SPECIES DIVERSITY AND HUMAN WELL-BEING: A SPATIAL ECONOMETRIC APPROACH

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Abstract

Economic valuation of biodiversity is generally carried out by applying revealed or stated preference approaches to determine people's willingness to pay for small changes in management options. Studies on species preservation investigating passive or nonuse values typically rely on stated preference methods such as the contingent valuation approach and often focus on single animal species. The total value of species preservation can only be derived by aggregating the various values. This paper proposes a different approach by investigating country level data on life-satisfaction attempting to explain differences in subjective well-being by reference to amongst other things species diversity. While most recent papers have concentrated on finding determinants of life-satisfaction other than income, little attention has been drawn to spatial interdependencies. Most researchers investigating the determinants of life-satisfaction implicitly assume that subjective well-being is unaffected by events in neighbouring locations. The existence of spatial relationships in the data has implications for the econometric techniques typically employed including misleading inference testing procedures, bias and inconsistency depending on the precise form of the spatial relationship. We extend our analysis by a spatial econometric approach investigating whether and to what extend spatial relationships exist. Spatially weighted variables are shown to be a highly significant determinant of life-satisfaction. As nature does not respect man-made borders, neither does peoples happiness. Furthermore, even when controlling for a range of other factors we find a significant relationship with species diversity; the higher a countries number of bird or mammal species or the lower the percentage of bird species threatened the more satisfied the people are. Overall and from a human perspective, bird species seem to be a better indicator for biodiversity.

Keywords: amenity value, biodiversity, life-satisfaction, spatial econometrics, species diversity, well-being

JEL Classification: R19, Q57

1 Introduction

Biodiversity and ecosystems provide a wide range of direct and indirect benefits. Four levels of biodiversity are generally considered: gene diversity, species diversity, ecosystem diversity and functional diversity (Turner et al., 1999). Human activity affects all levels; we contribute to the loss of genes and species, which consequently might threaten the stability of ecosystems as well as their provision of goods and services to us. A range of policy measures has been introduced on environmental protection. While costs of biodiversity protection measures are relatively easy to derive, so far it has been rather difficult to value biodiversity and ecosystem services as a whole as well as its differing levels.

To better understand the advantages and disadvantages of activities, information about the value of the levels of biodiversity is needed. The difficulty of obtaining this information arises from the many direct and indirect benefits. Stated preference techniques are often used to derive welfare benefits for species preservation. The contingent valuation method derives values by asking people directly about their willingness to pay. The method is often criticized because of the difficulties related to the construction of a market and its numerous potential biases (see Mitchell and Carson, 1989 or Bateman et al., 2002, for a more recent overview of the method). Studies mostly present values for single charismatic animal species including the grizzly bear, the grey whale or the bald eagle (for an overview of studies see Loomis and White, 1996, or Nunes and van den Bergh, 2001). These values are often location specific, time dependent and sensitive to study design. Aggregating individual values to a country or even global value is, therefore, challenging.

This paper proposes a different approach to valuing species preservation by investigating country level data on life-satisfaction attempting to explain differences in subjective well-being by reference to amongst other things species diversity. More specifically, the paper considers the link between on the one hand numbers of bird and mammals species as well as the percentage threatened and on the other hand self reported life-satisfaction using data from the World Value Survey for 73 countries.[1]

While most recent analyses have concentrated on finding determinants of subjective well-being other than income, little attention has been drawn to spatial interdependencies. Most researchers investigating the determinants of life-satisfaction implicitly assume that subjective well-being is unaffected by events in neighbouring locations. However, it seems reasonable to assume that observations drawn from geographically neighbouring countries might be more closely related than those from more distant ones. If spatial relationships exist in the data this has implications for the econometric techniques typically employed including misleading inference testing procedures, bias and inconsistency depending on the precise form of the spatial relationship. Another aim of this paper is, therefore, to explore the use of spatial econometric techniques in analysing differences in subjective well-being investigating whether and to what extend spatial relationships exist. To our knowledge, this has not been done before.

There are good reasons to suspect that there are spatial dependencies in the data. There may be causal links between countries. For example, widespread hardship in one country may suppress the mood in its neighbours, through the news, family links, or fear of spillovers. The sampling may have induced correlations – after all, culture and geography vary gradually, while national borders are historical accidents. There may be omitted variables that are correlated over space. The latter two reasons are particularly relevant for the current paper. Nature does not respect man-made borders. We use a proxy for biodiversity, and the

[1] Like other researchers we interpret 'subjective well-being', 'happiness', 'life-satisfaction' and 'utility' as meaning essentially the same thing.

measurement error may well be correlated over space. Besides, border areas are often sparsely populated by humans and hence rich in nature – shared with the neighbouring country.

The remainder of the paper is structured as follows. Section two presents an overview of the economic research into the determinants of happiness focussing in particular on those few studies that have attempted to link happiness with environmental quality and biodiversity in particular. In section three the data used in the analysis are discussed. Section four illustrates the econometric approach and section five reports on the econometric results. In section six the willingness to pay for species preservation is calculated while the final section concludes.

2 Literature review

One strand of economics is based on analysing people's decisions revealed through their market behaviour. Investigating, e.g., people's choices for tourism and recreational demand, should reveal their preferences for locations including environmental amenities such as wildlife or natural habitat. Other revealed preference methods such as the defensive expenditure or the hedonic pricing approach can be applied to uncover other aspects of biodiversity or ecosystem services. The willingness to pay for improved water quality can, for example, be studied with the defensive expenditure approach while the hedonic approach is able to provide implicit prices for differences in the quality of agricultural land. All these methods are limited to observations from market transactions and are unable to provide passive or non-use values (for an overview of methods see Braden and Kolstad, 1991). Stated preference methods are based on surveys and able to assess both use and non-use values. Applying, for example, the contingent valuation method respondents are directly asked for their willingness to pay for biodiversity enhancements. One challenge of the method is the suitable design of the questionnaire. If non-use values are considered the good under consideration is often unfamiliar to the respondent. Therefore, communicating all relevant information is more difficult the less familiar the respondent is and the more complex the environmental good gets (for an overview of the method see Mitchell and Carson, 1989; or Bateman et al., 2002). Nunes and van den Bergh (2001) provide a relatively recent review of the economic valuation literature on biodiversity applying the methods described above. Most studies were conducted for the US. They find support for a positive social value of biodiversity, but also point out that the economic literature is incomplete and not able to cover the entire range of biodiversity benefits.

An alternative to the above is to focus on "experienced" utility, stressing the pleasure of consumption, as provided by survey measures of happiness or life-satisfaction (see for example Kahnemann et al, 1997; or more recently Kahnemann and Sudgen, 2005). Here, respondents are not asked about their willingness to pay for certain policy measures but how satisfied they are with the life they lead.

Research into the determinants of happiness or life-satisfaction was for a long time solely the domain of psychologists and sociologists. In recent years however, it has become increasingly accepted into welfare economics. Today there is the general belief that data on subjective well-being are valid and can be used for formal analyses (Di Tella et al., 2003). Empirical work has furthermore shown that happiness is not a purely personal issue, but that economic conditions like income, unemployment and inflation also have a strong impact on people's subjective well-being (see e.g. Clark and Oswald, 1994; Di Tella et al., 2001; Easterlin, 2001). See Frey and Stutzer (2002) for a review of the literature.

Recent economic studies have included a range of other variables to test their influence on happiness. The political, economic and personal freedoms of a country have been found to be an additional determinant of happiness (Frey and Stutzer, 2000). In addition, differences in environmental quality were discovered to determine happiness. Noise nuisance as well as air pollution has been found to reduce happiness (Van Praag and Baarsma, 2001; Welsch, 2002 and 2006; Rehdanz and Maddison, forthcoming). Rehdanz and Maddison (2005) also found climate variables to have a highly significant effect on average self-reported levels of happiness. Frijters and Van Praag (1998) estimate the effects of climate on both welfare and well-being in Russia finding climate to be an important determinant of households' standard of living.

Research on biodiversity or ecosystem services, as determinants for people's happiness, is limited. Two studies exist using indices to explain differences in subjective well-being. Vemuri and Costanza (2006) derive a national well-being index based on the influence of three indices (human and built capital, social capital as well as natural capital) on life-satisfaction. The indices are measured by the UN's human development index, Freedom House's press freedom rating and the ecosystem services product (Sutton and Costanza, 2002). Zindansek (2007) uses country-level data on happiness for a correlation analysis between happiness and sustainable development. The environmental sustainability index (ESI) as well as the environmental performance index (EPI) are used as indicators for sustainable development. Presenting a slightly different type of analysis, Ferrer-i-Carbonell and Gowdy (2007) analyse the relationship between subjective measures of well-being and environmental attitudes. Environmental attitude is measured as the subjective concern about ozone pollution and species extinction on individual's well-being. They find a negative influence of ozone pollution and a positive for species extinction.

Our approach is different as it is based on objective measures of species diversity and preservation. Furthermore, we are interested in calculating the trade-off between income and levels of biodiversity. Changes in indices are generally more difficult to interpret, as they are composed of different individual key variables with different weights attached to them. Investigating the presence of spatial relationships in the data augments our analysis. To our knowledge, this is the first analysis into the determinants of happiness using a spatial econometric approach.

3 The data

Data on average levels of life-satisfaction (or well-being) are obtained from the 1999/2000 World Value Survey. Life-satisfaction, measured on an integer scale of 0-10, is available for 81 countries. Exploring the data, the least happy countries tend to be countries in Sub-Saharan Africa and Eastern Europe. The happiest countries tend to be in Western Europe and Southern America.

Turning to the independent variables, the choice is based on previous studies' results using country average data. As the number of observations in those studies is generally limited, and this study is no exception, the number of explanatory variables that can be considered in the empirical analysis is restricted.

Our empirical model first and foremost includes GDP per capita in 1995 USD converted using purchasing power parity exchange rates. Further economic variables considered are the annual growth rate in GDP and the percentage of unemployed. Demographic differences are included using life expectancy and the proportion of the population over 65. Population density as well as the proportion of the population living in urban areas is also included.[2] Furthermore, we included four indices describing climate; mean temperature of the coldest

[2] Data on GDP per capita is taken from World Resources Database along with data on population above 65 and life expectancy. The data on the rate of unemployment comes from the International Labor Office. Inflation rates and annual growth rates are obtained from World Development Indicators 2001.

month; mean temperature of the hottest month; mean precipitation of the driest month; mean precipitation of the wettest month; the number of cold months.[3] Climate was found to have a significant effect on people's happiness (Rehdanz and Maddison, 2005).

Species diversity is measured as the number of bird and mammal species as well as the number of threatened species relative to the number of known species in a country expressed as a percentage. The data is obtained from the World Resources Database and refers to the year 2004 for existing species and 2006 for threatened species. By making use of the data we assume that the number of existing and threatened species has not changed significantly between 2000 and 2004 or 2006 respectively. Table 1 in the Annex reports the data on a per country basis. It is apparent that the number of bird and mammal species in a country is highly correlated while there is little correlation between the number of species and the percentage threatened.

4 Empirical analysis

Economic analyses on the determinants of life-satisfaction based on country level data, generally estimate the following model over all *i* countries:

(1) $LIFE-SATISFACTION_i = \alpha + \beta_1 \times GDPCAP_i + \beta_2 \times GDPCAP_i^2 + \ldots + \varepsilon_i$

The explanatory variables are all included in their levels, apart from GDP per capita included as a linear and a quadratic variable in order to capture any possible curvature with respect to the dependent variable. This kind of specification does not take into account the possibility that subjective well-being might be affected by events in neighbouring countries. To explore this possibility the above specification is compared to models incorporating spatial relationships.

The spatial econometrics literature generally distinguishes two types of models: the spatial error model and the spatial lag model (for a detailed introduction see Anselin, 1988).[4] The spatial lag model hypothesises that the value of the dependent variable observed at a particular location is partially determined by a spatially weighted average of the value of the dependent variable as measured at other locations. In the spatial error model the errors associated with any one observation are a spatially weighted average of the errors at nearby sites plus a random error component. Both models are estimated through maximum likelihood techniques. If spatial dependence is present, the assumptions underlying OLS regression are violated. This implies inefficiency in parameter estimation (in case of spatial errors) or to inconsistency and bias (in case of spatial lags). It also implies that tests are invalid. These problems are similar to the ones that arise from ignoring temporal lags in a time series analysis.

The spatial error model, also known as the linear regression model with spatial autoregressive disturbance, is given by:

(2) $Y = \alpha + \beta X + \varepsilon$

where $\varepsilon = \lambda \times W\varepsilon + \mu$, λ is the spatial autoregressive parameter, W is the (NxN) spatial weight matrix and μ a vector of homoskedastic and uncorrelated errors. All the other terms are defined as above.

[3] Population weighted records for temperature and precipitation for each country are taken from Rehdanz and Maddison (2005).
[4] Reviewing the literature on spatial econometrics is beyond the scope of this paper. Anselin (2002) or two special issues of the International Regional Science Review (2003) provide some recent overviews.

The second model, also known as the mixed regressive spatial-autoregressive model, is given by:

(3) $Y = \alpha + \beta X + \rho WY + \varepsilon$

where ρ is the spatial autoregressive parameter and WY is the spatially lagged dependent variable. All the other terms are defined as above.

The elements of the spatial weights matrix can be expressed as the presence or absence (binary weights matrix) or the degree of potential spatial interaction between each pair of locations. A contiguity matrix, for example, could indicate which countries share a land border with others but has the disadvantage that countries separated by a narrow strip of sea are unrelated. Alternative measures of spatial proximity include the use of country centroids. The use of centroids has its shortcomings particularly for large and oddly shaped countries. While the literature provides a numbers of diagnostic tests to investigate whether spatial relationships are present it is more difficult to choose between different weight matrixes. However, empirical studies generally apply weights matrices based on the inverse geographical distances between countries. Spatial weights matrices are commonly row standardised such that their rows sum to unity and have zeros along the leading diagonal.

5 Results

Employing the data described in section 3, table 1 presents the results of the OLS regression for three different model specifications. In model 1, species numbers are omitted while model 2 includes the number of bird species within a country and model 3 the number of mammal species. Additional models are specified below when the spatial econometric approach is applied. The data as well as the summary statistics are presented in table 2 in the Annex. Note that due to missing values the number of total observation is reduced to 73.

All three model specifications pass the RESET test for functional form calculated by including the squared value of the predicted value in an auxiliary regression. Comparing the results of both model specifications, large similarities exist. GDP per capita is statistically significant as well as its square indicating a diminishing marginal utility of income. Higher life expectancy, serving as a proxy for health status, greatly improves life satisfaction. Subjective well-being decreases as the proportion of individuals over the age of 65 increases. Also, as previous studies have found, higher temperatures in the coldest month and lower temperatures in the hottest month increase happiness.

A higher number of existing bird species or a higher number of mammal species increases subjective well-being as well. The coefficient for birds is significant at the ten percent level. It is interesting to note that the estimated coefficient for mammal species is three times higher than the coefficient for bird species, indicating that an additional mammal species would increases life-satisfaction more than an additional bird species. The other variables have the expected sign but are statistically not significant. Excluding insignificant variables does not significantly influence the results.[5]

As noted above, if spatial dependence is present, the assumptions our regression results are based on are violated. This leads to inefficiency and invalid hypothesis testing procedures in the case of spatial error dependence or to bias and inconsistent parameter estimates in the case of spatial lags. The above results are preliminary and suspect, as the presence of a spatial relationship has not yet been analyzed.

[5] We also tested different functional forms including the semi-log and log-log transformation. The results obtained are similar to those of the linear specification.

Table 1: The OLS regression models

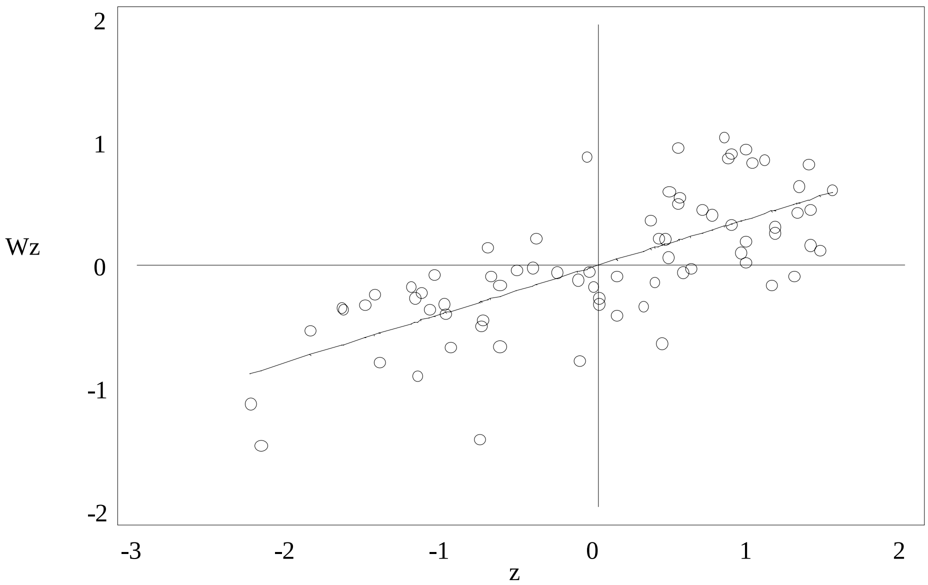
	No Species		Birds		Mammals	
	Coefficient	P-values	Coefficient	P-values	Coefficient	P-values
Constant	3.13E+00	0.009	2.84E+00	0.017	2.84E+00	0.016
GDPcap	1.67E-04	0.000	1.58E-04	0.000	1.55E-04	0.000
$GDPcap^2$	-2.48E-09	0.004	-2.30E-09	0.007	-2.28E-09	0.007
Growth	4.88E-03	0.836	6.34E-03	0.785	7.87E-03	0.733
Unemployed	-6.45E-03	0.479	-3.39E-03	0.709	-2.12E-03	0.816
Popdens	-1.18E-03	0.093	-6.58E-04	0.379	-5.30E-04	0.482
Urban	8.96E-04	0.879	-4.37E-05	0.994	6.94E-04	0.904
Pop65	-6.47E+00	0.016	-5.70E+00	0.032	-5.43E+00	0.041
Lifeexp	4.47E-02	0.008	4.88E-02	0.004	5.03E-02	0.003
MinTemp	4.36E-02	0.002	4.19E-02	0.002	4.55E-02	0.001
MaxTemp	-4.74E-02	0.097	-5.57E-02	0.052	-6.39E-02	0.029
MaxPrec	2.15E-03	0.553	1.35E-03	0.706	1.48E-03	0.677
MinPrec	2.25E-03	0.122	1.39E-03	0.354	1.41E-03	0.338
Birds			4.60E-04	0.083		
Mammals					1.29E-03	0.047
No. Obs.	73		73		73	
R^2	0.7829		0.7938		0.7970	
RESET test (Prob>F)	0.2458		0.4908		0.4483	

Before turning to the statistical hypothesis tests for spatial data analysis, it is helpful to visualize the type and strength of spatial autocorrelation using Moran's I statistic. This statistic determines the extent of linear association between the value for a location with values in neighbouring locations. It is a measure of global spatial autocorrelation. To obtain Moran's I statistic, a weight matrix needs to be specified. We test two different specifications of a spatial weights matrix; the inverse distance between the countries capital cities as well as the inverse distance between the countries centroids. Both matrices are row standardized. A weight matrix based on the inverse distance between capital cities was chosen to better reflect that countries are not evenly populated. This is especially important for large countries like Russia or Canada, where fewer people life close to the Artic Circle.

Figure 1 provides the Moran scatter plot (Anselin, 1995) for our dependent variable where W represents the spatial weights matrix and $z = (Y - \overline{Y}) / sd(Y)$.[6] The positive slope indicates a positive spatial autocorrelation with spatial clustering of high values of the dependent variable around high-value locations and low values of the dependent variable around low-value locations.

[6] The inverse distance between countries capital cities is used as spatial weights matrix. The results for the other weights matrix are very similar. The slope of Moran's I is 0.397.

Figure 1: Moran scatterplot



The indication of a significant pattern of spatial clustering is the first step in analysing spatial data. The next step is to add statistical hypotheses tests for determining which kind of spatial dependence is present in the data. For spatial error and spatial lag dependence two tests are preformed respectively, a simple Lagrange multiplier and a robust Lagrange multiplier test. For details on the tests see Anselin and Hudak (1992) or Anselin et al. (1996). The test statistics for our two models are displayed in table 2.[7]

Table 2: Test statistics for spatial dependence

	No Species		**Birds**		**Mammals**	
	Statistic	P-values	Statistic	P-values	Statistic	P-values
Spatial Weights Matrix = Row Standardised Inverse Distance (capital)						
LM Error	0.299	0.584	0.466	0.495	0.306	0.580
Robust LM Error	2.065	0.151	1.627	0.202	1.367	0.242
LM Lag	6.134	0.013	6.379	0.012	5.120	0.024
Robust LM Lag	7.900	0.005	7.540	0.006	6.181	0.013
Spatial Weights Matrix = Row Standardised Inverse Distance (centroid)						
LM Error	0.239	0.625	0.132	0.716	0.027	0.869
Robust LM Error	3.824	0.051	3.92	0.048	3.518	0.061
LM Lag	7.142	0.008	6.959	0.008	5.501	0.019
Robust LM Lag	10.727	0.001	10.747	0.001	8.992	0.003

[7] The calculations are performed using STATA.

Turning the results investigating the presence of a spatial lag first, both the LM test and the robust LM test are significant at the 5% level for all model specifications and weights matrices. Spatial error dependence is less pronounced. The robust LM test is significant on the ten percent level of significance for models 1 and 3 and at the five percent level for model 2 when the spatial weight matrix is based on distance to centroids.

On the basis of these results, we reanalyse the data applying a spatial lag regression for six model specifications analysing different possibilities to measure species diversity and preservation. The first two specifications are based on the models discussed above. The next two models include the number of species, birds and mammals respectively, as well as the percentage threatened.[8] However, including too many biodiversity indicators leads to problems of multicollinearity – recall that there are 73 observations only. As the number of bird and mammal species are highly correlated, the fifth model corrects the number of mammal species for its correlation with birds.[9] The final regression is based on the previous specification but includes the percentage of both species threatened as additional variables.

The results are shown in table 3. For clarity only the spatial weight matrix based on distance to capital cities is used. Comparing tables 1 and 3 it is apparent that the same set of variables are significant but the level of significance is partly different. The number of bird species is always significant at the five percent level, independent of the model specified. In addition, the percentage of bird specifies threatened is negative and significant indicating that a higher percentage decreases happiness. The number of mammal species is significant but the percentage of mammal species threatened is not. However, the number of mammal species in a country is insignificant if included together with the number of bird species, even if corrected for multicollinearity.

The number of amphibian or reptile species is not or weakly significant (results not shown). From a human perspective, and as the results indicate, mammals and in particular bird species seem to be a better indicator for biodiversity.

Turning to the spatially lagged dependent variable ρ, the variable is highly significant in all specifications indicating that a one percent change in neighbourhood life-satisfaction causes a change in life-satisfaction by about 0.4 percent. The tests for the existence of a spatial lag are all significant, at least at the five percent level of significance and have the right ordering in terms of their magnitude (W>LR>LM; see Anselin, 1988, for more detail).

[8] We considered other indices for biodiversity including the number of species per capita as well as the number of species per area. These turned out insignificant. Note that we also tested whether people in larger countries are happier. The parameter for land area is insignificant.

[9] The auxiliary regression (mammals = a + b*birds) was estimated and the new variable was calculated by replacing mammals with (mammals - b*birds).

Table 3: The spatial lag models

	Birds (1)		Mammals (2)		Birds (3)		Mammals (4)		Birds and mammals (5)		Birds and mammals (6)	
	Number		Number		Number + % threatened		Number + % threatened		Number		Number + % threatened	
	Coeff.	P-value	Coeff.	P -value	Coeff.	P -value	Coeff.	P -value	Coeff.	P-value	Coeff.	P -value
Constant	1.56E+00	0.147	1.69E+00	0.115	1.30E+00	0.217	1.84E+00	0.085	1.61E+00	0.137	1.53E+00	0.150
GDPcap	1.58E-04	0.000	1.56E-04	0.000	1.68E-04	0.000	1.54E-04	0.000	1.56E-04	0.000	1.65E-04	0.000
GDPcap^2	-2.28E-09	0.001	-2.28E-09	0.001	-2.58E-09	0.000	-2.30E-09	0.001	-2.27E-09	0.001	-2.61E-09	0.000
Growth	5.06E-03	0.796	6.27E-03	0.749	3.38E-03	0.859	4.60E-03	0.812	5.73E-03	0.770	4.32E-03	0.819
Unemployed	-2.02E-03	0.792	-1.42E-03	0.855	-4.75E-03	0.532	-3.43E-03	0.658	-1.56E-03	0.840	-4.89E-03	0.520
Popdens	-1.41E-04	0.829	-1.36E-04	0.836	-2.00E-04	0.754	7.13E-05	0.914	-1.11E-04	0.866	-1.48E-05	0.982
Urban	-4.96E-03	0.337	-3.84E-03	0.458	-4.63E-03	0.359	-3.54E-03	0.489	-4.45E-03	0.401	-2.77E-03	0.592
Pop65	-4.79E+00	0.031	-4.72E+00	0.034	-5.85E+00	0.009	-5.12E+00	0.021	-4.72E+00	0.034	-6.00E+00	0.007
Lifeexp	3.12E-02	0.038	3.34E-02	0.029	3.05E-02	0.038	3.88E-02	0.013	3.25E-02	0.034	3.75E-02	0.015
MinTemp	3.42E-02	0.002	3.80E-02	0.001	2.78E-02	0.015	3.77E-02	0.001	3.60E-02	0.003	3.27E-02	0.006
MaxTemp	-4.12E-02	0.089	-4.83E-02	0.055	-2.45E-02	0.331	-4.73E-02	0.057	-4.52E-02	0.081	-3.41E-02	0.185
MaxPrec	1.22E-03	0.687	1.43E-03	0.636	3.67E-03	0.253	1.28E-03	0.666	1.28E-03	0.672	4.10E-03	0.212
MinPrec	5.67E-04	0.661	7.46E-04	0.557	7.25E-04	0.565	7.68E-04	0.540	6.11E-04	0.637	9.29E-04	0.460
Birds	4.40E-04	0.046			4.40E-04	0.041			4.39E-04	0.047	4.65E-04	0.031
Mammals			1.08E-03	0.048			1.31E-03	0.020				
Birds threatened					-4.25E-02	0.055					-4.74E-02	0.057
Mammals threatened							-2.31E-02	0.118			-1.32E-02	0.395
Mammals (auxiliary)									5.36E-04	0.663	1.83E-03	0.160
r (lag)[1]	3.91E-01	0.004	3.61E-01	0.009	4.11E-01	0.002	3.19E-01	0.025	3.76E-01	0.008	3.40E-01	0.018
Test statistics/Regression diagnostics												
Wald-test (chi2(1))	8.286	0.004	6.764	0.009	9.553	0.002	5.052	0.025	7.104	0.008	5.628	0.018
LR test (chi2(1))	7.301	0.007	6.077	0.014	8.303	0.004	4.648	0.031	6.320	0.012	5.117	0.024
LM test (chi2(1))	6.379	0.012	5.120	0.024	7.817	0.005	3.830	0.050	5.225	0.022	4.329	0.037
R^2	0.818		0.817		0.827		0.822		0.818		0.831	
Obs	73		73		73		73		73		73	

[1] Acceptable range for rho: -1.044 < rho < 1.000; spatial weights matrix = inverse distance to capital cities row standardized.

6 The willingness to pay for species preservation

The final step is to determine the value of small changes of species diversity. Employing the information provided in table 3 it is possible to calculate the willingness to pay to avoid a decline in the number of species or an increase in species threatened. However, before turning to the results it is important to note, that the calculation is more involved since spatial lag models are estimated. That is, subjective well-being in country *i* is affected by two components; the marginal change in species diversity in country *i* as well as marginal changes in other countries. The total value of a change in a country's biodiversity is, therefore, the sum of the direct impact from a change in country *i* plus the induced impact if a unit change were induced in every country (for more detail see Won Kim et al., 2003).[10]

Table 4 reports the average willingness to pay for species preservation based on our results displayed in table 3 for all model specifications. For comparison, information on the percentage of income affected by the changes is included as well. On average individuals are willing to pay US$ 4 per capita per year to prevent a unit decline in the number of existing bird species from an average of 582 to 581 species. This is independent of model specification and is equivalent to a reduction in GDP per capita by 0.04 percent on average. The estimates for mammal species are three times larger. People would be willing to pay US$ 11 to US$ 13 to prevent a drop by one species from an average of 176. The willingness to pay numbers to reduce the percentage of threatened bird or mammal species are much higher. However, a decrease of one percent in threatened bird species is relatively large compared to an average of 4.31 percent threatened over all countries. As the calculations are based on our GDP estimates the willingness to pay for individual countries is higher in high-income countries and lower in low-income countries. This is displayed in figure 1 for bird and mammal species using the results of the first two model specifications. Figure 2 shows the number of bird and mammal species for different income groups. The peaks at 6000, 12000, and 24000 coincide with high-income countries. Figures 1 and 2 together show that biodiversity values are driven by ability to pay rather than absolute scarcity.

[10] The spatial multiplier for a unit change in every country by $1/(1-\rho)$.

Table 4: The average willingness to pay for changes in species diversity (US$)[1]

Models	WTP per capita to prevent a decline in species		WTP per capita for a lower percentage of threatened species	
	Birds	Mammals	Birds	Mammals
Birds (1)	4 (0.04)			
Mammals (2)		11 (0.09)		
Birds (3)	4 (0.04)		394 (3.36)	
Mammals (4)		13 (0.11)		232[2] (1.97)
Birds and mammals (5)	4 (0.04)	5[3] (0.04)		
Birds and mammals (6)	4 (0.04)	18[3] (0.15)	459 (3.91)	127[2] (1.08)

[1]1995 USD converted using purchasing power parities. The figures in parenthesis indicate the change in GDP per capita.
[2] Statistically not significant.
[3] The calculation is based on the results of the auxiliary regression as discussed above. The estimates are statistically not significant.

Figure 1: WTP per capita (US$) for different income levels

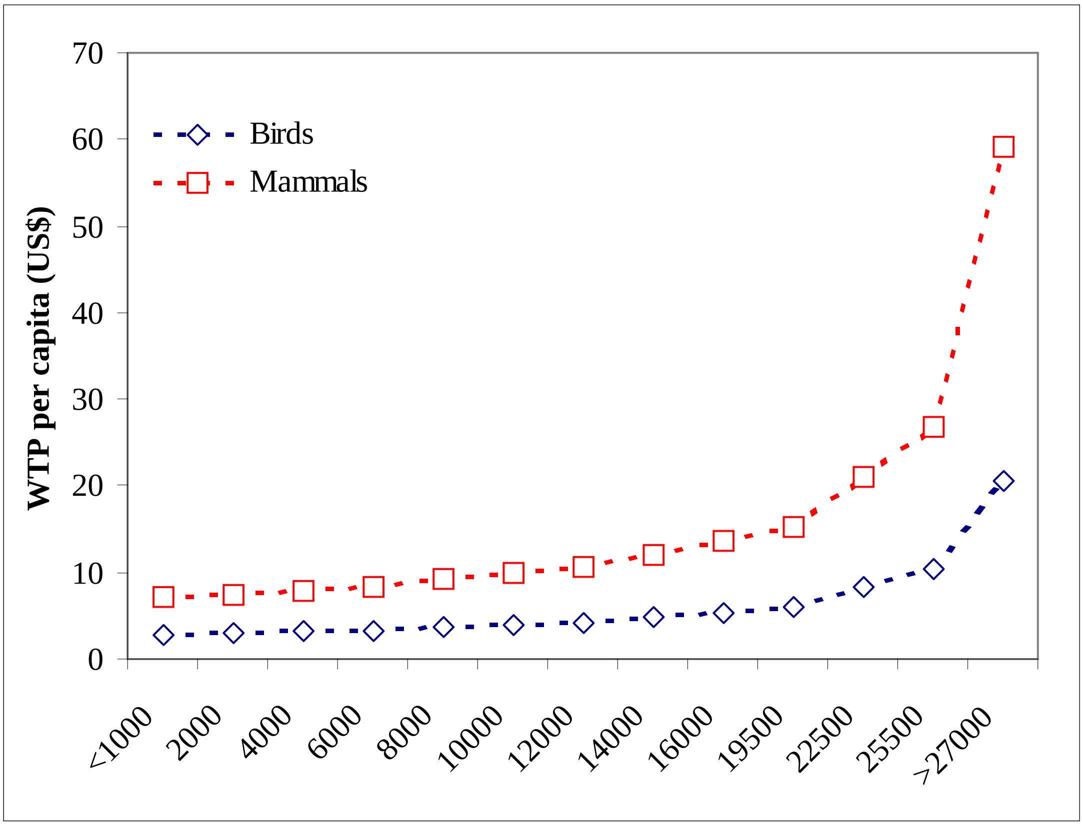
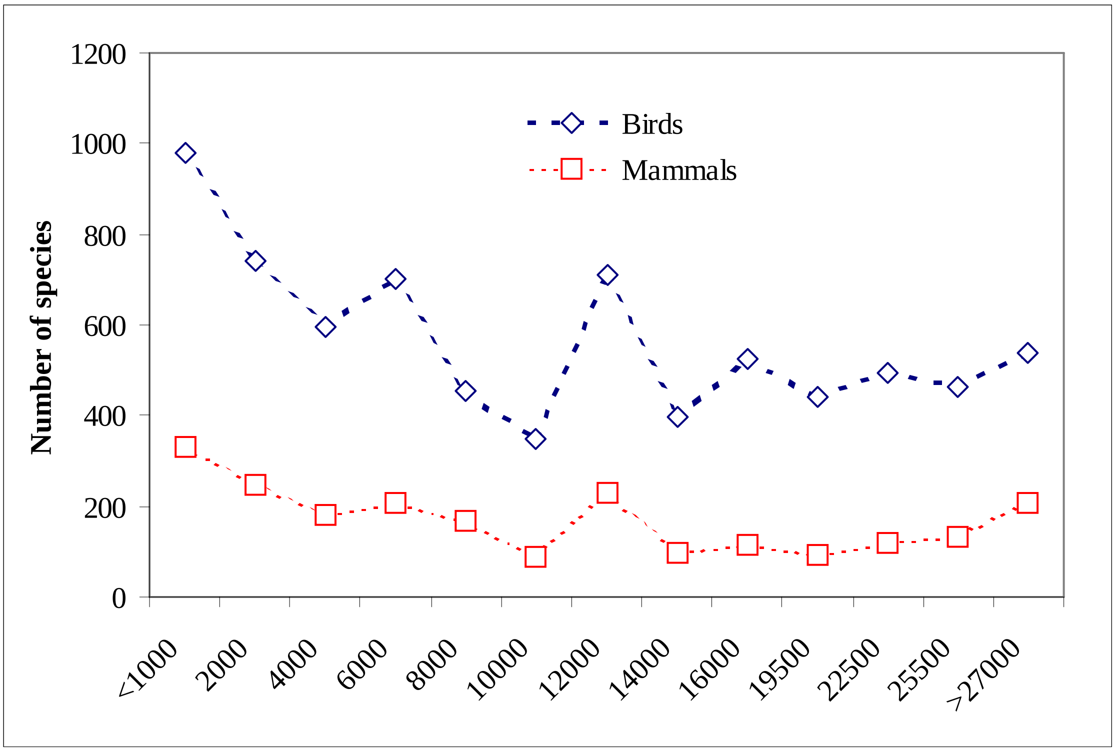


Figure 2: Number of species for different income levels



It is difficult to compare our results to studies reporting economic estimates of the value of species diversity using data based on subjective well-being. The only other study is Ferrer-i-Carbonell and Gowdy (2007) using the concern about species extinction as a subjective measure of species diversity to explain differences in life-satisfaction finding a positive effect for caring more about species extinction. However, we can compare our results to other studies using different approaches. For single bird and mammal species a number of contingent valuation studies exist investigating the willingness to pay to avoid loss, increase the population or the chance of survival of rare, threatened and endangered species.

Loomis and White (1996) is the most recent review the economic literature. They report values of US$ 13 for the red-cockaded woodpecker to US$ 70 for the northern spotted owl. Most estimates range between US$ 20 and US$ 30. These numbers are calculated as the willingness to pay per year per household. Assuming an average household size of three persons per household our estimates based on per capita income are comparable at the lower end to those reported by Loomis and White (1996).

7 Discussion and conclusion

Studies on species preservation investigating use or nonuse values typically rely on revealed or stated preference methods and often focus on single species and specific locations. The total value of species preservation can in that circumstances only be derived by aggregating the various values. As studies are often location specific, time dependent and sensitive to study design, aggregation is a challenge. This paper has demonstrated that the total economic value of species preservation can be derived without investigating preservation values for specific single species. Species diversity is defined as the number of bird and mammal species as well as the percentage threatened. The analysis investigates data on life-satisfaction attempting to explain differences in subjective well-being by reference to amongst other things species diversity. Even when controlling for a large number of other determinants of subjective well-being, the results suggest that people are concerned with lower levels of existing bird and mammal species as well as higher levels of bird species threatened. Accounting for the fact that subjective well-being might be affected by events in neighbouring locations, using a spatial econometric approach, we find a positive and significant relationship. Overall, from a human perspective, bird species seem to be a better indicator for biodiversity.

The limited number of studies investigating the economic value of species preservation based on data of subjective well-being makes comparisons to other research work difficult. As this is the first study relating differences in self-reported levels of life-satisfaction to objective measures of biodiversity, our findings cannot readily be compared. However, our results compare at the lower end to those of other studies applying, for example, the contingent valuation method.

This analysis needs to be extended in several ways. We have restricted the analysis to bird and mammal species implicitly assuming that all species are similarly important. Of course, keystone species might be important to biodiversity. Also, the analysis has been constrained to the country level. The number of existing species as well as the percentage threatened differs not only between countries, but also within countries. It would be interesting to see how this would affect people’s life-satisfaction in the different regions of a country. Furthermore, we have analyzed the effect of differences in biodiversity for one year and did not look at changes over time. An analysis using panel data for individuals rather than country averages would have been superior. All this is deferred to future research.

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Appendix

Table 1: Number of species as well as percentage threatened per country

Country	Birds Number	Mammals Number	Birds threatened Percentage	Mammals threatened Percentage
Albania	303	73	2.97	2.74
Algeria	372	100	3.49	15.00
Argentina	1038	375	5.49	8.53
Armenia	302	78	3.97	14.10
Australia	851	376	7.64	17.02
Austria	412	101	2.91	5.94
Azerbaijan	364	82	3.57	13.41
Bangladesh	604	131	5.30	23.66
Belarus	226	71	2.21	8.45
Belgium	427	92	2.81	9.78
Bosnia and Herzegovina	312	78	2.88	10.26
Brazil	1712	578	7.24	12.63
Bulgaria	379	106	3.17	12.26
Canada	472	211	4.45	8.53
Chile	445	159	7.87	13.84
China	1221	502	7.21	16.73
Colombia	1821	467	4.83	8.14
Croatia	365	96	3.01	7.29
Czech Republic	386	88	2.85	7.95
Denmark	427	81	2.81	4.94
Dominican Republic	224	36	6.25	13.89
Egypt	481	118	3.74	11.86
El Salvador	434	137	0.92	2.92
Estonia	267	67	1.50	7.46
Finland	421	80	2.61	5.00
France	517	148	3.29	10.81
Germany	487	126	3.29	7.94
Great Britain	557	103	2.33	9.71
Greece	412	118	3.64	10.17
Hungary	367	88	3.27	10.23
Iceland	305	33	0.66	24.24
India	1180	422	6.95	21.09
Indonesia	1604	667	7.54	21.89
Iran	498	158	3.82	15.82
Ireland	408	63	2.21	6.35
Israel	534	115	3.93	13.91
Italy	478	132	3.35	9.09
Japan	592	171	9.46	22.22
Jordan	397	93	3.78	12.90
Latvia	325	68	2.77	7.35
Lithuania	227	71	2.20	8.45
Luxembourg	284	66	1.06	4.55
Macedonia	291	89	3.78	10.11
Mexico	1026	544	6.04	13.60
Moldova	203	50	3.94	10.00

Morocco	430	129	3.26	13.18
Netherlands	444	95	2.93	10.53
New Zealand	351	73	22.79	10.96
Nigeria	899	290	1.11	10.34
Northern Ireland	557	103	2.33	9.71
Norway	442	83	1.58	12.05
Pakistan	625	195	5.12	11.79
Peru	1781	441	5.50	10.43
Philippines	590	222	12.54	22.97
Poland	424	110	3.30	11.82
Portugal	501	105	3.19	14.29
Romania	365	101	3.84	14.85
Russian Fed.	645	296	8.22	14.86
Slovakia	332	87	3.92	9.20
Slovenia	350	87	2.29	8.05
South Korea	423	89	8.27	13.48
Spain	515	132	4.08	15.15
Sweden	457	85	2.41	5.88
Switzerland	382	93	2.36	4.30
Tanzania	1056	375	3.69	9.33
Turkey	436	145	3.67	12.41
Uganda	1015	360	1.48	7.78
Ukraine	325	120	4.00	14.17
United States	888	468	8.90	8.76
Uruguay	414	118	6.28	5.93
Venezuela	1392	353	1.80	7.37
Vietnam	837	279	5.02	16.13
Zimbabwe	661	222	1.66	4.50

Source: World Resources Database, own calculations.

Table 2: Definition of variables and summary statistic

Variable	Definition	Mean	Std. Dev.
Happy	Average score of self-reported happiness on a 0-10 scale	6.53	1.18
GDPcap	GDP per capita in 1995 USD converted using purchasing power parities	11750.66	9836.42
Growth	Annual GDP growth rate (%)	3.04	3.41
Unemployed	Annual rate of unemployment (%)	11.23	9.92
Popdens	Population density in persons per square kilometer	125.29	148.43
Urban	Percentage of the population living in urban areas	65.38	19.17
Pop65	Proportion of the population over 65 years	0.10	0.05
Lifeexp	Life expectancy in years	71.45	8.23
MaxTemp	Average mean temperature in hottest month (°C)	4.88	11.46
MinTemp	Average mean temperature in coldest month (°C)	20.81	5.01
MaxPrec	Average mean precipitation in wettest month (mm)	38.04	27.13
MinPrec	Average mean precipitation in driest month (mm)	136.39	91.96
Birds	Number of bird species	582.12	374.84
BirdsThreat	Number of bird species threatened divided by the number of known bird species in a country (%)	4.31	3.14
Mammals	Number of mammals species	176.22	146.15
MammalsThreat	Number of mammal species threatened divided by the number of known mammal species in a country (%)	11.27	4.82

Source: see text