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Time vs. money metrics for contingent valuation surveys: Theory and correlations from data on two marine ecosystems

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Abstract

Money remains the most commonly used metric in valuation surveys involving non-market goods, though recent evidence suggests that alternative metrics can be equally effective. This research contributes to the literature by (i) suggesting a theoretical model to explain the links between metrics, (ii) proposing a bivariate lognormal model to account for any correlation between the answers to the valuation questions, and (iii) providing new data on the value of preserving ”blue goods” in a rural area of a developing country. We study a measure of willingness to pay (WTP) for a non-market good in a time and money metric and show that the ratio between WTP in the time/money metric is equal to the wage in a competitive economy. Our model is tested using a field survey on conservation of ”blue goods” (ecosystems involving the husbandry of water resources) in rural Philippines, and the results provide further support for the use of alternative metrics in valuation studies.

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1. Introduction

When using the Contingent Valuation Method (CVM), it is common to ask respondents to provide a subjective valuation in a money metric. However, in some cases, alternative metrics may be more useful. For instance, unemployed respondents may not be willing to pay for a good, even if it has value to them, because they do not have a current source of income. Pondorfer and Rehdanz (2018), for example, elicited public good preference in non-monetized societies in Papua New Guinea. Similarly, respondents who distrust public office may not provide an accurate valuation in money terms due to their distrust. On the other extreme, one can think of a CEO that has a lot of money to contribute, but has no time. In these and other cases, it is worth considering the use of alternative metrics, and comparing valuation in terms of time and money. This is related to theoretical literature on the cost of time in recreation benefit studies (McConnell, et al. 1981; Cesario, 1976). But, that literature does not compare environmental valuation in terms of time and money. Focus is mainly on maximizing utility in terms of choosing trips. The main focus of our paper is quantifying volunteer time to protect marine ecosystems, and considers this volunteer time as the opportunity cost of leisure and labor.

Kassahun et al. (2020) have recently argued that combining metrics can help explain the ”low” monetary values found in many CVMs in developing countries.:

> *We argue that in a setting where 1) there is imperfect substitutability between money and other measures of wealth (e.g., labor), and 2) institutions are perceived to be corrupt, including payment vehicles that are currently available to the individuals and less prone to corruption may be needed to obtain valid welfare estimates. Otherwise, we risk underestimating the welfare benefit of projects.* Kassahun et al (2020, p. 1067)

The first study on the use of different metrics in CVM was carried out by Swallow & Woudylawev (1994) in a study related to a program that reduced a disease spread by the Tse-Tse fly. While the program was initially successful (e.g. reducing the prevalence of trypanosomiasis in cattle), it was marred by theft of the targets used to attract the Tse-Tse fly. A CVM-study was carried out in the Ethiopian Ghibe valley Tse-Tse control area in January 1993.

> *Respondents were asked if they were willing to contribute money to a fund for replacing materials and/or labour time for constructing, monitoring and maintaining the targets* (Swallow & Woudylawev (1994, p. 155))

The idea of using different metrics has later been used by a significant number of studies. Table 1 in Kassahun et al (2020) has a comprehensive literature review of 20 studies that have used labor time and money metrics in CVM-studies. To take one example from the literature, Navrud & Vondolia (2019) studies $\{time, rice, money\}$ as alternative payment mechanisms for the purchase of flood insurance in Ghana (in a follow-up study Vondolia & Navrud (2019) go on to argue that non-monetary metrics are more uncertain).

We add to the literature on metrics in CV in three ways. First, we provide a theoretical model that unravels a number of assumptions that need to be made in order to make a proper comparison of metrics. Second, our theoretical model can conveniently be estimated by regression or a bivariate lognormal model. The bivariate lognormal model provides a way to directly address the potential correlation between the answers to two valuation questions that target the same change but uses different metrics. In addition, the model can be extended to include zero WTP (which ordinarily is modelled such that is has a zero probability of occurring). As far as we know, this is the first study that combines theory and empirics in this way to further understand the choice of metric in CVM. Third, we add new information about preferences in certain fairly remote areas of a developing country.

The paper proceeds as follows: section 2 presents a theoretical model detailing what we want to measure in the empirical part, section 3 outlines the policy background to our study and how the survey was implemented, section 4 contains our statistical analysis, section 4.2 presents the results of a regression model and a bivariate log-normal model. The paper ends in section 5 with a discussion and conclusions.

2. Theoretical model

The individual has an endowment of time $\overline{T} > 0$, out of which l is supplied to the labor market. The individual's leisure time is thus $F = \overline{T} - l$. We assume a competitive labor market, p_x and w are the respective competitive market prices for the good and labor time. These prices are assumed to be given throughout. The individual's utility is determined by a standard neoclassical utility function of the form $U(F, x, z)$, where F is leisure demand, x is a composite private good, and z is a public good. Each good contributes positively to the individual's utility, and the marginal utilities are positive and decreasing throughout the changes considered. Let m denote income, i.e. the value of the time endowment; we assume that the individual does not have any other endowment in the status quo. Consider an environmental improvement, represented as the change $z^0 \rightarrow z^1, z^1 > z^0$. Assume that the individual maximizes utility subject to the constraints and let V denote the resulting indirect utility function. Define $F^* = T - l^*$, where l^* is the utility-maximizing time offered to the labor market in the status quo.

In order to define our metrics, set $\mathrm{K}^0 = \{m^0, p_x, z^0, w\}$, $V^0 = V^0(m^0, p_x, z^0, w) = V^0(\mathrm{K}^0)$. We are now equipped to define two measures of value in two different metrics. Given the way we set up our survey, it is natural to use the compensating variation (CV), and thus fix utility at the benchmark level.

$$\begin{aligned} V(m^0 - CV_m, p_x, z^1, w) &= V^0 \\ U(T - l^*(\mathrm{K}^1) - CV_F, x(\mathrm{K}^1), z^1) &= V^0 \end{aligned}$$

where $\mathrm{K}^1 = \{m^0, p_x, z^1, w\}$. In the case of CV_m the individual is, in a contingent valuation study, asked about the maximum WTP for the change in z (typically ceteris paribus). CV_F gives the maximum number of units of time an individual willingly gives up in exchange for Δz[1]. Observe that F (or its mirror image l) are choice variables, so the individual is asked to give up units of the given endowment, T.

[1] Note that the demand for goods and leisure are computed at $\{m^0, p_x, z^1, w\}$. Income does not change, because we assume that prices do not change

Furthermore, $U(T - l^*(\mathrm{K}^0), x(\mathrm{K}^0), z^1) > V^0$, since the individual must be better off when z is increased exogenously, i.e. $CV_F > 0$. Yet, in the empirical application we find that more than 35% report a zero WTP[2].

To explain why an individual report a zero WTP, we need a different model, in which z does not contribute to utility. A particular challenge in our case is a mixed outcome, i.e. when a respondent reports a positive valuation in one metric and a zero valuation in the other. Our theoretical model can only handle a case when a respondents submits a zero bid in both dimensions, by assuming that z is a "non-good" for such a respondent (and thus the utility change is zero). The mixed outcome is difficult to model under standard assumption.

To approach the empirical implementation of the model, let us approximate equation 1 and 2 linearly,

$$\begin{aligned} c_1 \bullet w + c_2 \bullet p_x^0 + \beta \bullet (m^0 - CV_m) + \alpha \bullet z^1 &= V^0 \\ b \bullet (T - l^* - CV_F) + \gamma \bullet x + \alpha \bullet z^1 &= V^0 \end{aligned}$$

in which $c_i, i = 1{,}2$ and α, β, γ are positive constants. Since we have assumed that prices and income are constant across states-of-world, solving for CV_m and CV_F gives:

EQUATION 1:

$$\begin{aligned} \frac{\alpha}{\beta}(z^1 - z^0) &= CV_m \\ \frac{\alpha}{b}(z^1 - z^0) &= CV_F \end{aligned}$$

Because z is assumed a (pure) public good, we can set $(z^1 - z^0) = 1$. Note that α can be interpreted as the marginal utility of environmental improvement, β the marginal utility of income and b the marginal utility of leisure. Thus, $\frac{CV_m}{CV_F} = \frac{b}{\beta}$, i.e. the marginal utility of leisure (or the marginal disutility of working time), is converted into money by the division of β. In a perfect market economy, this ratio will be equal to the wage. Note that b has the unit $\frac{U}{h}$, where h is a unit of time, while the unit of β is $\frac{U}{\$}$. Therefore the ratio has the unit $\frac{\$}{h}$, or "dollars per hour".

Our empirical strategy was to use a survey with interviewers to elicit the two CV-measures, using open-ended valuation questions. All respondents have similar profiles. They all belong to poor, rural households within the same municipality. They do not have a fixed amount of labor time daily, as most of them are engaged in informal work like cleaning other people's house or family-related tasks (e.g. farming, fishing). Finally, we complemented these questions with self-selected interval questions, in case the individual was uncertain about his or her valuations any interval containing their "true" valuation could be stated. Our theoretical model can only provide point-

[2] From the proportion of no-answers to the questions "Would you be willing to contribute your time (money) to prevent cutting 1 hectare of mangroves?" and similarly for seagrass. Contributing labor time to the seagrass project had 58% zeroes, the other alternatives between 24 and 38%

valuations, and therefore we do not go into details about the interval-valued valuations in this paper. We next turn to a description of our survey.

3. Study design

3.1 Mangroves and seagrass ecosystems

Mangroves is a forest ecosystem composed of shrubs and trees that grow in low-oxygen soil and slow-moving water which thrive in warm climate zones. Mangrove forests are characterized by a thick tangle of tree roots, serving as a natural barrier against storms and coastal erosion, provide habitat for a variety of wildlife, and support local livelihoods through the provision of fish and other seafood, fuelwood, and other resources. However, mangrove forests can also be threatened by development, pollution, and overuse, which can lead to conflicts between those who depend on these ecosystems and those who seek to use them for other purposes (Barbier (2000), Rönnbäck (1999)). Seagrass is a generic term for underwater plants characterized by long and narrow green leaves (Dewsbury et al. (2016)), providing many ecosystem services, such as a habitat for fish and invertebrates, stabilizing sediments and protecting coastlines from erosion. However, seagrass can also be threatened by pollution, coastal development, and overfishing. These activities can cause seagrass to become degraded or lost, which can have negative impacts on the marine environment and the people who depend on it.

Policies that address the husbandry of mangroves and seagrass ecosystems may be supported by information from valuation studies, whence these shed light on the key trade-offs(Small et al. (2017); Rosenberger et al. (2009); Farber et al. (2002)). Valuation studies can thus help decision-makers to better understand the economic value of natural resources from the perspective of the local community (Boyd & Krupnick (2009)). They could serve as decision-support to policymakers when creating programs and policies for the protection of ecosystems (see, further, PSA (2018)). The value ’locals’ put the two ecosystems in focus here is the subject of our survey study on small rural communities in the Philippines (see also Losada et al. (2017)).

Our survey was carried out in the island province of Aklan in the Philippines. Randomly selected respondents in select municipalities of the province were asked about their Willingness-to-pay (WTP) to protect mangroves and seagrass ecosystems located in another province. The choice of these two ecosystems as our ”goods” was, inter alia, based on the differing knowledge in the population of study regarding the usefulness of mangroves and seagrass ecosystems from an economic and ecological point of view. We also conjectured, given the sociodemographics of the study area, that a money metric would not necessarily be the most effective metric. Rather, we wanted to explore the use of different metrics, such as time.

3.2 Study sites

The province of Aklan is located in the Western Visayas region of the Philippines. It is a province of geographic diversity, best known for the island of Boracay, renowned worldwide for its powder-like white sands and pristine beaches. The total land area is 1,821 square kilometers, composed of rural communities that rely mostly on fishing, farming (mostly rice farmers), and tourism-based employment as sources of household income. The site selection process began with a focus on Aklan, the province's capital (and the main gateway to Boracay) in the municipality of Kalibo, and a municipality near the coastline, Ibajay (about 20 Km from Kalibo). The research team had previously established connections with local officials in both municipalities, who provided the necessary permits and assistance to conduct the survey that allowed for a smooth survey of respondents.

The choice of Aklan was based on socio-economic characteristics and logistical support for the survey work. Firstly, the province is not wealthy. It has a poverty rate close to 20% in 2018, with unemployment at approximately 4.8% (it was almost 14% in 2020 due to the pandemic). Because most of the employment in the province is based on fishing, farming and tourism, the trade-off between environmental quality and economic parameters is apparent. Secondly, there was strong logistical support for the survey from Aklan State University and the local government.

3.3 The survey process and the valuation questions

Before conducting fieldwork, the questionnaire was evaluated for validity according to ethical standards, such as checking the appropriateness of the wording. Pre-tests were conducted prior to the survey being implemented in the field. Barangays (the smallest administrative division in the Philippines) in each municipality were assigned a random number. Random sampling of households in Kalibo and Ibajay municipalities was done using weights based on the size of the barangay. Approximately 300 randomly-selected households were targeted to ensure a large enough sample size for statistical analysis. Names and addresses of households were requested and obtained from the barangay offices and each name was assigned a number for random selection. A table of non-repeating, randomly-generated numbers equal to twice the target sample size was created for each barangay. Before the interview, each respondent was asked for consent to participate and assured that their responses and personal data would remain anonymous and confidential. They were informed that the survey was being conducted for academic research and that they were not in any danger due to a permit from the local government units. Local enumerators from Aklan State University were carefully recruited and underwent a two-day training before conducting the survey. The interviewers were selected based on their knowledge of the two ecosystems their command of Tagalog and the native language in Aklan.

Each respondent was asked about the WTP to conserve two types of "blue carbon goods": mangrove and seagrass. The context for the mangrove question was (translated into english):

> There is a move to cut down the mangroves in (NAME OF NEXT MUNICIPALITY). The government said that the only way to prevent this is by paying for guards and regular maintenance, but the LGU does not have money for this anymore, and so voluntary contributions from residents in your municipality are being asked.
>
> and similarly for seagrass:
>
> Seagrass is another coastal ecosystem and natural resource. There is a move to pull out the seagrass in (NAME OF NEXT MUNICIPALITY). Just as in the previous situation, the government said that the only way to prevent this is by paying for guards and regular maintenance, but the LGU does not have money for this anymore, and so voluntary contributions from residents in your municipality are being asked.

Valuations were elicited in both time (number of volunteer hours) and money (in Philippine pesos, where 1 USD was approximately equal to 50 Pesos). If the subject answered "No" to a question about whether or not they would be willing to contribute to the project in the two ways offered, it was assumed that their WTP was equal to zero in both metrics (thus, negative WTP was assumed away). English translations of the interval-based valuation questions are available in the appendix. In addition to the interval estimates, we also extracted point-estimates of WTP. We will use the point estimates, as our theoretical model is based on points, not intervals. In the focus groups, it was discovered that the residents in the barangays are familiar with the benefits that can be derived from mangroves, such as storm surge protection and wood fuel, while knowledge regarding the usefulness of seagrass was minimal. Participants often viewed seagrass as a hindrance to fishing, as boats can become entangled in it. Whether familiarity with the good in question is a necessary precondition for the effective application of CVM is an issue that has been debated in the literature. See e.g. Knivilä (2006) for an analysis of how users and non-users of conservation areas interact. Next we look at our empirical results, beginning with descriptives before turning to our statistical models.

4. Statistical analysis

4.1 Descriptive statistics

Descriptive statistics for the sample are summarized in Table 1. On average, the respondents were around 49 years old, with a slight majority being female. Approximately 65% of the respondents reported being married, while around 10% were either single or widowed. Additionally, 66% of the sample held a qualification lower than a high school diploma, while the remaining 25% had obtained a high school diploma. Our sample respondents reported an average daily income of roughly Php 545, while the median income was 300 (which is equal to the official estimate of the average daily wage in the region, which is discussed further below). The mean is significantly influenced by three large observations (8000, 8000, 11600); removing these gives an average of around 420 pesos per day.

The questions posed about the ecosystems were structured in the same way. Individuals were first asked if they would be willing to contribute anything at all (in each metric) for the proposed project. If they answered "no" to this screening question, we assumed that their valuation was equal to zero. For the remainder of the paper, we will mainly focus on mangrove valuation and present some statistics on how respondents replied to the mangrove valuation question. Table 2 shows that 60 out of the 315 responses were zero in both metrics, while there were 151 responses with positive valuations. Additionally, 54 (50) individuals gave a mixed response, with their complementary valuation being zero. To further understand the response patterns, we present the sociodemographic characteristics of the four valuation groups in Table 3, with the case of mangroves.

Table 1. *Socioeconomic demographics.*

A star signifies that the variable is categorical. Gender is coded 1=male, 2=female. Marital status is coded as 1=Married, 2= Single, 3=Widow(er),4=Other. Education is coded as a numerical variable, from 1='No schooling',,, 8= 'College Graduate'

	vars	mean	sd	median	min	max
Gender*	2	1.38	0.49	1	1	2
EDUC_numeric	4	3.78	1.75	4	1	8

Table 2. *Number of respondents by valuation of mangroves in time and money*

Mangrove Valuation	n
Both > 0	151
Time > 0	50

Table 3. *Respondent demographics by mangrove valuation group*

mangrove_value	AGE_Mean	GENDER_Mean	EDUC_Mean	DAILY INCOME_Mean
Both > 0	44.15	1.64	4.02	722.38
Time > 0	45.22	1.58	3.64	298.25

There is a tendency for younger people to pay more often in time rather than money, perhaps because their opportunity cost of time is lower. The lowest income is, as expected, found in the group that do not want to contribute at all to the project. Mean income is significantly higher in the group where both valuations are positive, but this is manly due to a few outliers. We also find that those who contributes in both metrics tend to have more education. There is little difference between the sexes regarding in which valuation group they happen to be found in the case of mangroves.

Next, we turn to descriptives of WTP, collected in table 4. To underline our assumption that the valuation is zero if the individual did not want to contribute to the project (and hence were not asked for a value), we name our WTP variable WTPz.

Table 4. *Descriptive statistics of valuation measures.*

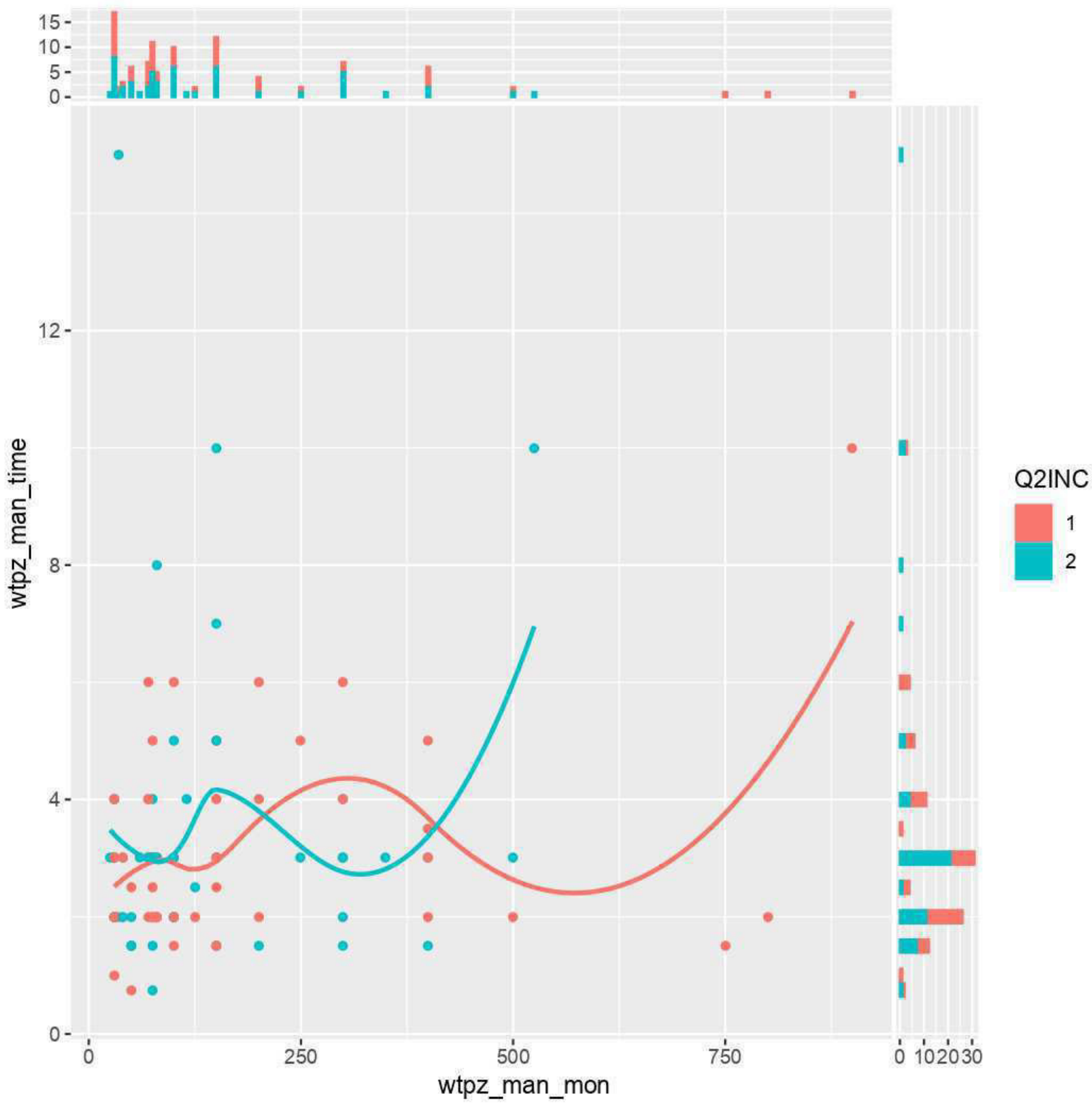
$WTPz\_k\_m$*=willingness to pay for mangrove(k=man) or seagreass(k=sea) in the monetary (m=mon) or time metric (m=time), given the assumption that a rejection to pay is equivalent to a valuation of zero (z).*

Variable	n	mean	sd	median	min	max
WTPz_man_mon	315	90.30	134.18	40	0	900
WTPz_sea_mon	196	85.78	142.69	40	0	900
WTPz_man_time	315	2.09	2.26	2	0	15
WTPz_sea_time	308	1.44	3.38	0	0	50

Overall, the valuations are quite similar across projects. Observe the impact of our assumption that wtp=0 if the individual denies contributing. Also, notice the difference between the mean and the median. Histograms for the WTPz-measure is in Figure 1.

The distributions are skewed, a common finding in the valuation literature. This could be due to the fact that the income distribution is skewed, with the mean being significantly lower than the median. Furthermore, the histograms also suggest the substantial fraction of zeroes in the data. These are not necessarily ”protest-bids”, but could simply reflect that the public goods under scrutiny are not a part of preferences. To obtain further insights into the data generation process, we now turn to our statistical models.

FIGURE 1. Histogram of Willingness-to-Pay.



4.2 Empirical Models

We extend the empirical analysis by presenting two statistical modela, a regression model and a bivariate lognormal model. The regression model follows immediately from our theoretical set-up, while the bivariate lognormal model is useful in order to explore the potential correlations between answers.

4.2.1 OLS regression

Rewriting equation EQUATION 1 and adding two i.i.d random error terms ϵ_m, ϵ_F with mean zero we have two regression equations

$$
\begin{aligned}
CV_m &= \frac{\alpha}{b} + \epsilon_m \\
CV_F &= \frac{\alpha}{\beta} + \epsilon_F
\end{aligned}
$$

Taking expectations of each equation and dividing them, we have the ratio $\frac{CV_m}{CV_F} = \frac{b}{\beta}$, which according to theory should be equal to the wage rate. If, as one might suspect, the error terms are correlated, one might use the delta method to obtain the variance of the ratio.

The lack of"explanatory variables" is a feature of the modelling assumptions; individual characteristics that are constant across the scenarios cancels out under the linearity assumption. Since our focus is on the average valuation, the lack of explanatory variables in the regression model makes little difference (because the regression line goes through the means). An official estimate of the hourly wage in the region at the time of study is 37.5 pesos. To test the hypothesis that $\frac{CV_m}{CV_F} = \frac{b}{\beta} = 37.5$ pesos, we simply run a regression of the ratios against a constant and assume that the error terms are independently normal. Regression results are reported in table 5.

Table 5. *Linear regression of the ratio of WTP in money (m) and hours(h).*

assuming that WTP> 0 in both metrics and that the error terms are uncorrelated. Standard errors estimated using Whites estimator.

	Dependent variable:		
2-4			
	Mangroves Peso	Mangroves Hours	M_Peso/M_hour
	(1)	(2)	(3)
Constant	145.828	3.278	54.977
	t = 13.924***	t = 0.224***	t = 9.832***
Observations	151	151	151
R^2	0.000	0.000	0.000
Adjusted R^2	0.000	0.000	0.000

Residual Std. Error (df = 150)	155.829	2.037	68.710
Note:	*p<0.1; **p<0.05; ***p<0.01		

These models do not fit the data well, which affects the hypothesis test, because the tests are valid given the correctness of the model. The lack of fit is related to the fact that the models do not take into account any consumer heterogeneity (up to an additive random error term). The marginal disutility of working time (pesos per hour) converted into money, $\frac{b}{\beta}$, is about 55 pesos, conditional on a positive valuation of the public good. The ratio is rather precisely estimated[3] and we thus reject the hypothesis that the average wage is 37.5 under the stated assumptions.

There are two issues that merit further investigation. First, we have not taken into account any potential correlation between the answers to the valuation questions. Second, given the fairly common zero-response, we should take those into account.

4.2.2 Bivariate lognormal model

Because two valuation questions are asked in order, a number of theoretical and empirical issues potentially surface. The first is the so-called sequencing problem, which means that the answers on each question might depend on the order in which they are asked. This might not appear to be an economics issue, rather one of survey design. However, economic theory does not preclude the sequencing problem (see Johansson (1993)). From a statistical perspective, the answers to the two valuation questions might be correlated; there is reason to believe that a high value in one metric is positively correlated with a high value on the other. As an extension for future work, randomization of the order of questions could have been done. For this study, that was not feasible due to budget constraints and the sample size is limited to access to remote households.

There are different ways to solve this issue, but a natural extension of our regression approach is to use a bivariate lognormal model. This assumes that valuations are strictly positive and follows a skewed distribution (the log-normal), much like the distribution of income. Furthermore, the correlation is related to a parameter of the bivariate lognormal distribution.

It will be useful to first consider the bivariate plot of WTP in the two metrics, split by median income, see Figure 2.

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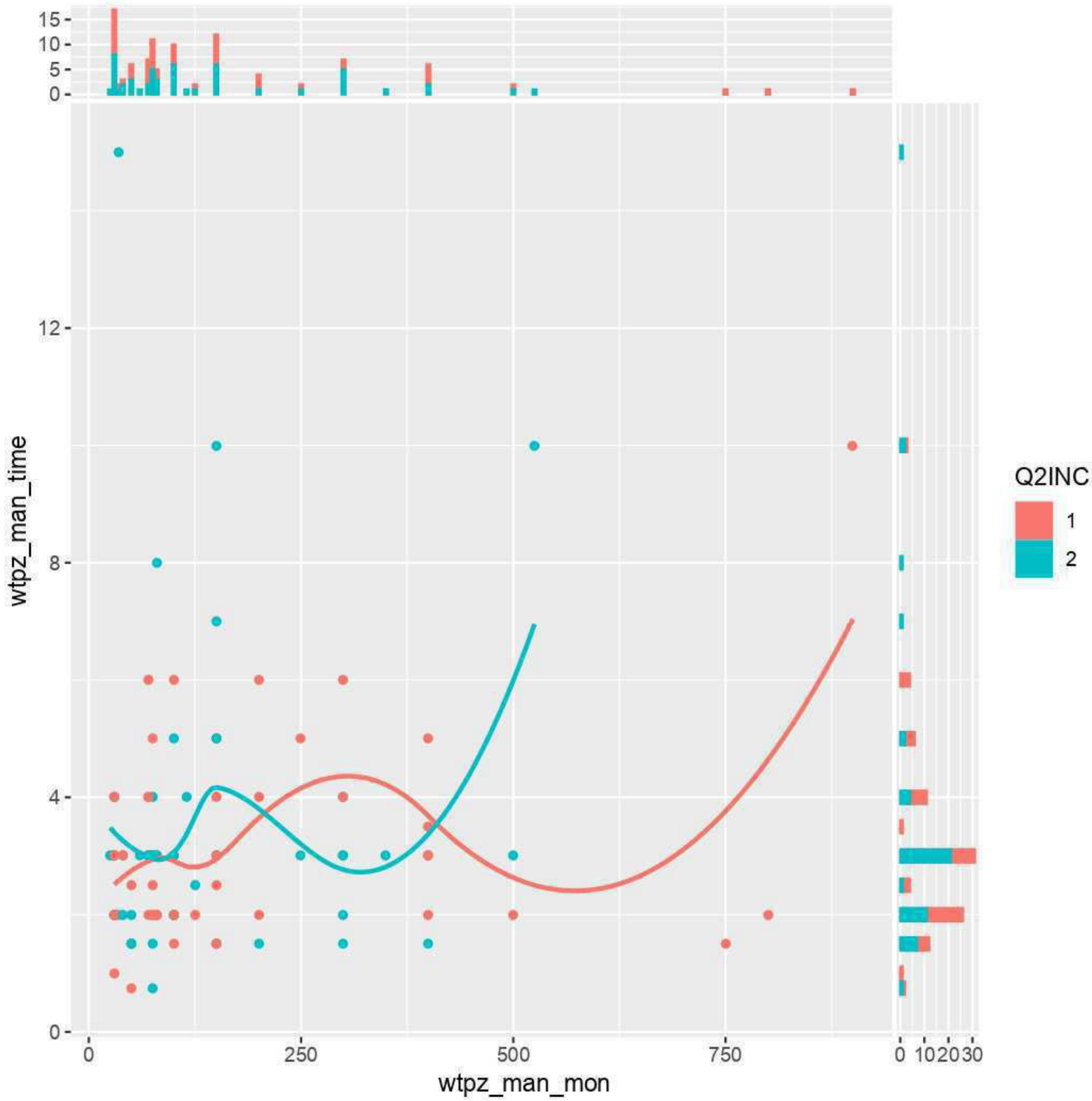
[3] We have used the sandwich package in R to obtain a heteroscedasticity consistent covariance matrix ("White") for the test.

FIGURE 2. The relationship between (positive) valuations of the mangrove-project in time ($\mathrm{wtpz}_{\mathrm{m}}\mathrm{an}_{\mathrm{t}}\mathrm{ime}$) and money ($\mathrm{wtpz}_{\mathrm{m}}\mathrm{an}_{\mathrm{m}}\mathrm{on}$) metrics, split by median income (Q2INC).



The LOESS-smother suggest a non-linear relationship between money and time metrics for both income groups, i.e. below or above median income. The figure makes apparent three outliers in the low income group, regarding paying in money terms. These outliers makes mean WTP in money terms higher in the poorer group, while the median is lower. If these outliers are removed, WTP is higher in the group with an income greater than the median. We have no particular reason, however, to exclude these outliers, so that they will be retained in the further analysis of the data. Let us now turn to the estimation of the bivariate normal model.

4.2.3 Hypothesis-testing in the bivariate lognormal model

We follow the notation and the exposition in Gupta et al (2013) regarding well-known facts about the bivariate lognormal distribution. For any variable v, let $v^* = \log(v)$ Let X,Y be random variables corresponding to CV_m, CV_F, with observed values x,y. Let (X,Y) follow a log-normal distribution with parameters $\mu_1, \mu_2, \sigma_1, \sigma_2, \rho$. Maximum likelihood estimators of these parameters are known to be (Gupta et al (2013)) $\overline{\mu_1} = \widehat{x^*}, \overline{\mu_2} = \widehat{y^*}, \widehat{\sigma_x^2} = \widehat{s_x^{*2}}, \widehat{\sigma_y^{*2}} = \widehat{s_y^{*2}}, \hat{\rho} = r^*$, in which

$$
\begin{aligned}
\bar{x^*} &= \frac{1}{n}\sum_1^n x_i^* \\
\bar{y^*} &= \frac{1}{n}\sum_1^n y_i^* \\
s_x^{*2} &= \frac{1}{n}\sum_1^n (x_i^* - \bar{x^*})^2 \\
s_y^{*2} &= \frac{1}{n}\sum_1^n (y_i^* - \bar{y^*})^2 \\
r^* &= \frac{\sum(x_i^* - \bar{x^*}) \cdot (y_i^* - \bar{y^*})}{\sqrt{\sum(x_i^* - \bar{x^*})^2) \cdot ((y_i^* - \bar{y^*})^2)}}
\end{aligned}
$$

We first address the issue of correlation and it is convenient to use the Maximum Likelihood method. The density function and the resulting log-likelihood is given in the appendix. Parameter-estimates are in tale

Likelihood values for the full and restricted ($\rho = 0$*) model.* $ll^{Full} = -27.09$, $ll^{Restricted} = -28.42$

	$\widehat{\mu_1}$	$\widehat{\mu_2}$	$\widehat{\sigma_1}$	$\widehat{\sigma_2}$	$\hat{\rho}$
Full	4.58	1.05	0.87	0.51	0.13
$\rho = 0$	4.58	1.05	0.87	0.51	0.00

Let us first test the hypothesis that $\rho = 0$, which is a test of the hypothesis that the answers to the two valuation questions are uncorrelated. Bickel & Doksum (2001, p. 267) provides two different tests, a likelihood-ratio test and a t-test. If $\hat{\rho}$ denotes the sample correlation coefficient, then their proposed tests are written

$$\text{likelihood-ratio test} = \frac{-n}{2}(1-\hat{\rho}^2)$$
$$\text{T-test} = \frac{\sqrt{n-2\cdot\hat{\rho}}}{\sqrt{1-\hat{\rho}^2}}$$

Inserting the maximum likelihood values for the unconstrained likelihood and constrained likelihood ($\rho = 0$), we obtain a test value of twice the difference between the likelihood values, which gives a p-value of about 0.1. The Bickel & Doksum tests gives a value of 74.18 and 12.38, respectively. Either way, we reject the hypothesis that there is no correlation.

Next we want to test the hypothesis about the model prediction $E\left(\frac{CV_m}{CV_F}\right) = E\left(\frac{b}{\beta}\right) =$ average wage. If two random variables (X,Y) are log-normally distributed, then the logarithm of their ratio is the difference between two normally distributed variables. Thus, let $Z = \frac{X}{Y}$ be lognormal, with parameters $\{\mu_Z, \sigma_Z^2\}$, then $\log(Z) = \log(X) - \log(Y)$ and $E(Z) = \exp\left(\mu_z + \frac{1}{2\sigma_Z^2}\right)$. An estimate can then be obtained by assuming that b and β are independently normally distributed. The expected value of $\frac{b}{\beta}$ is then ≈ 53.64 using this formula. Because there is roughly 36% zero responses for both type of valuations in the case of mangroves, we can take an estimate of the unconditional mean to be $(1-0.355)\cdot 53.64 \approx 36.6$, rather close to official estimates that have the daily income at 300 pesos[4], if we assume an 8-hour working day. Alternatively, we can use the sample data without making any particular distributional assumption. A t-test of the hypothesis is rejected, if we assume strictly positive valuations. If, however, we allow zero valuations, we obtain a 95% confidence interval of {28.55,42.92}, so that we cannot reject the hypothesis.

5. Concluding remarks

The outcome of this study is encouraging for valuation studies using surveys, e.g. the CVM, because our results give additional support to the idea of using other metrics than money. Enlarging the space of possible metrics is useful, not the least when applying survey methods in areas where a monetary metric is difficult to use.

Is the choice of metric innocuous? In the standard Arrow-Debreu model, the choice of numeraire does not matter for the allocation of resources; the demand functions are homogenous of degree one. Unfortunately, there is no general agreement in the economics literature if we go beyond the Arrow-Debreu model and introduce non-priced public goods. Brekke (1997) argues that the choice of numeraire matters in CBA, while Johansson(1997) maintains that the standard result carries over to economies with public goods. Garnache & Merel's (2022) recent results support the "numeraire matters" argument. Their argument roughly goes as follows: when a good/factor is taxed in the Arrow-Debreu economy, consumers/producers face two different prices - their levels depend on the numeraire, but the general equilibrium allocation will be independent of the

[4] https://nwpc.dole.gov.ph/regionandwages/region-vi-western-visayas/

numeraire, since relative prices are unaffected given the numeraire. Conversely, a non-priced public good remains non-priced, regardless of the numeraire and the choice of the numeraire might therefore matter. Furthermore, according to Guerra et al (2018), there is a numeraire dependency even in perfect economy settings when calculating the Hicksian measures. These considerations are, as far as we can tell, not major concerns given the assumptions we have made. Indeed, constant prices across states of the world together with the ”small” project assumption, suggest that either of the two measures can be used.

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Appendix 1: Density and log-likelihood for the bivariate normal model

$$f(x,y) = \frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}xy}\cdot$$

$$\exp\{-\frac{1}{2(1-\rho^2}\left[\left(\frac{\log(x)-\mu_1}{\sigma_1}\right)^2 + \left(\frac{\log y-\mu_2}{\sigma_2}\right)^2 - 2\rho\left(\frac{\log(x)-\mu_1}{\sigma_1}\right)(\frac{\log(y)-\mu_2}{\sigma_2}\right]\}$$

with $x > 0, y > 0, -\infty < \mu_1 < \infty, -\infty < \mu_2 < \infty, \sigma_1 > 0, \sigma_2 > 0$ and $-1 < \rho < 1$.

Let n be the sample size, and $x[i], y[i] = \log(CV_k[i])$, where k=m,F and i=1..151, then we can write the log-likelihood (ll) as

$$ll = n \cdot \left(\log(\sigma_1) + \log(\sigma_2) + 0.5 \cdot \log(1-\rho^2)\right) - \frac{0.5}{(1-\rho^2)} \cdot (\Sigma((x[i]-mu_1)^2)/\sigma_1^2 + \Sigma(y[i]-\mu_2)^2)/\sigma_2^2 - 2 \cdot \rho \cdot \Sigma(x[i]-\mu_1) \cdot (y[i]-\mu_2)/(\sigma_1 \cdot \sigma_2)))$$

Appendix 2: Willingness to pay questions

Each respondent was asked an interval-based questionnaire stating their Willingness-To-Pay (WTP) to conserve two types of blue carbon goods: mangrove and seagrass. Their valuations were elicited in both time (number of volunteer hours) and money (in Philippine pesos were 1 USD = approx. 50 Pesos). Prior to the interview, each respondent was asked for their consent to participate and were told that their responses and personal data will remain anonymous and confidential. They were told that survey's objective is only for academic research. Local enumerators from Aklan State University were carefully recruited and properly trained prior to the conduct of the survey. Finally, interviews were done using the Philippine's national language, Tagalog. English translations of the interval-based questions are detailed below. Note that valuations in intervals are only elicited when they answered "Yes" in the first question for each environmental good, e.g. Would you be willing to contribute your time to prevent cutting 1 hectare of mangroves? (To the enumerator: Make sure their answer is between the minimum and maximum number stated in the previous questions.)

Mangrove

1. Would you be willing to contribute your time to prevent cutting 1 hectare of mangroves?

    a. If Yes, what is the minimum number of hours you are willing to volunteer to protect mangroves?

    b. If Yes, what is the maximum number of hours you are willing to volunteer to protect mangroves? Overall, how many hours are you willing to volunteer to protect mangroves?

1. Would you instead be willing to contribute money to prevent cutting 1 hectare of mangroves?

a. If Yes, what is the minimum amount of money you are willing to contribute to protect mangroves?

b. If Yes, what is the maximum amount of money you are willing to contribute to protect mangroves?

c. Overall, how much money are you willing to contribute to protect mangroves?

Seagrass

1. Would you be willing to contribute your time to prevent uproot (bunutin) 1 hectare of seagrass?

    a. If Yes, what is the minimum number of hours you are willing to volunteer to protect seagrass?

    b. If Yes, what is the maximum number of hours you are willing to volunteer to protect seagrass?

    c. Overall, how many hours are you willing to volunteer to protect seagrass?

1. Would you instead be willing to contribute money to prevent cutting 1 hectare of seagrass?

    a. If Yes, what is the minimum amount of money you are willing to contribute to protect seagrass?

    b. If Yes, what is the maximum amount of money you are willing to contribute to protect seagrass?

    c. Overall, how much money are you willing to contribute to protect seagrass?