for purchasing power parity and income to perform best (e.g. Czajkowski et al. 2017, Ready et al. 2004).

A central finding of most studies is that accounting for income plays a central 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 to use formulas for mean income correction (UBA 2012, Pearce et al. 2006, Defra 2007), and many academic studies on benefit transfer employ these (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, income inequality has, to our knowledge, so far gained no attention in benefit transfer.[4]

So far, the literature on benefit transfer has been mainly driven by empirical ap-

[4]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).

proaches, with only few exceptions of studies following a more structural utility theoretic approach.[5] Bateman et al. (2011) argue that parameters controlled for in benefit transfer should be based on economic theory rather than best-fitting ad-hoc statistical approaches, that may be over parametrized when applied out of the sample. Recently, Baumgärtner et al. (2016) have studied how WTP for environmental public goods depends on the distribution of income, based on a structural model with equal constant-elasticity-of-substitution preferences and an unequal distribution of income, and have derived benefit transfer factors in particular for mean income and income inequality.

This paper builds on these theory-driven benefit transfer factors to systematically examine income inequality adjustment in a nine-country Baltic Sea case study on water quality improvement (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 single, well-defined change in environmental quality. 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. We then evaluate WTP 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 insights on the following questions: (i) Can theory-driven income inequality adjustment reduces errors made by benefit transfer?; (ii) Under which conditions can income inequality adjustment lower transfer errors?; (iii) What is the relative effect of adjusting benefit transfers for mean income and

[5]Bergstrom and Taylor (2006) provide an overview of 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 few studies providing a structural utility-theoretic model that specifies the relationship between mean WTP of a population and its key explanatory variables to be applied in benefit transfer (Baumgärtner et al. 2016; Smith et al. 2002, 2006)

income inequality? For our nine-country Baltic Sea case study, we find that (i) income inequality adjustment decreases transfer errors by 1.5 percentage points on average; (ii) Income inequality adjustment becomes particularly relevant when income at the policy site is more unequally distributed than at the study site and decreases transfer errors by 5 percentage points on average when inequality at the study site is less than 80% of the policy site's income inequality; (iii) Adjusting benefit transfer for mean income is considerably more important empirically than adjustment for income inequality. It is thus reassuring that most applied approaches already control for differences in mean income. Over and above this adjustment for mean income, our study shows that accounting for income inequality can further improve benefit transfers and is straightforward to do so for practitioners. Our results are therefore relevant for the practice of benefit transfer, policy guidance on environmental project appraisal and the role of income inequality in environmental valuation more generally.

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 our Baltic Sea case study and describe in Section 4 our strategy to empirically test the proposed transfer factors. Results are reported in Section 5. Finally, we discuss limitations to our analysis in Section 6 and conclude in Section 7.

# 2 Theory-driven benefit transfer factors

As much of benefit transfer has been conducted in an ad-hoc fashion, there have been calls for a theory-driven approaches to performing benefit transfer (Bateman et al. 2011). Recently, Baumgärtner et al. (2016) have derived a generic transfer function with disentangled individual transfer factors for mean income and income inequality. We follow the framework of Baumgärtner et al. (2016) and cast it more specifically in the setting of (international) 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 region $p$ (the 'policy site').

Assume there are $N^{\mathrm{i}}$ individuals j in country or region i, with $\mathrm{i} \in \{\mathrm{s}, \mathrm{p}\}$, who derive utility from the consumption of a market-traded private good, $X_{\mathrm{j}}^{\mathrm{i}}$, and a non-market-traded pure public environmental good, $E_{\mathrm{j}}^{\mathrm{i}}$. The consumption good is traded at a given market price $P^{\mathrm{i}} > 0$, while the consumption of the environmental good is fixed endogenously at level $E_{\mathrm{j}} = E^{\mathrm{i}} > 0$ for all $j$. Individuals share identical preferences over these two goods represented by a constant elasticity of substitution utility function

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

where $\theta \in (0, +\infty)$ is the constant elasticity of substitution 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.[6]

The decision problem of each individual $j$ is then to maximize utility over the consumption of these two goods subject to the income constraint and the fixed level of $E^{\mathrm{i}}$. While we assume that individuals have the same preferences, they differ in their individual incomes $Y_{\mathrm{j}}^{\mathrm{i}}$, which are given exogenously. Specifically, income assumed to be distributed log-normally with mean, $\mu_Y^{\mathrm{i}}$, and standard deviation, $\sigma_Y^{\mathrm{i}}$.[7]

Individual j's WTP for the environmental good $E^{\mathrm{i}}$ is then determined by the level of income $Y^{\mathrm{i}}$ and the parameters of the utility function and the level of $E^{\mathrm{i}}$

$$\mathrm{WTP}(Y_{\mathrm{j}}^{\mathrm{i}}) = \kappa^{\mathrm{i}}\, Y_{\mathrm{j}}^{\mathrm{i}\,\eta} \quad \text{with} \quad \kappa^{\mathrm{i}} = \frac{1-\alpha}{\alpha}(P^{\mathrm{i}} E^{\mathrm{i}})^{1-\eta}, \quad \eta = \frac{1}{\theta} , \tag{2}$$

where $\eta$ is the income elasticity of WTP. The constant elasticity of substitution utility function implies that the income elasticity of WTP, $\eta$, is the inverse of the elasticity of substitution, $\theta$, between the market-traded consumption good, $X^i$, and non-market-traded public environmental good, $E^{\mathrm{i}}$, and thus also a constant.[8] While this simple

[6]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.

[7] The assumption of log-normality is necessary to yield simple, closed-form solutions (Baumgärtner et al. 2016). It is also a good approximation for many income distributions at a national level, as well as for the world as a whole (Pinkovskiy and Sala-i-Martin 2009).

[8]While the empirical validity of assuming a constant income elasticity of WTP has been challenged

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 Baumgärtner et al. (2016) have shown that mean WTP for a change in $E^{\mathrm{i}}$ depends on mean income, income inequality and income elasticity of WTP as follows

$$\mu^{\mathrm{i}}_{\mathrm{WTP}}(\mu^{\mathrm{i}}_Y, \mathrm{CV}^{\mathrm{i}}_Y, P^{\mathrm{i}}, E^{\mathrm{i}}) \;=\; {\mu^{\mathrm{i}}_Y}^{\eta} \left(1 + {\mathrm{CV}^{\mathrm{i}}_Y}^2\right)^{\frac{\eta(\eta-1)}{2}} \; \frac{1-\alpha}{\alpha} \, (P^{\mathrm{i}} E^{\mathrm{i}})^{1-\eta} \,, \tag{3}$$

where $\mathrm{CV}^{\mathrm{i}}_Y := \sigma^{\mathrm{i}}_Y / \mu^{\mathrm{i}}_Y$ is the coefficient of variation of income, which is a 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. 2016). 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 individuals 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.[9]

recently (Barbier et al. 2016), it has been shown to be superior to other functional forms in benefit transfer for the case study that we use in this paper (Czajkowski et al. 2017) and it is typically applied by practitioners of benefit transfer.

[9] 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.

The benefit transfer function, $\mathcal{T}(\cdots)$, for transferring mean WTPs from the study site, $\mu^{\mathrm{s}}_{\mathrm{WTP}}$, to the policy site, $\mu^{\mathrm{p}}_{\mathrm{WTP}}$, 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:

$$\begin{aligned}\mathcal{T}(\mu^{\mathrm{p}}_Y, \mathrm{CV}^{\mathrm{p}}_Y, P^{\mathrm{p}}, E^{\mathrm{p}};\ \mu^{\mathrm{s}}_Y, \mathrm{CV}^{\mathrm{s}}_Y, P^{\mathrm{s}}, E^{\mathrm{s}}) \quad &:= \quad \frac{\mu^{\mathrm{p}}_{\mathrm{WTP}}(\mu^{\mathrm{p}}_Y, \mathrm{CV}^{\mathrm{p}}_Y, P^{\mathrm{p}}, E^{\mathrm{p}})}{\mu^{\mathrm{s}}_{\mathrm{WTP}}(\mu^{\mathrm{s}}_Y, \mathrm{CV}^{\mathrm{s}}_Y, P^{\mathrm{s}}, E^{\mathrm{s}})} \\ &\overset{\text{(Equ. 3)}}{=} \quad \frac{(\mu^{\mathrm{p}}_Y)^{\eta}(1+\mathrm{CV}^{\mathrm{p}\,2}_Y)^{\frac{\eta(\eta-1)}{2}}\ \dfrac{1-\alpha}{\alpha}(P^{\mathrm{p}}E^{\mathrm{p}})^{1-\eta}}{(\mu^{\mathrm{s}}_Y)^{\eta}(1+\mathrm{CV}^{\mathrm{s}\,2}_Y)^{\frac{\eta(\eta-1)}{2}}\ \dfrac{1-\alpha}{\alpha}(P^{\mathrm{s}}E^{\mathrm{s}})^{1-\eta}}\end{aligned}$$

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

$$\begin{aligned}\mu^{\mathrm{p}}_{\mathrm{WTP}} &= f(\mu^{\mathrm{s}}_{WTP}) \\ &= \mathcal{T}_{\mu}(\mu^{\mathrm{p}}_Y, \mu^{\mathrm{s}}_Y) \cdot \mathcal{T}_{\mathrm{CV}}(\mathrm{CV}^{\mathrm{p}}_Y, \mathrm{CV}^{\mathrm{s}}_Y) \cdot \mathcal{T}_{p}(P^{\mathrm{p}}, P^{\mathrm{s}}) \cdot \mathcal{T}_{E}(E^{\mathrm{p}}, E^{\mathrm{s}}) \cdot \mu^{\mathrm{s}}_{\mathrm{WTP}}\ . \qquad (4)\end{aligned}$$

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:[10]

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

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

It is common practice to adjust WTP estimates in international benefit transfer for differences in mean income using $\mathcal{T}_{\mu}(\mu^{\mathrm{p}}_Y, \mu^{\mathrm{s}}_Y)$. 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) explicitly stated this formula in policy advice for European Commission for international benefit transfer on health estimates. Moreover,

[10] The theory also yields transfer factors for the market price level $\mathcal{T}_P(P^{\mathrm{p}}, P^{\mathrm{s}}) = \left(\frac{P^{\mathrm{p}}}{P^{\mathrm{s}}}\right)^{1-\eta}$ and the quantity of the environmental good $\mathcal{T}_E(E^{\mathrm{p}}, E^{\mathrm{s}}) = \left(\frac{E^{\mathrm{p}}}{E^{\mathrm{s}}}\right)^{1-\eta}$. As this paper focuses on the effects of the distribution of income, we leave an analysis of these two transfer factors for future research. We thus make the simplifying assumption of $E^{\mathrm{p}} = E^{\mathrm{s}}$. Furthermore, we directly use the income and WTP data from the case study, which have already been PPP-adjusted.

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. In contrast, 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 value cases for $\eta$. We first focus on the simplest case of $\eta = 1$ that is most often assumed in the academic literature on benefit transfer (see, e.g., Barton (2002) and Czajkowski and Scasny (2010)) as well as in policy applications, e.g. $\eta = 1$ was used for the estimation of the total economic value of ecosystem services from Natura 2000 sites commissioned by the European Commission (ten Brink et al. 2011). Although such studies have hitherto assumed $\eta = 1$ for simplicity and only accounted for the difference in mean income in the study and policy site, the theory-driven transfer factors indeed suggest that controlling only for this difference is correct if and only if the income elasticity were equal to unity. 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 the other factors, including income inequality.

As there is only sparse empirical evidence for $\eta > 1$, we focus on the empirically most relevant case of $\eta < 1$.[11] 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, $\mathcal{T}_{\mu}(\mu_Y^{\mathrm{p}}, \mu_Y^{\mathrm{s}})$. The theory-driven transfer factor for income inequality, $\mathcal{T}_{\mathrm{CV}}(\mathrm{CV}_Y^{\mathrm{p}}, \mathrm{CV}_Y^{\mathrm{s}})$, increases in the ratio of income inequality at the study and the policy site, $\frac{CV_Y^{\mathrm{s}}}{CV_Y^{\mathrm{p}}}$, 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).

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

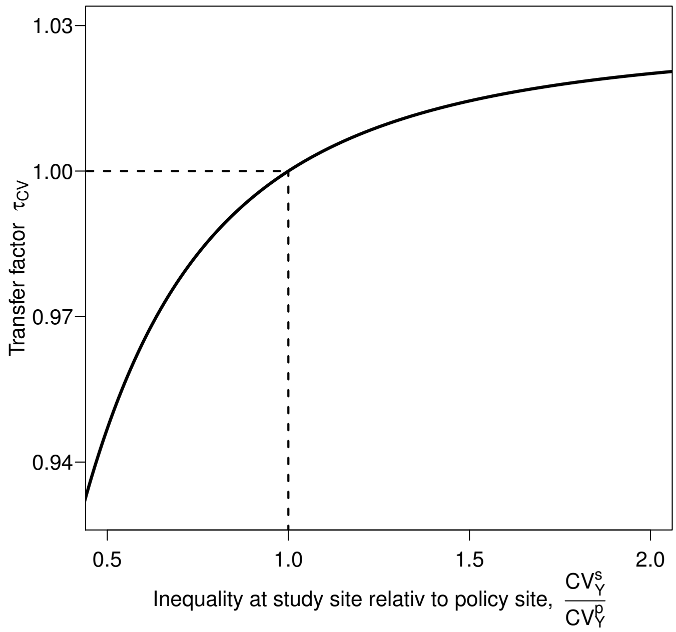


Figure 1: Relationship between the transfer factor for income inequality $\mathcal{T}_{\mathrm{CV}}(\cdot)$ and the ratio of income inequality in the study and policy country for $\eta = 0.28$ and $CV_Y^s = 0.56$.

# 3 Case study

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

The case study 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 income distributions. Ahtiainen et al. (2014) designed the survey such that it is both comparable and meaningful to the population in each country bordering the Baltic See. Respondents were informed that the benefits of nutrient reductions would fall in open-sea areas across

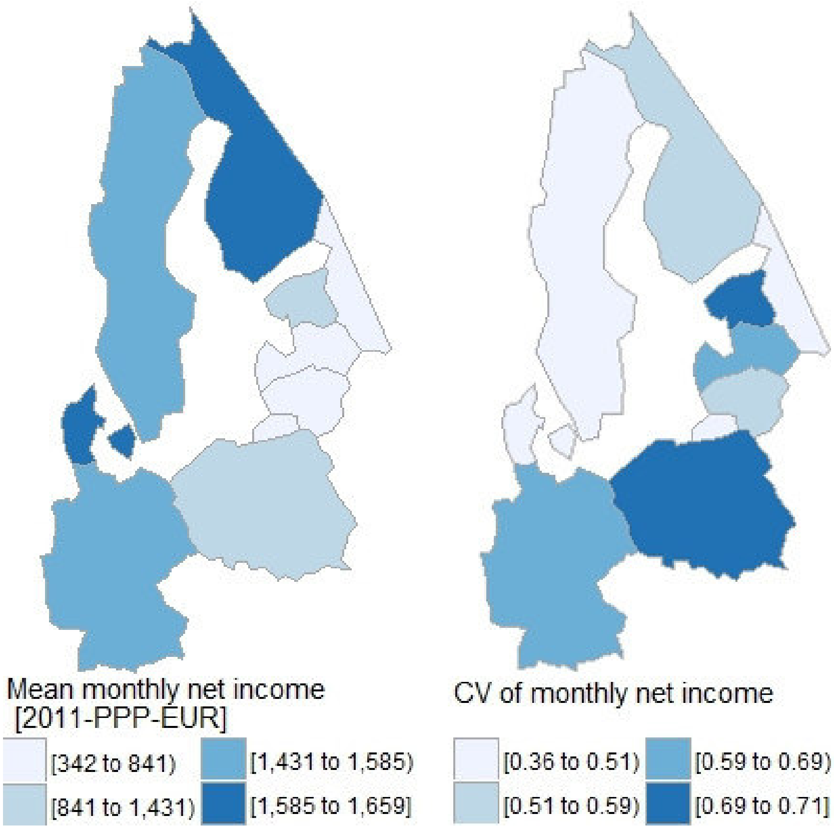


Figure 2: Countries neighboring the Baltic Sea with mean income, $\mu_Y$, and income inequality, $CV_Y$, of surveyed population.

the whole Baltic Sea and they predominantly state that they considered the whole Baltic Sea opposed to the shore line when stating their WTP values (Czajkowski et al. 2017).[12] The environmental good thus exhibits public good characteristics.

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 points 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

[12]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?"

Table 1: Sample statistics by country

| **Country** | N | $\tilde{\mu}^{\mathrm{i}}_{Y}$ | $\tilde{CV}^{\mathrm{i}}_{Y}$ | $\mathrm{Gini}^{\mathrm{i}}_{Y}$ | $\tilde{\mu}^{\mathrm{i}}_{\mathrm{WTP}}$ |
|---|---|---|---|---|---|
| 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.

bordering the Baltic Sea: Denmark (DEN), Estonia (EST), Finland (FIN), Germany (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, $\tilde{\mu}^{\mathrm{i}}_{\mathrm{WTP}}$, (Table 1).[13] 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. Histograms for all country specific income distributions can be found in the Appendix, Figure 5.

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, $\tilde{\mu}^{\mathrm{i}}_{Y}$, ranges from 343 [2011-PPP-EUR] in Lithuania up to 1,659 [2011-PPP-EUR] in Denmark. The surveyed income inequality is lowest in Sweden with

[13]We qualify estimates with a tilde to distinguish them from the true values in the population.

a coefficient of variation, $\tilde{CV}^{\mathrm{i}}_{Y}$, of 0.36 and highest in Estonia with a $\tilde{CV}^{\mathrm{i}}_{Y}$ of 0.71, corresponding to Gini-coefficients, $Gini^{\mathrm{i}}_{Y}$, of 0.20 and 0.37, respectively.

Compared to national statistics, respondents mean income is below the national averages for most countries (exceptions are Poland and Estonia were respondents mean income is slightly higher). The mean absolute deviation (± standard deviation) from the national income level is 14.48(±15.09)%. Concerning income inequality the picture is more mixed: The respondents income inequality as measured with the $Gini_Y$ is below national levels 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 Oblasthas shows a substantially lower $Gini_Y$ than for the whole country.[14]

# 4 Empirical strategy

For each pair of countries in our data set 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.[15]

The accuracy of benefit transfer is assessed by calculating transfer errors, which are a common measurement to study the 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

[14] National mean monthly net income [2011-PPP-EUR]: DEN $2,385$; EST 542; FIN $2,031$; GER $1,827$; LAT 428; LIT 387; POL 492; RUS 462; and SWE 2024 (Barbier et al. 2016). Corresponding $Gini_Y$-coefficients (2011): DEN 0.27; EST 0.32; FIN 0.26; GER 0.29; LAT 0.35; LIT 0.33; POL 0.31; RUS 0.41; and SWE 0.24 (source: eurostat, except RUS taken from world bank)

[15] Note that the estimate from the primary valuation at the policy site, $\tilde{\mu}^{\mathrm{s}}_{WTP}$, might itself be a biased estimate of the 'true' WTP, $\mu^{\mathrm{s}}_{WTP}$.

site $f(\tilde{\mu}^{\mathrm{s}}_{WTP})$, and the actually observed mean WTP-estimate at the policy site, $\tilde{\mu}^{\mathrm{p}}_{WTP}$, as a percentage (Kirchhoff et al. 1997):

$$|TE| = \frac{|WTP_{trans} - WTP_{obs}|}{WTP_{obs}} \cdot 100 = \frac{|f(\tilde{\mu}^{\mathrm{s}}_{WTP}) - \tilde{\mu}^{\mathrm{p}}_{WTP}|}{\tilde{\mu}^{\mathrm{p}}_{WTP}} \cdot 100 \tag{7}$$

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

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

$$|TE|_{unit} = \frac{|\tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}|}{\tilde{\mu}^{\mathrm{p}}_{WTP}} \cdot 100. \tag{8}$$

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 $\mathcal{T}_{\tilde{CV}}(\tilde{CV}^{\mathrm{p}}_{Y}, \tilde{CV}^{\mathrm{s}}_{Y}) = \left(\frac{1+\tilde{CV}^{\mathrm{p}\,2}_{Y}}{1+\tilde{CV}^{\mathrm{s}\,2}_{Y}}\right)^{\frac{\tilde{\eta}(\tilde{\eta}-1)}{2}}$ (Equation 6), and for mean income $\mathcal{T}_{\mu}(\tilde{\mu_Y}^{\mathrm{p}}, \tilde{\mu_Y}^{\mathrm{s}}) = \left(\frac{\tilde{\mu_Y}^{\mathrm{p}}}{\tilde{\mu_Y}^{\mathrm{s}}}\right)^{\tilde{\eta}}$ (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:

$$|TE|_{\mathcal{T}_{CV}} = \frac{\left|\mathcal{T}_{CV}(\tilde{CV}^{\mathrm{p}}_{Y}, \tilde{CV}^{\mathrm{s}}_{Y}, \tilde{\eta}) \cdot \tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}\right|}{\tilde{\mu}^{\mathrm{p}}_{WTP}} \cdot 100, \tag{9}$$

$$|TE|_{\mathcal{T}_{\mu}} = \frac{|\mathcal{T}_{\mu}(\tilde{\mu}^{\mathrm{p}}_{Y}, \tilde{\mu}^{\mathrm{s}}_{Y}, \tilde{\eta}) \cdot \tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}|}{\tilde{\mu}^{\mathrm{p}}_{WTP}} \cdot 100 \tag{10}$$

and

$$|TE|_{\mathcal{T}_{CV,\mu}} = \frac{\left|\mathcal{T}_{CV}(\tilde{CV}^{\mathrm{p}}_{Y}, \tilde{CV}^{\mathrm{s}}_{Y}, \tilde{\eta}) \cdot \mathcal{T}_{\mu}(\tilde{\mu}^{\mathrm{p}}_{Y}, \tilde{\mu}^{\mathrm{s}}_{Y}, \tilde{\eta}) \cdot \tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}\right|}{\tilde{\mu}^{\mathrm{p}}_{WTP}} \cdot 100. \tag{11}$$

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

$$\begin{aligned} \Delta\,|TE|_{\mathcal{T}_{CV}} &:= |TE|_{\mathcal{T}_{CV}} - |TE|_{unit} \\ &= \frac{|\mathcal{T}_{CV}(\cdot) \cdot \tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}| - |\tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}|}{\tilde{\mu}^{\mathrm{p}}_{WTP}} \cdot 100 \end{aligned} \tag{12}$$

and

$$\begin{aligned}\Delta\,|TE|_{\mathcal{T}_{CV,\mu}} &:= |TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{\mathcal{T}_{\mu}} \\ &= \frac{|\mathcal{T}_{CV}(\cdot)\cdot\mathcal{T}_{\mu}(\cdot)\cdot\tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}| - |\mathcal{T}_{\mu}(\cdot)\cdot\tilde{\mu}^{\mathrm{s}}_{WTP} - \tilde{\mu}^{\mathrm{p}}_{WTP}|}{\tilde{\mu}^{\mathrm{p}}_{WTP}}\cdot 100. \quad (13)\end{aligned}$$

Our model assumed 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 empirical estimate for the income elasticity, $\tilde{\eta}$, from a meta-study such as Jacobsen and Hanley (2009).[16] In the context of this case 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 therefor rely on the estimate for pooling income and WTP data across all countries by 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).[17]

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) on transfer errors $|TE|_{\cdot}$. 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.

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[16]We also explore the option of country-specific income elasticies and report the corresponding results in the discussion (Section 6).

[17]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.

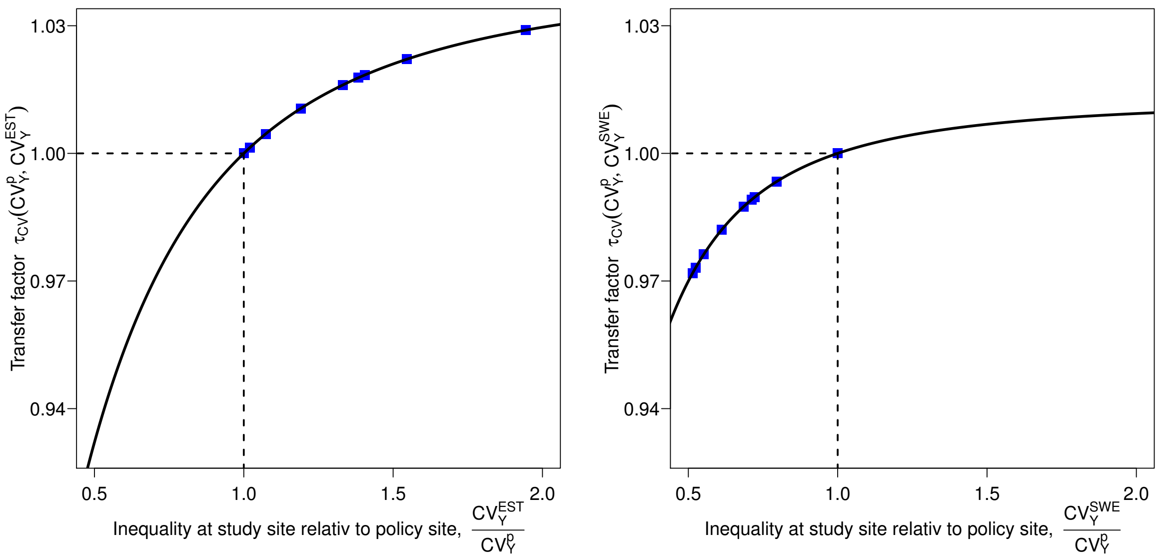


Figure 3: Relationship between the transfer factor for income inequality $\mathcal{T}_{CV}(\cdot)$ and the ratio of income inequality in the study and policy sites, for Estonia (Sweden) as the study site in the left (right) panel. Each blue dot represents a possible benefit transfer.

# 5 Results

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 in our sample. 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.

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.

Table 2: Transfer errors $|TE|$ summary statistics

| | $|TE|_{unit}$ | $|TE|_{\mathcal{T}_{CV}}$ | $|TE|_{\mathcal{T}_{\mu}}$ | $|TE|_{\mathcal{T}_{CV,\mu}}$ |
|---|---|---|---|---|
| mean | 152.4 | 150.6 | 115.5 | 114.0 |
| median | 72.9 | 72.8 | 67.4 | 66.1 |
| sd | 215.6 | 211.3 | 152.7 | 149.4 |

Simple unit transfers that are only adjusted for PPP-differences result in substantial transfer errors, with a mean absolute transfer error of 152.4%. This mean transfer error is reduced to $|TE|_{\mathcal{T}_{CV}} = 150.6\%$ when WTP-estimates are adjusted for income inequality and substantially reduced to $|TE|_{\mathcal{T}_{\mu}} = 115.5\%$ when adjusting for mean income.[18] Combining income inequality with mean income adjustment produces the best result ($|TE|_{\mathcal{T}_{CV,\mu}} = 114.0\%$). The same pattern holds for successively reduced median transfer errors and standard deviations (see Table 2).[19]

As Figure 4 also shows that there are cases in which income inequality adjustment does not improve benefit transfer errors, we further investigate under which conditions income inequality adjustment improves transfer errors.[20] For this, we relate transfer errors to income inequality at both the study and policy site. 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, $\frac{\tilde{CV}^s}{\tilde{CV}^p}$. It shows that income inequality adjustment substantially reduces

[18]The transfer errors associated with each individual benefit transfer are reported on a country-by-country basis in Tables 4 to 7 in the Appendix.

[19]A recent analysis using the same case study (Czajkowski et al. 2017) reports a similar estimate for the transfer error for simple unit transfer. However, they find that using an income elasticity of unity performs better vis-à-vis the estimated pooled income elasticity of $\tilde{\eta} = 0.28$ (cf. Barbier et al. 2016).

[20]Note that this is not only the case for income inequality adjustment but that there are also cases for which mean income adjustment does not reduce but increase transfer errors.

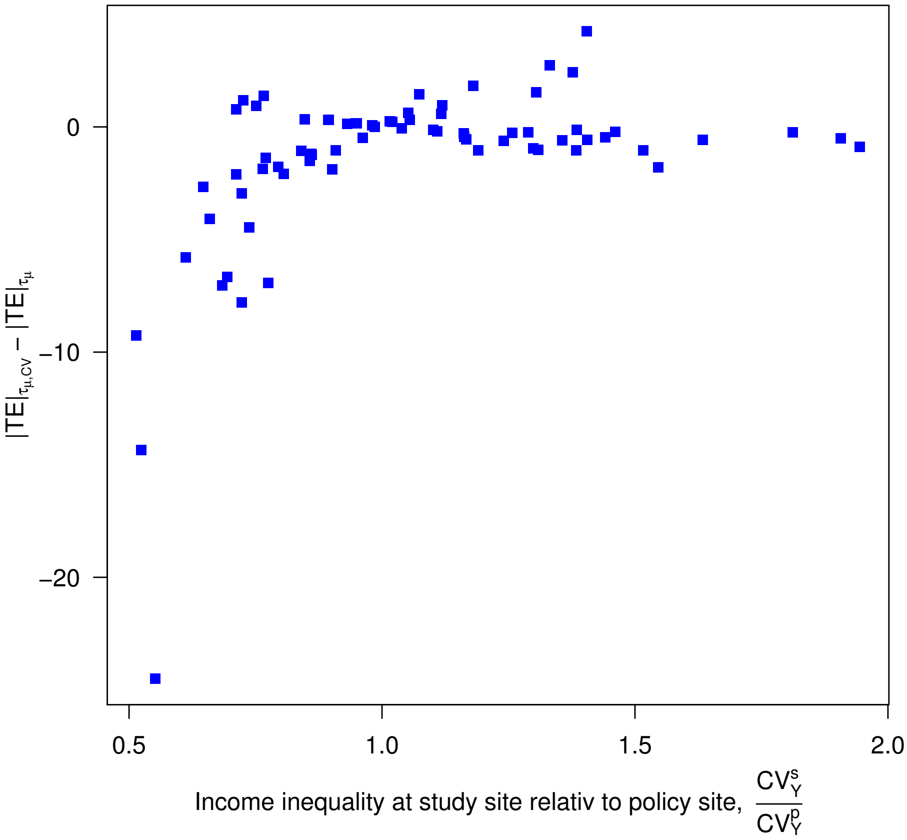


Figure 4: Relationship between reductions in transfer errors after additional income inequality adjustment, $|TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{\mathcal{T}_\mu}$, and the ratio of income inequality in the study and policy country for $\tilde{\eta} = 0.28$.

transfer errors in cases where income inequality is higher at the policy site than at the study site. The most substantial reduction of transfer errors in our dataset 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%. This is driven by both the large differences in mean WTP and income inequality between Sweden and Latvia.

Table 3 presents this observation based on aggregated data. For all 72 country-to-country transfers, we find a mean reduction in transfer errors of $-1.8$ percentage points for pure income inequality adjustment, $\Delta\,|TE|_{\mathcal{T}_{CV}}$, and of $-1.5$ percentage points for additional income inequality adjustment, $\Delta\,|TE|_{\mathcal{T}_{CV,\mu}}$ For the 36 transfers where in-

Table 3: Reductions in mean transfer errors (in percentage points) for income inequality adjustment compared to unit transfer and mean income adjusted transfer for different ratios in income inequality

| | all | $\frac{CV^s}{CV^p} < 1$ | $\frac{CV^s}{CV^p} < 0.8$ |
|---|---|---|---|
| N | 72 | 36 | 20 |
| $\Delta \lvert TE \rvert_{\mathcal{T}_{CV}}$ | -1.8 | -3.8 | -6.3 |
| $\Delta \lvert TE \rvert_{\mathcal{T}_{CV,\mu}}$ | -1.5 | -3.0 | -5.0 |

come inequality is higher at the policy site than at the study site, mean reduction in transfer errors roughly doubles compared to the whole set of transfers to $-3.8$ percentage points for pure income inequality adjustment, $\Delta \lvert TE \rvert_{\mathcal{T}_{CV}}$, and to $-3.0$ percentage points for additional income inequality adjustment, $\Delta \lvert TE \rvert_{\mathcal{T}_{CV,\mu}}$. The improvements in transfer quality due to income inequality adjustment are even more pronounced for the 20 transfers where income inequality in the study sites is less than 80% of the policy site's estimate. Here, average reductions in transfer errors are $-5.0$ and $-6.3$ percentage points for pure and additional income inequality adjustment, respectively. Furthermore, two-sided t-tests reveal that mean changes in transfer errors from both income inequality adjustment, $\Delta \lvert TE \rvert_{\mathcal{T}_{CV}}$, and additional income inequality, $\Delta \lvert TE \rvert_{\mathcal{T}_{CV,\mu}}$, are significantly different from a zero transfer error reduction at $p < 0.01$ already for the whole sample of 72 transfers.[21]

[21] This finding holds also when using non-parametric tests such as the Wilcoxon signed-rank test, or when considering the subset of only 36 or 20 cases where income inequality is is higher at the policy site than at the study site.

# 6 Discussion

This section provides a discussion of crucial assumptions and major limitations of our analysis. These include (i) the limited public good character of environmental quality improvement in the Baltic Sea, (ii) the quality of the income data, (iii) alternative measures of income income inequality, (iv) the assumption of identical preferences regarding $\eta$ and $\alpha$, as well as (v) the potential for non-constant income elasticities.

First, the employed theory-driven benefit transfer factors rely on the assumption of a pure public good character of the environmental good in question. However, water quality improvement is not always a pure public good, but entails a number of benefits that have a mixed-use or private good character. However, in this specific case study, respondents were informed that the benefits of nutrient reductions would occur in open-sea areas (beyond national territorial limit) across the whole Baltic Sea. Indeed, respondents predominantly stated that they considered the whole Baltic Sea, as opposed to only the shore line of their country when stating their WTP values (Czajkowski et al. 2017). These responses indicate that the environmental good in question exhibits mainly public good characteristics and hence makes us confident that for this case study assuming public good character is a valid approximation.

Second, the quality of the income data is not ideal, as income was only elicited on a limited interval scale.[22] 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 probably a conservative estimate of the actual effect. This limited information on income data also does not allow for a proper test of the assumption of log-normally.

Third, there are a number of different measures for income inequality (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, $\sigma_Y^{\mathrm{i}}$, as well as the prominent $Gini_Y$-coefficient. It is possible to derive transfer

[22] With few exceptions (see histograms in Appendix, Figure 5), the data is based on quintiles only.

factors for benefit transfer for differences in these measures of absolute income inequality (Baumgärtner et al. 2016). 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, $CV_Y^{\mathrm{i}}$, 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 our case 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 7.7 percentage points for $\Delta\left|TE\right|_{\mathcal{T}_{CV}}$ and by 6.1 percentage points for $\Delta\left|TE\right|_{\mathcal{T}_{CV,\mu}}$. This suggests that the 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 rely on the assumption of equal preferences within and across countries. Specifically, we assumed (a) that the weight individuals put on the consumption of environmental goods relative to consumption goods, $\alpha$, 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 leading to a higher or lower weight put on environmental goods consumption (think, for example, of Sweden versus Latvia).[23] The transfer function would then need to be extended by a factor for the weight parameter: $\mathcal{T}_\alpha(\alpha^{\mathrm{p}}, \alpha^{\mathrm{s}}) = \dfrac{\alpha^{\mathrm{s}}}{\alpha^{\mathrm{p}}}\left(\dfrac{1-\alpha^{\mathrm{p}}}{1-\alpha^{\mathrm{s}}}\right)$.

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

[23]Hynes et al. (2013) discuss and study how international benefit transfer may be adjusting for cultural differences.

assumption. For example, Baumgärtner et al. (2016) 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 $\eta$-estimates in both countries is usually not available in the context of benefit transfer, otherwise it might not be necessary to transfer value internationally in the first place, and often times no pertinent meta-study is available. The more relevant case of the practice of environmental valuation and management is thus 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).[24] We find that income elasticities of WTP of seven out of nine countries fall within the usual range from 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 $\Delta\,|TE|_{\mathcal{T}_{CV}} = 2.3$ and $\Delta\,|TE|_{\mathcal{T}_{CV,\mu}} = 1.7$ percentages points for pure and additional income inequality adjustment down to a total average transfer errors of $|TE|_{\mathcal{T}_{CV,\mu}} = 108.3$ percentages when controlled 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.[25]

Finally, and relatedly, 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

[24]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).

[25]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.

produce the best fit in terms of reducing transfer errors in the benefit transfer analysis of the Baltic Sea case study by Czajkowski et al. (2017). Despite these encouraging results and the attractiveness of a constant income elasticity approach for tractability reasons, it is unlikely that the income 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 case 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. 2015, Drupp 2016), or environmental risk and individual risk-aversion (Baumgärtner et al. 2017). While further research on benefit transfer functions that build on conditions which do not presume a constant income elasticity of WTP is certainly necessary, this paper provides a theory-driven analysis of income inequality adjustment in benefit transfer that rests on the up-to-date most widely used and accepted framework.

# 7 Conclusion

This paper has studied 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—also called value transfer—is of tremendous importance for environmental policy appraisal, as benefit transfer has perhaps become the most important source of environmental 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 Seas case study 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. (2016) to scrutinize whether and to what degree inequality adjustments can improve benefit transfer.

We find that income inequality adjustment significantly reduces benefit transfer errors, by 1.5 percentage points on average for our Baltic sea case study. While this 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. In our case study, additional income inequality adjustment reduces transfer errors by up to 25 percentage points, and by 5 percentage points on average, when income inequality at the study site is more than 20 percent lower than the level of inequality at the policy site. However, relative to benefit transfer adjustments for mean income, these reductions in transfer errors are comparatively small: correcting for mean income appears to be considerably more important than adjustment for income inequality.

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 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.[26] This simple application highlights 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 have been 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 administration sees a further increasing scope of benefit transfer as value databases expand (HM Treasury 2011: 21) and actively supports their development (Defra 2007).

[26] 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 upperlimits of percentiles for disposable household income in 2011 per capita (equivalised). Dencentiles 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.

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, a report by the UN, EU, OECD, FAO and World 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 an academic debate on 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. United Nations et al. (2014: 127) therefore 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-marketed environmental goods. They suggest that while accounting for differences in mean income is relatively more important, taking into account income inequality results in substantial improvements in the performance of benefits transfers.

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# Appendix

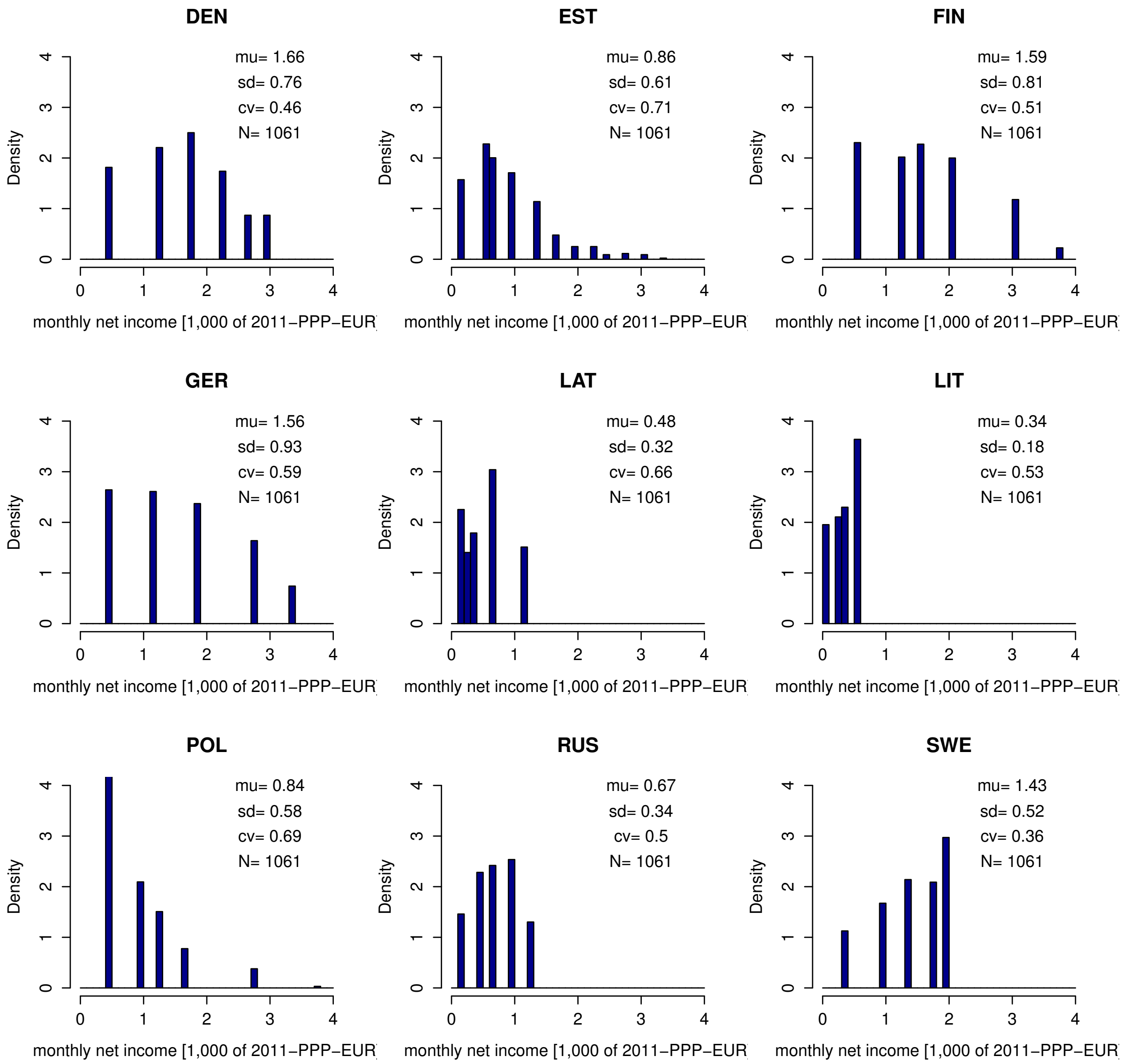


Figure 5: Histogram of the distribution of monthly income [in 2011-PPP-EUR] as surveyed in the nine-country Baltic Sea contingent valuation study on water quality improvement.

Table 4: Transfer errors $|TE|$ (in %) for unit transfer

| from: \ to: | DEN | EST | FIN | GER | LAT | LIT | POL | RUS | SWE |
|---|---|---|---|---|---|---|---|---|---|
| DEN | 0 | 48.4 | 26.5 | 23.1 | 448.7 | 227.8 | 142.5 | 267.6 | 60.9 |
| EST | 32.6 | 0 | 50.4 | 17 | 269.8 | 121 | 63.5 | 147.8 | 73.7 |
| FIN | 36 | 101.8 | 0 | 67.4 | 646.2 | 345.8 | 229.8 | 399.9 | 46.9 |
| GER | 18.8 | 20.5 | 40.3 | 0 | 345.6 | 166.3 | 97 | 198.6 | 68.3 |
| LAT | 81.8 | 73 | 86.6 | 77.6 | 0 | 40.3 | 55.8 | 33 | 92.9 |
| LIT | 69.5 | 54.7 | 77.6 | 62.4 | 67.4 | 0 | 26 | 12.1 | 88.1 |
| POL | 58.8 | 38.8 | 69.7 | 49.2 | 126.2 | 35.2 | 0 | 51.6 | 83.9 |
| RUS | 72.8 | 59.6 | 80 | 66.5 | 49.3 | 10.8 | 34 | 0 | 89.4 |
| SWE | 156 | 279.8 | 88.2 | 215.2 | $1,304.4$ | 739.1 | 520.8 | 841 | 0 |

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

| from: \ to: | DEN | EST | FIN | GER | LAT | LIT | POL | RUS | SWE |
|---|---|---|---|---|---|---|---|---|---|
| DEN | 0 | -3.2 | 0.3 | -1.4 | -9.4 | -1.9 | -4.9 | -1.3 | -0.3 |
| EST | -1.5 | 0 | -0.9 | -0.9 | 1.7 | 3.6 | 0.2 | 4.6 | -0.8 |
| FIN | 0.6 | -3.5 | 0 | -1.2 | -9.7 | -0.7 | -5.3 | 0.3 | -0.6 |
| GER | -0.9 | -1.3 | -0.4 | 0 | -2.6 | 1.5 | -1.8 | 2.3 | -0.6 |
| LAT | -0.3 | 0.1 | -0.2 | -0.1 | 0 | -0.7 | 0.1 | -0.9 | -0.2 |
| LIT | -0.2 | 0.7 | 0 | 0.2 | -1.9 | 0 | 1.1 | 0.3 | -0.2 |
| POL | -0.9 | 0.1 | -0.5 | -0.5 | 0.7 | 2 | 0 | 2.6 | -0.4 |
| RUS | -0.1 | 0.7 | 0 | 0.3 | -2 | 0.2 | 1.1 | 0 | -0.1 |
| SWE | -1.7 | -10.7 | -2 | -5.6 | -33.3 | -10.5 | -16.7 | -9.7 | 0 |

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

| from: \ to: | DEN | EST | FIN | GER | LAT | LIT | POL | RUS | SWE |
|---|---|---|---|---|---|---|---|---|---|
| DEN | 0 | -25.2 | 0.9 | -2.1 | -161.4 | -117.8 | -42.3 | -83.5 | 1.6 |
| EST | -13.8 | 0 | -9.4 | -15.3 | -55.3 | -50.4 | -0.9 | -17 | -4.1 |
| FIN | 1.8 | -32.2 | 0 | -0.8 | -212.8 | -156.6 | -54.1 | -108.5 | 1.5 |
| GER | -1.4 | -18.7 | -0.3 | 0 | -125.6 | -92.7 | -31.5 | -63.7 | 0.8 |
| LAT | -7.6 | -4.8 | -5.3 | -8.8 | 0 | 5.5 | -7.5 | -6.4 | -2.6 |
| LIT | -17.1 | -13.4 | -12.1 | -20.1 | 17 | 0 | -21.4 | 23.2 | -5.9 |
| POL | -8.7 | -0.3 | -5.9 | -9.7 | -32.8 | -30.3 | 0 | -9.7 | -2.6 |
| RUS | -8 | -3 | -5.5 | -9.1 | -13 | 15.3 | -4.5 | 0 | -2.6 |
| SWE | 10.9 | -51.2 | 5.5 | 7.7 | -371.1 | -278.8 | -86.6 | -182.8 | 0 |

Table 7: $|TE|_{\mathcal{T}_{CV,\mu}} - |TE|_{unit}$ (in percentage points)

| from: \ to: | DEN | EST | FIN | GER | LAT | LIT | POL | RUS | SWE |
|---|---|---|---|---|---|---|---|---|---|
| DEN | 0 | -27.9 | 1.2 | -3.5 | -168.1 | -119.1 | -46.4 | -84.5 | 1.3 |
| EST | -15.6 | 0 | -10.4 | -16.3 | -53.9 | -47.7 | -0.7 | -12.8 | -5 |
| FIN | 2.3 | -35.1 | 0 | -2 | -219.7 | -157.1 | -58.5 | -108.3 | 0.9 |
| GER | -2.4 | -19.8 | -0.7 | 0 | -127.5 | -91.8 | -33 | -61.9 | 0.2 |
| LAT | -8.1 | -4.6 | -5.6 | -9 | 0 | 4.9 | -7.3 | -7.4 | -2.8 |
| LIT | -17.4 | -12.5 | -12.2 | -19.8 | 15 | 0 | -20 | 23.5 | -6.2 |
| POL | -9.8 | -0.2 | -6.5 | -10.2 | -32.2 | -28.7 | 0 | -7.2 | -3.1 |
| RUS | -8.1 | -2.2 | -5.5 | -8.8 | -14.8 | 15.4 | -3.3 | 0 | -2.7 |
| SWE | 9.1 | -60.5 | 3.4 | 1.9 | -395.6 | -285.8 | -100.9 | -190.6 | 0 |