Income Distribution and Willingness to Pay for Ecosystem Services

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Abstract: We study how global income distribution, and income inequality in particular, affects the average willingness to pay (WTP) for ecosystem services. We use a model (extending Ebert 2003) where individual households have identical preferences over consumption goods and ecosystem services, which are represented by a constant-elasticity-of-substitution utility function, and income is log-normally distributed over individuals with given mean and standard deviation. We show that (i) average WTP for ecosystem services increases with mean income if ecosystem services and consumption goods are substitutes or weak complements, and (ii) average WTP for ecosystem services decreases (increases) with income inequality if ecosystem services and consumption goods are substitutes (complements). We illustrate our results with empirical data on the global income distribution (from World Bank 2011) and on the income elasticity of WTP for ecosystem services (from the meta-study of Jacobsen and Hanley 2009).

JEL-Classification: Q51, D63, H23, H43

Keywords: ecosystem services, income distribution, inequality, willingness to pay, contingent valuation

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1 Introduction

An important question for environmental economic research is how people value ecosystem services and how their willingness to pay (WTP) e.g. for policies that preserve the environment relates to their income. Over past decades, various methods have been developed to account for ecosystem services in economic analysis (see, e.g., Bateman et al. (2011) for a recent overview, or Freeman (2003)). A prominent example of these valuation methods is the survey-based Contingent Valuation (CV) method, which is commonly used to elicit preferences for non-marketed goods such as ecosystem services and, in particular, to account for non-use values (see, e.g., Carson (2011) for a survey of over 7,500 CV studies). There has been and still is a heated debate on the validity of CV studies and its applicability (see Diamond and Hausmann (1994), Hanemann (1994), Carson (2000), Carson et al. (2001) and Schläpfer (2008), to cite just a few). The purpose of this paper, however, is not to further discuss the relevant general points raised in this debate but rather to focus on the novel question of how the distribution of income affects the WTP for ecosystem services.

As some of these valuations of environmental goods are used in benefit-cost studies or for the purpose of damage assessments in judicial processes, it is an important question whether the distributional implications of these studies accord with the conceptions of justice as held by the public. Furthermore, it is important to know how the distribution of income affects the measured WTP if one wants to compare valuations conducted in different populations.

In this study, we examine theoretically how the valuation of ecosystem services depends on the distribution of income. Using a simple model, we can show how the average WTP for ecosystem services depends on the level of income per capita and on income inequality. It follows from our model that for ecosystem services serving as substitutes to consumption goods – which seems to be the empirically relevant case as currently suggested by CV studies[1] – the average WTP increases with the level of income and decreases with an increase in income inequality. These theoretical results are further

[1]Compare the following review of the literature and the theoretical model for an explanation.

illustrated in a case study using world income data.

The remainder of this paper is organized as follows: First, we provide an overview of the previous literature in Section 2 and develop our theoretical model in Section 3. In Section 4 we present the illustrative case study, while Section 5 concludes with a discussion.

2 Literature on the income dependency of WTP

One facet of the general debate on the validity of CV studies has been how WTP depends on income and whether the assessed income dependency can be used to determine whether the ecosystem services in question are necessities or luxury goods. Early criticism of CV studies has claimed that the ‘unusually low income effects’ observed in CV studies (i.e. income elasticities smaller than unity) do not accord with economic intuition, as this would imply that environmental goods are necessities rather than luxury goods (see, e.g., McFadden and Leonard (1993)).

Flores and Carson (1997), and more recently Ebert (2003), however, have shown that – given the rationed public good nature of most ecosystem services – an income elasticity of WTP smaller than unity does not allow one to conclude that the income elasticity of demand is also smaller than unity – where the latter is necessary to decide on whether the ecosystem service in question is a necessity or a luxury good. Ebert (2003) has also shown that the income elasticity of WTP has an inverse relationship to the elasticity of substitution between normal consumption goods and the environmental good in question. It thus follows from his theoretical argument that the income elasticity of WTP is smaller (greater) than unity if the environmental good serves as a substitute (complement) to normal consumption goods.

Empirical evidence, as gathered in numerous CV studies, suggests that the income elasticity of WTP is generally below unity – usually between 0.1 and 0.6 – and, thus, that the environmental goods assessed in these studies have a substitutive relationship with consumption goods from the viewpoint of the average consumer (see, e.g., Kriström and Riera (1996); Horowitz and McConnell (2003); Hökby and Söderqvist (2003); Liu and Stern (2008); Jacobsen and Hanley (2009); Broberg (2010)).[2]

This clear result throughout the CV literature has been challenged, however, by recent work of Schläpfer and others (see, e.g., Schläpfer and Hanley (2006), Schläpfer (2006, 2008, 2009), and Schläpfer et al. (2008)). Schläpfer (2006) conducts a meta-analysis to analyse how the income effect is determined by the survey characteristics and concludes his argument by stating that the incidences of income elasticities of WTP smaller than unity may be an "artefact" of the current design of CV studies. Furthermore, Schläpfer provides recommendations as to how the current practice of CV studies could be improved (Schläpfer, 2008). However, as of today, there is no sizable empirical evidence that CV studies conducted using Schläpfer's recommendations would indeed produce income elasticities of WTP that are greater than unity.

3 Model analysis

We use a simple model of an economy with two goods, a composite consumption good X, and an ecosystem service G. Consumption of the ecosystem service is rationed. All agents are assumed to have the same preferences, which are given by a CES utilty function of the form

$$U = \left(\alpha X^{\frac{\theta-1}{\theta}} + (1-\alpha)\, G^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}}, \quad 0 < \theta < \infty. \tag{1}$$

where α is the weight for the consumption bundle in utility. The elasticity of substitution between the consumption good and the ecosystem service is given by θ.

We assume a continuum of agents with lognormally distributed income Y. For the world income distribution, this is a fairly valid assumption as has been shown by recent work of Pinkovskiy and Sala-i-Martin (2009). Average income is then given by μ_Y, with a standard deviation of σ_Y as a measure of the inequality of the income distribution.

We look at one period only, so all income has to be spent on the consumption good. The derivation of an agent's WTP has been discussed before in the literature (e.g. Ebert

[2]For a more detailed review of the previous literature on the empirical estimation of the income elasticity of WTP in CV studies, see Jacobsen and Hanley (2009) and Broberg (2010).

(2003)), hence we constrain our discussion to a minimum.

Following Ebert (2003), under the above stated assumptions, especially rationed consumption of the ecosystem service G, the marginal WTP ω can be derived from an agent's indirect utility function $V(Y,p,G)$ according to

$$\omega = \frac{\partial V/\partial G}{\partial V/\partial Y}. \tag{2}$$

With the CES-function specified in equation (1) the consumer's marginal WTP is given as

$$\omega = p\,\frac{1-\alpha}{\alpha}\left(\frac{Y/p}{G}\right)^{\frac{1}{\theta}} \tag{3}$$

while his total WTP is given by $\text{WTP} = \omega\, G$. Note that this measure of consumer benefit from ecosystem services does not account for inframarginal units or a consumer surplus (see, e.g., Ebert (2003) for a discussion of different approaches to measure WTP).

It is now straightforward to see that the income elasticity η of (marginal) WTP is simply the inverse of the elasticity of substitution θ between consumption of the composite private good and the ecosystem service:

$$\eta = \frac{1}{\theta}. \tag{4}$$

This result, which has been previously shown by Ebert (2003), merits some attention. The inverse relationship laid out in equation (4) could qualify the empirical finding of income elasticities of WTP $\eta < 1$. It reflects the fact that the subject of these studies are generally ecosystem services with locally restricted benefits. These are perceived to be substitutes for consumption goods rather than complements, as one would expect from indispensable global ecosystem services such as e.g. providing for oxygen, which have not yet been covered in CV studies.

Another useful implication of equation (4) is that it allows for an indirect estimation of θ from the various reported income elasticities of WTP in the numerous CV studies mentioned in Section 2. This might prove useful in the light of the difficulty of revealing consumer's preferences empirically and, in particular, their elasticity of substitution between different types of goods.

The next step is to derive the average WTP μ_{WTP} for the ecosystem service in our economy. We assumed a continuum of agents with identical preferences but different incomes. Hence, the average WTP is

$$\mu_{\text{WTP}} = \int_0^\infty f(Y; m, s)\, \text{WTP}(Y)\, dY \tag{5}$$

where $f(Y; m, s)$ is the lognormal distribution of income with parameters m and s. Rewrite WTP as WTP $= w\, Y^\eta$, where $w \equiv \dfrac{1-\alpha}{\alpha} p^{1-\eta} G^{-\eta}$. Then the average WTP is given as (cf. Appendix A.1)

$$\mu_{\text{WTP}} = w\, \mu_Y^\eta \left(1 + \frac{\sigma_Y^2}{\mu_Y^2}\right)^{\frac{\eta(\eta-1)}{2}} \tag{6}$$

Comparative statics of the average WTP with respect to mean incomce in the economy μ_Y implies that for most empirically revealed values of η an increase of the mean income leads to an increase in the average WTP. However, if the ecosystem service is a very strong complement to other consumption goods and if the initial income level is relatively low compared to income inequality, then it may even happen that a rise of income in the economy may lead to lower valuations of the ecosystem service. This is summarized in the following proposition:

Proposition 1

The average WTP for an ecosystem service

1. increases with mean income if the ecosystem service and consumption good are substitutes or weak complements:

$$\frac{d\,\mu_{\text{WTP}}}{d\,\mu_Y} > 0 \qquad \text{if } \theta > 1/2\ ; \tag{7}$$

2. has a U-shaped form in μ_Y-μ_{WTP}-space, with a unique minimum at $\mu_Y^{\min} = (\eta - 2)/\sigma_Y^2$, if the ecosystem service and consumption good are strong complements:

$$\frac{d\,\mu_{\text{WTP}}}{d\,\mu_Y} \begin{cases} < 0 & \text{for} \quad \mu_Y < \mu_Y^{\min} \\ > 0 & \text{for} \quad \mu_Y > \mu_Y^{\min} \end{cases} \qquad \text{if } \theta < 1/2\ . \tag{8}$$

Proof. See Appendix A.2. □

The analysis of changes in the inequality of the income distribution as measured by the standard deviation σ_Y shows that the influence of σ_Y crucially depends on whether the ecosystem service and the consumption good are substitutes or complements. In the latter case, the average WTP is increased by a more unequal distribution of income. In the former case, however, which is the empirically relevant one, the average WTP is increased by a more equal distribution of income. The rationale behind this result is as follows. Given an income elasticity of WTP below unity, individuals with lower incomes are willing to pay relatively more of their income for the ecosystem service than are individuals with higher income. This means that if an individual experiences an increase (decrease) in income, his WTP increases (decreases) only by less than his income. Additionally, a more equal income distribution shifts *probability* (??) mass from higher to lower income levels closer to the mean. Taking these two effects together explains the result, as shifting income from relatively high, but rare, income levels to lower levels reduces the WTP of the higher income levels, but it also increases the WTP of lower incomes, and the sum of increases is larger than the sum of reductions in the upper echelons of the distribution function. This line of thought is summarized in the following proposition:

Proposition 2

The average willingness to pay for an ecosystem service decreases (increases) with income inequality, if the ecosystem service and consumption good are substitutes (complements):

$$\frac{d\,\mu_{\mathrm{WTP}}}{d\,\sigma_Y} \begin{cases} < 0 & \text{if} \quad \theta > 1 \\ > 0 & \text{if} \quad \theta < 1 \end{cases} . \tag{9}$$

Proof. See Appendix A.3. □

Considering how changes in both standard deviation of income σ_Y and mean income μ_Y affect the average WTP, one has to constitute mixed results. Looking at substitutes (i.e. an η smaller than unity), the effects of income inequality on average WTP in the economy are aggravated at lower income levels, but become less apparent as income rises except for relatively high levels of η. For relatively weak complements, the effects of income inequality increase with the level of mean income, while for the case of strong complements, the opposite holds true.

This leads us to establish the following proposition:

Proposition 3

The effects of changes in income inequality, σ_Y, on average WTP for an ecosystem service, μ_{WTP}, are

1. higher or lower for lower levels of mean income, μ_Y, than for higher levels if the ecosystem service and consumption good are substitutes ($\theta > 1$). The effect is decreasing until a threshold level of η is reached – which is determined by the current level of μ_Y, the increase in mean income and σ_Y – and increases above that threshold level.

2. higher for lower levels of mean income, μ_Y than for higher levels if the ecosystem service and consumption good are relatively weak complements ($1/2 < \theta < 1$).

3. lower for lower levels of mean income, μ_Y than for higher levels if the ecosystem service and consumption good are relatively strong complements ($\theta < 1/2$).

Proof. See Appendix A.4. □

4 Empirical illustration

In the following, we provide a case study to illustrate the above-demonstrated theoretical results regarding the dependancy of average WTP for ecosystem services on the distribution of income in an economy. In particular, we want to show how the income dependancy of WTP manifests itself at levels of the income elasticity of WTP (η) that seem most empirically relevant – i.e. values of η between 0.1 and 0.6. Most recently, Jacobsen and Hanley (2009) have made an attempt to capture global WTP for biodiversity conservation in a meta-study covering 46 different CV studies from six continents and measured an η of 0.38. A further topical study by Broberg (2010) examined income effects in a policy to protect Swedish predators and found values of η ranging from 0.14

to 0.4. However, in order to also facilitate an illustration of other values of η, particularly the case of a complementary relationship between an ecosystem service and consumption goods with income elasticities greater than unity, we chose to freely adjust η, while normalising the parameter w to one.[3]

To specify the world distribution of income as a log-normal parametric distribution function, with the necessary parameters μ_Y and σ_Y, we employ data on per capita PPP-adjusted 2006 US $ Gross National Income (GNI) values, as provided for 176 countries in the World Development Indicator Database of the World Bank (2011).[4]

It follows from the data set (World Bank, 2011) that world average income (μ_Y) is 11690,51 US $ and that the standard deviation σ_Y – the measure of inequality in the world income distribution – has a value of 13156,69 US $. It should be noted that for this calculation, each country's GNI has been treated as one income estimate irrespective of its population share and the different intra-country income distributions. Using this data as an approximation of the world distribution of income, we can proceed to illustrate our theoretical results from proposition 1-3.

Illustration of Proposition 1

Figure 1 illustrates the relationship between average WTP μ_Y and mean income μ_Y for different income elasticites of WTP η for ecosystem services regarded as substitutes to consumption goods (i.e. $\eta < 1$). It can be clearly seen that average WTP is an increasing, concave function of mean income. Furthermore, this effect is becoming stronger as the income elasticity of WTP increases, that is the elasticity of substitution between the ecosystem service in question and consumption goods decreases.

For an η of 0.4, which is equal to the upper bound of Broberg's (2010) range and roughly equal to the value provided by Jacobsen and Hanley (2009) for the global income elasticity of WTP for biodiversity conservation, a hypothetical doubling of average world

[3]Setting $w \equiv 1$ implies that α equals 0.5 if p and G are normalised to one, since $w \equiv \dfrac{1-\alpha}{\alpha} p^{1-\eta} G^{-\eta}$.

[4]It has been shown by Pinkovskiy and Sala-i-Martin (2009) that the assumption of log-normally distributed world income can be defended empirically. A Kolmogorov-Smirnov test also revealed for this representation of the world income distribution that the null-hypothesis of log-normality cannot be rejected at common significance levels.

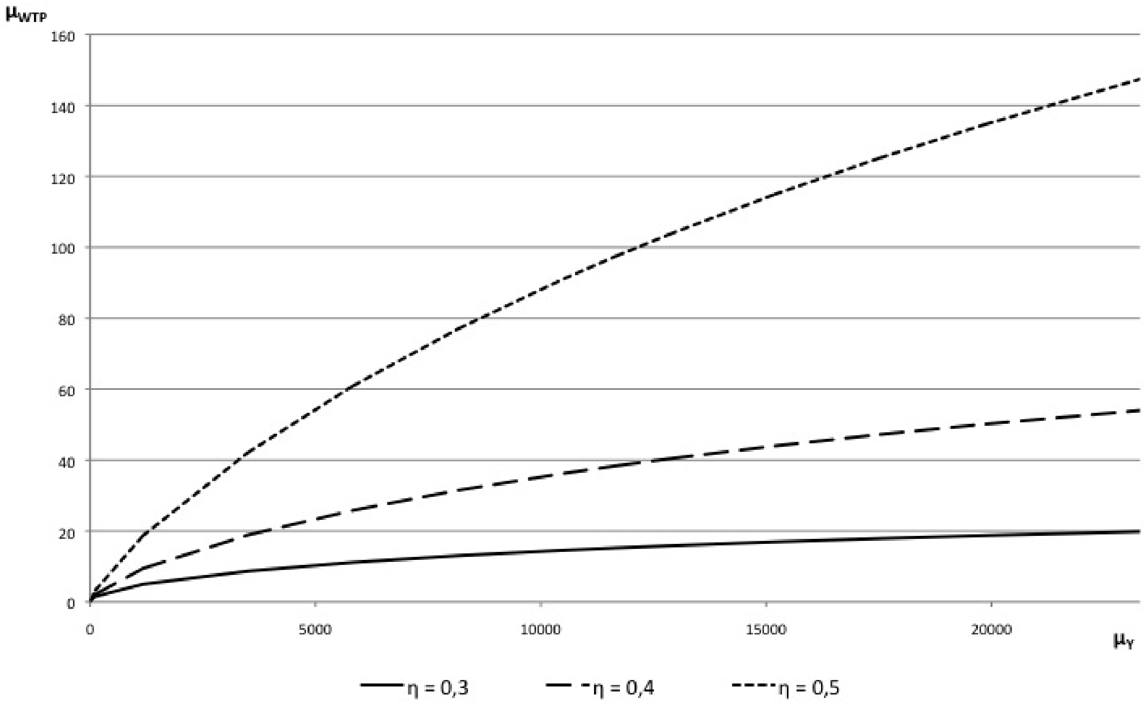

Figure 1: μ_{WTP} for different μ_Y and $\eta < 1$. The units on both axes are given in 2006 US \$, here and in the following Figures, if not explicitely stated otherwise.

income from the current state of 11690,51 US \$ would lead to an increase of average WTP of about 40%.

The same relationship is shown for relatively strong complements in Figure 2. For values of $\eta \leq 2$, μ_{WTP} is growing globally with an increasing degree, while for values of $\eta > 2$ the average WTP function has a U-shaped form. This latter case is here illustrated for $\eta = 2.1$ and highlights the threshold effect at $\mu_Y = (\eta - 2)/\sigma_Y^2$ (cf. Appendix A.2): Average WTP first declines with mean income until it reaches a global minimum – in this case at an average income of 4160,51US \$ – and from then on increases with mean income. Abstracting from the technical description, it must be noted that the scale of μ_{WTP} is given in million US \$. The interpretation for these two presented cases of η thus simply is that people would be willing to pay a substantially higher amount for ecosystem services that are strong complements than they actually have at

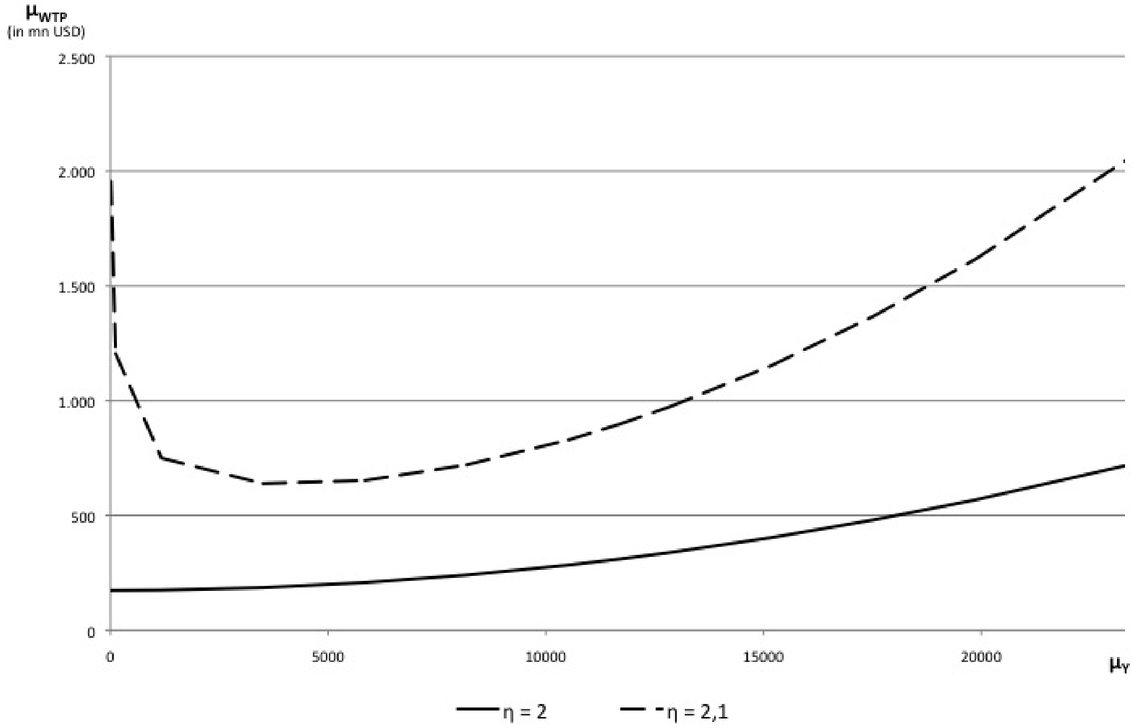

Figure 2: μ_{WTP} for different μ_Y and $\eta > 1$; μ_{WTP} is in million US \$.

their disposal.

Illustration of Proposition 2

Proposition 2 examines the effect of income inequality on average WTP for ecosystem services and states that μ_{WTP} decreases (increases) as income inequality rises if the ecosystem service is a substitute (complement) to consumption goods.

Figure 3 illustrates the effects of an increase in income inequality on μ_{WTP} for different substitutive relationships, i.e. potentially different ecosystem services ($\eta = 0.3$, 0.4 and 0.5). Examining the case of an income elasticity of WTP of 0.4 as it is close in magnitude to the figure provided by Jacobsen and Hanley (2009), we can state that global μ_{WTP} for biodiversity conservation would fall by 11% if world income inequality was hypothetically increased by factor two. For a growth in income inequality of factor 1.1 (1.5), μ_{WTP} would still fall by 1.4% (6.2%).

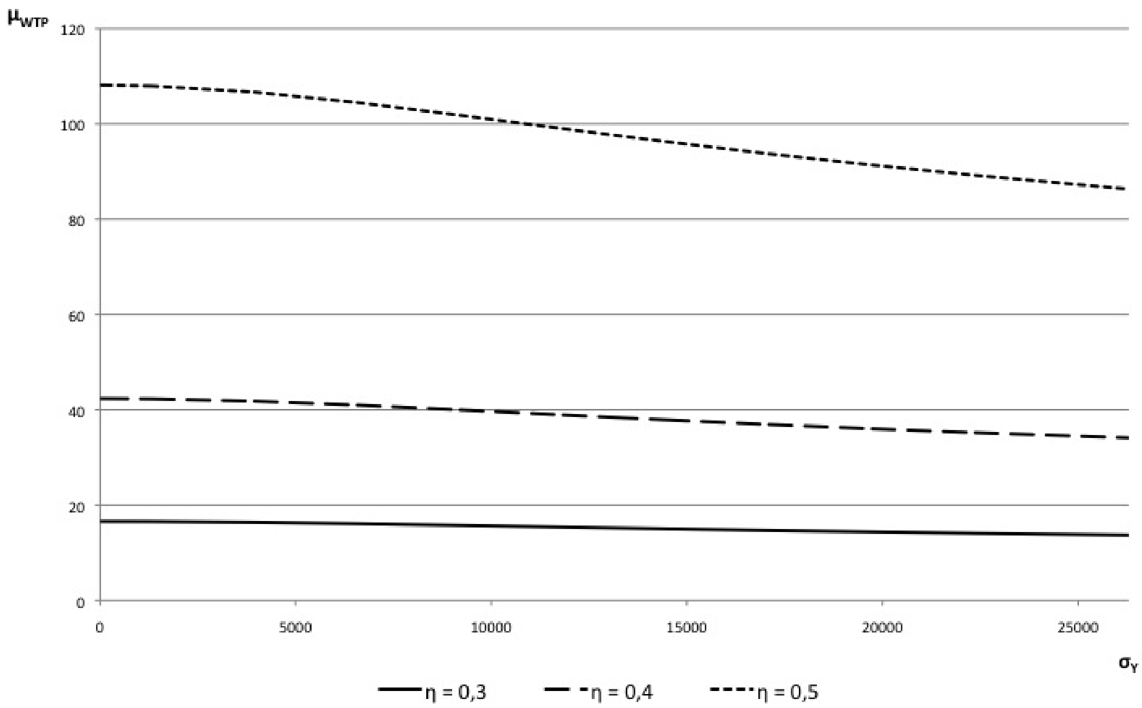

Figure 3: μ_{WTP} for different σ_Y and $\eta < 1$.

Figure 4 again illustrates the effect of a variation in income inequality on average WTP for ecosystem services, yet here, we show this effect for the case of a complementary relationship between ecosystem services and consumption goods by looking at $\eta = 1.1$. In contrast to the case of substitutes (here η=0.9), the average WTP function rises with an increase in income inequality. Whereas μ_{WTP} falls by 4.3% for η=0.9 as income inequality (σ_Y) is increased by factor 2, it rises by 5.6% for η=1.1.

Illustration of Proposition 3

Figure 5 illustrates the first part of Proposition 3, which concerns the case of a substitutive relationship between the ecosystem service and consumption goods. From the theoretical derivations in Appendix A.4, we know that the effect of a change in income

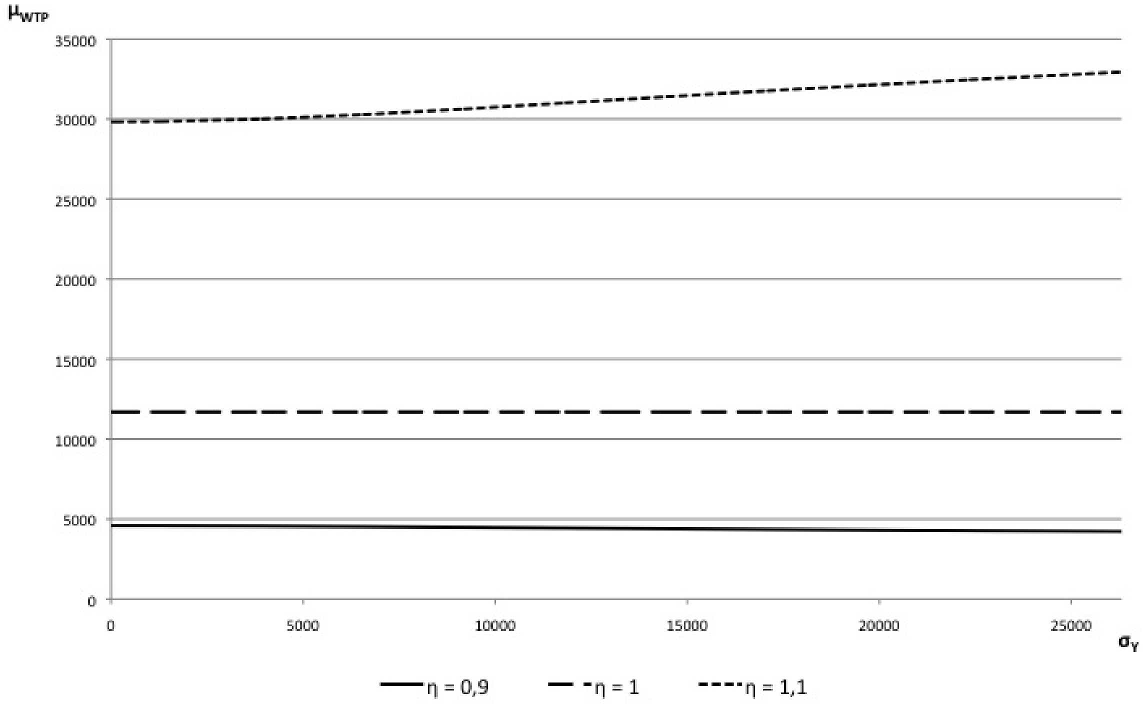

Figure 4: μ_{WTP} for different σ_Y and η.

inequality (cf. Illustration of Proposition 2) is stronger for values of η that lie below a certain threshold value η_1 as defined by equation (A.20). In the case depicted in Figure 5, this threshold value of η, with $\mu_Y + \Delta\mu_Y = 0.7 * \mu_Y$, is 0.56 and thus just above the illustrated level of η.

We can, thus, conclude that the adverse effect of a rise in income inequality on the average WTP is aggravated in a case where the average income is lower than at present: An increase in income inequality by factor 2 leads, for example, to a reduction in average WTP of 11.58% for the original μ_Y and of 13.41% if average income is hypothetically lowered by 30%.

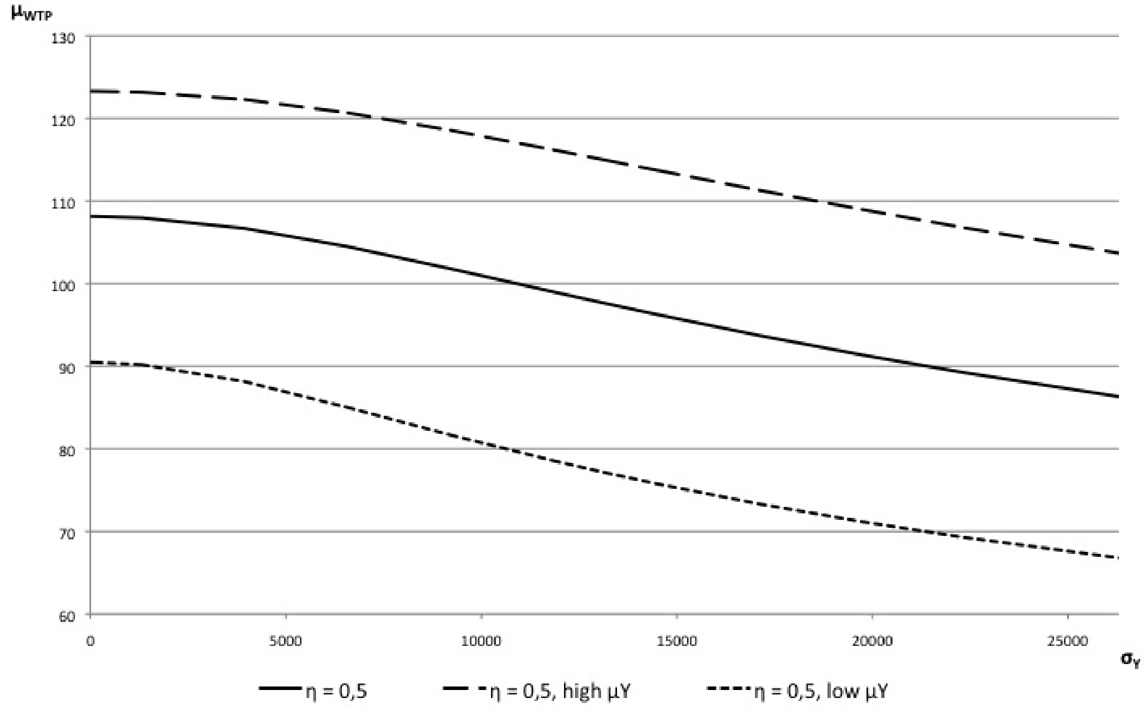

Figure 5: μ_{WTP} for $\eta = 0.5$, different σ_Y and μ_Y, 1.3*μ_Y and 0.7*μ_Y.

5 Discussion and conclusion

This paper has theoretically scrutinized the question of how the valuation of ecosystem services as elicited in CV studies depends on the distribution of income. Previous CV studies have generally found income elasticities of willingness to pay (WTP) for ecosystem services smaller than unity, which implies that these services have a substitutive relationship to normal consumption goods. With our theoretical model, we can show that – for income elasticities smaller than unity – average WTP for ecosystem services systematically increases with the level of average income in an economy and decreases with a rise in income inequality. We furthermore find that the adverse effect of an increase in income inequality is aggravated for relatively low levels of the income elasticity of WTP. Our model, however, also examines the case of income elasticities greater than unity, i.e. the income dependency of WTP for ecosystem services that are complements to consumption goods. In this case, the average WTP for ecosystem services rises with a growing income inequality, whereas the other effects depend on whether the ecosystem service serves as a relatively strong or weak complement to consumption goods. An empirical case study illustrating these systematic effects using world income data, moreover, allows the conclusion that these effects are non-negligible.

These results have important implications for further research on the valuation of ecosystem services:

First, if for the sustainable development of a population, an income distribution that differs from the currently prevailing one is deemed desirable, e.g. an income distribution that is more equitable, it should be pondered whether valuations of ecosystem services should be made on the basis of the desired income distribution. Our results clearly show that there will be a systematic difference between the two valuations. For the case of low income elasticities currently established in the CV literature, such a change would imply to value ecosystem services higher as compared to the current practice in CV studies that build on the actual income distribution, which is not grounded on a reasonable conception of justice.

Second, our results are relevant to the current practice on benefit transfer, as the effects of differing income distributions on the measured WTP in different countries may be, to some degree, explained by our findings. In any case, the effects of differences in the income distributions should be explicitly analysed when comparing valuations conducted in different populations.

Third, it also follows from our results that – for relatively small income elasticities – the adverse effect on the average WTP of a growing income inequality is higher in the case of lower average incomes. Consequently, the effect of the income distribution on the average WTP is distinctly larger in developing countries, as these countries typically exhibit a smaller mean income and a higher income inequality as compared to OECD countries. This leads to the recommendation that, in particular, studies conducted in countries with a relatively low mean income should pay special attention to the effects of income inequality on the inferred average WTP.

Furthermore, the assumptions of our presented theoretical model shall be discussed:

First, it might seem unreasonable to assume a constant income elasticity over all parts of the (world) population. This is, in fact, an assumption that is hardly defendable on empirical grounds. We chose this restrictive assumption for our theoretical model, as this is common practice throughout the CV literature, and our aim was to examine, in particular, the effect of the income distribution on average WTP in the most common setting for CV studies. Second, we are aware that it is clearly not possible to adjust sigma in the way we did here in the real world – these sometimes far-reaching adjustments have only been made to illustrate the systematic effects derived in our theoretical model. Third, we have used an explicit Cobb-Douglas utility function to derive closed-form solutions. However, our results should be easily generalized to other homothetic utility functions, yet with more algebra involved. It would be an interesting question for further research to see whether the effects would be even larger for non-homothetic preferences.

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Appendix

A.1 Derivation of the average willingness to pay

The lognormal distribution function is given by

$$f(Y; m, s) = \frac{1}{Y\sqrt{2\pi s^2}} \exp\left(-\frac{(\ln Y - m)^2}{2s^2}\right) \tag{A.10}$$

The moments of $f(Y;m,s)$ are given as

$$m = \ln \mu_y - \frac{1}{2}\ln\left(1+\sigma_Y^2/\mu_Y^2\right) \tag{A.11}$$

$$s^2 = \ln\left(1+\sigma_Y^2/\mu_Y^2\right) \tag{A.12}$$

with μ_Y and σ_Y being the moments of the underlying income data. Recall from above that WTP $= w\,Y^\eta$. Then

$$\begin{aligned}
\mu_{\text{WTP}} &= \int_0^\infty \text{WTP} f(Y;m,s)\,dY \\
&= \int_0^\infty \frac{w\,Y^{\eta-1}}{\sqrt{2\pi s^2}} \exp\left(-\frac{(\ln Y - m)^2}{2s^2}\right) dY \\
&\overset{\ln Y = Z}{=} \frac{w}{\sqrt{2\pi s^2}} \int_{-\infty}^\infty \exp(\eta Z) \exp\left(-\frac{(Z-m)^2}{2s^2}\right) dZ \\
&= w\,\exp\left[(\eta)\left(m+\frac{\eta}{2}s^2\right)\right] \\
&= w\,\mu_Y^\eta\left(1+\frac{\sigma_Y^2}{\mu_Y^2}\right)^{\frac{\eta(\eta-1)}{2}}
\end{aligned} \tag{A.13}$$

where the last step made use of equations (A.11) and (A.12).

A.2 Proof of Proposition 1

Taking the derivative of μ_{WTP} (Equation 6) with respect to μ_Y yields

$$\frac{d\,\mu_{\text{WTP}}}{d\,\mu_Y} = \eta\,w\,\mu_Y^{\eta-1}\left(1+\frac{\sigma_Y^2}{\mu_Y^2}\right)^{\frac{\eta(\eta-1)}{2}}\left[1-(\eta-1)\frac{\sigma_Y^2/\mu_Y^2}{1+\sigma_Y^2/\mu_Y^2}\right]. \tag{A.14}$$

Because $\eta, w, \mu_Y, \sigma_Y > 0$ this implies that

$$\frac{d\,\mu_{\text{WTP}}}{d\,\mu_Y}\begin{cases} >0 & \text{if} \quad \eta < 2+\mu_Y^2/\sigma_Y^2 \\ <0 & \text{if} \quad \eta > 2+\mu_Y^2/\sigma_Y^2 \end{cases}. \tag{A.15}$$

This means that for income elasticities $\eta < 2$, i.e. elasticities of substitution $\theta > 1/2$, $d\mu_{\text{WTP}}/d\mu_Y$ is always positive. In the case of strong substitutability ($\theta < 1/2$), $d\mu_{\text{WTP}}/d\mu_Y$ attains a unique minimum at the income level $\mu_Y^{\min} = (\eta-2)/\sigma_Y^2$. In this case, μ_{WTP} falls with mean income for income levels below $\mu_Y^{\min}$ and increases with mean income above $\mu_Y^{\min}$.

A.3 Proof of Proposition 2

Taking the derivative of μ_{WTP} (Equation 6) with respect to σ_Y yields

$$\frac{d\,\mu_{\text{WTP}}}{d\,\sigma_Y} = \eta\,(\eta-1)\,w\,\mu_Y^{\eta}\left(1+\frac{\sigma_Y^2}{\mu_Y^2}\right)^{\frac{\eta(\eta-1)}{2}-1}\frac{\sigma_Y}{\mu_Y^2}\,. \tag{A.16}$$

Because $\eta, w, \mu_Y, \sigma_Y > 0$ it follows directly that

$$\frac{d\,\mu_{\text{WTP}}}{d\,\sigma_Y}\begin{cases} <0 & \text{if} \quad \eta<1 \quad \Leftrightarrow \quad \theta>1 \\ >0 & \text{if} \quad \eta>1 \quad \Leftrightarrow \quad \theta<1 \end{cases}\,. \tag{A.17}$$

A.4 Proof of Proposition 3

Consider an arbitrary levels of mean income μ_Y and a marginally higher level of income $\mu_Y + \Delta\mu_Y$. Now compare the size of the effect of an infinitesimal change in income inequality σ_Y for both μ_Y and $\mu_Y + \Delta\mu_Y$ by looking at the difference between the two:

$$\begin{aligned}&\frac{\partial\,\mu_{\text{WTP}}(\mu_Y,\sigma_Y)}{\partial\,\sigma_Y}\,d\sigma_Y - \frac{\partial\,\mu_{\text{WTP}}(\mu_Y+\Delta\mu_Y,\sigma_Y)}{\partial\,\sigma_Y}\,d\sigma_Y \\ =\ &\left[\eta\,(\eta-1)\,w\,\sigma_Y\left(\mu_Y^{\eta-2}\left(1+\frac{\sigma_Y^2}{\mu_Y^2}\right)^{\frac{\eta(\eta-1)}{2}-1} - (\mu_Y+\Delta\mu_Y)^{\eta-2}\left(1+\frac{\sigma_Y^2}{(\mu_Y+\Delta\mu_Y)^2}\right)^{\frac{\eta(\eta-1)}{2}-1}\right)\right]d\sigma_Y\end{aligned} \tag{A.18}$$

We want to show under which conditions the effect described in Proposition 2 is of a larger scale for lower levels of income. Hence for the case of substitutes (complements), where the derivative (A.16) is negative (positive), the difference in eq. (A.18) should be negative (positive).

Cancelling terms, taking logs and rearranging gives

$$\left(2\eta-\eta^2\right)\left[\ln\mu_Y - \ln\left(\mu_Y+\Delta\mu_Y\right)\right] + \frac{\eta^2-\eta-2}{2}\left[\ln\left(\mu_Y^2+\sigma_Y^2\right) - \ln\left(\left(\mu_Y+\Delta\mu_Y\right)^2+\sigma_Y^2\right)\right] > 0 \tag{A.19}$$

In order to derive conditions under which the effect is as postulated in Proposition 3, the LHS of eq. (A.19) has to be positive regardless of the size of η. This stems from dividing by $\eta-1$ which entails a change in the sign of the inequality from (A.18) to (A.19) for $\eta<1$.

Equation (A.19) is a quadratic equation in η and hence has two solutions which are

$$\eta_1 = \frac{\ln\left(\mu_Y^2+\sigma_Y^2\right) - \ln\left(\left(\mu_Y+\Delta\mu_Y\right)^2+\sigma_Y^2\right)}{2\left[\ln\mu_Y - \ln\left(\mu_Y+\Delta\mu_Y\right)\right] - \left[\ln\left(\mu_Y^2+\sigma_Y^2\right) - \ln\left(\left(\mu_Y+\Delta\mu_Y\right)^2+\sigma_Y^2\right)\right]} \tag{A.20}$$

and

$$\eta_2 = 2 \tag{A.21}$$

Because of the strict concavity of the ln-function and Jensen's inequality we know that

$$\left[\ln\left(\mu_Y^2+\sigma_Y^2\right) - \ln\left(\left(\mu_Y+\Delta\mu_Y\right)^2+\sigma_Y^2\right)\right] > \left[\ln\mu_Y - \ln\left(\mu_Y+\Delta\mu_Y\right)\right] \tag{A.22}$$

Note that both these differences are negative, which implies that the term on the RHS is absolutely larger.

This inequality entails that $0 < \eta_1 < 1$ for all μ_Y and σ_Y. Additionally, we know that because of the typical U-shape of the quadratic form of eq. (A.19), that for $\eta < \eta_1$ the effect is larger with lower income, while it increases with income for $\eta_1 < \eta < 2$. This establishes the first and second part of Proposition 3.

Furthermore, we know that

$$2\eta - \eta^2 > \frac{\eta^2 - \eta - 2}{2} \qquad \forall \quad \eta > 2. \tag{A.23}$$

Inequalities (A.22) and (A.23) imply that for $\eta > \eta_2 = 2$ inequality (A.19) is always positive. This proves the third part of Proposition 3.

References

Bateman I.J., Mace G.M. Fezzi C. Atkinson G. and R.K. Turner (2011), Economic analysis for ecosystem service assessments, *Environmental and Resource Economics* **48**(2): 177–218.

Broberg, T. (2010), Income treatment effects in contingent valuation: the case of the Swedish predator policy, *Environmental and Resource Economics* **46**(1): 1–17.

Carson, R.T. (2000), Contingent valuation: a user's guide, *Environmental Science & Technology* **34**(8): 1413–1418.

Carson, R.T. Flores, N.E. and N.E. Meade (2001), Contingent valuation: controversies and evidence, *Environmental and Resource Economics* **19**(2): 173–210.

Carson, R.T. (2011), *Contingent Valuation: A Comprehensive Bibliography and History*, Cheltenham: Edward Elgar (forthcoming).

Diamond, P. and J. Hausman (1994), Contingent Valuation: Is some number better than no number? *Journal of Economic Perspectives* **8**(4): 45–64.

Ebert, U. (2003), Environmental goods and the distribution of income, *Environmental and Resource Economics* **25**(4): 435–459.

Flores, N.E. and R.T. Carson (1997), The relationship between the income elasticities of demand and willingness to pay, *Journal of Environmental Economics and Management* **33**(3): 287–295.

Freeman, A.M. (2003), *The Measurement of Environmental and Resource Values: Theory and Methods*, Washington: Resources for the Future.

Hanemann, W.M. (1994), Valuing the environment through contingent valuation, *Journal of Economic Perspectives* **8**(4): 19–43.

Hökby, S. and T. Söderqvist (2003), Elasticities of demand and willingness to pay for environmental services in Sweden, *Environmental and Resource Economics* **26**(3): 361–383.

Horowitz, J.K. and K.E. McConnell (2003), Willingness to accept, willingness to pay and the income effect, *Journal of Economic Behavior and Organization* **51**: 537–545.

Jacobsen, J. and N. Hanley (2009), Are there income effects on global willingness to pay for biodiversity conservation? *Environmental and Resource Economics* **43**(2): 137–160.

Kriström, B. and P. Riera (1996), Is the income elasticity of environmental improvements less than one? *Environmental and Resource Economics* **7**: 45–55.

Liu, S. and D.I. Stern (2008), A meta-analysis of contingent valuation studies in coastal and bear-shore marine ecosystems, *CSIRO Working Paper Series 2008-15*.

McFadden, D. and G.K. Leonard (1993), Issues in the contingent valuation of environmental goods: methodologies for data collection and analysis, in J. Hausman (ed), *Contingent Valuation: A Critical Assessment*, Amsterdam: North Holland Press, pp. 165–215.

Pinkovskiy, M. and X. Sala-i-Martin (2009), Parametric estimations of the world distribution of income, *NBER Working Paper 15433*.

Schläpfer, F. and N. Hanley (2006), Contingent valuation and collective choice, *KYKLOS* **59**(1): 115–135.

Schläpfer, F. (2006), Survey protocol and income effects in the contingent valuation of public goods: A meta-analysis, *Ecological Economics* **57**(3): 415–429.

Schläpfer, F. (2008), Contingent valuation: a new perspective, *Ecological Economics* **64**(4): 729–740.

Schläpfer, F. M. Schmitt and A. Roschewitz (2008), Competitive politics, simplified heuristics, and preferences for public goods, *Ecological Economics* **65**(3): 574–589.

Schläpfer, F. (2009), Contingent valuation: confusions, problems, and solutions, *Ecological Economics* **68**(6): 1569–1571.

World Bank (2011), *World Development Indicators*, available at: http://data.worldbank.org/data-catalog/world-development-indicators, last accessed: 01.05.2011.