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Economic modeling of biodiversity in the scenario of global change: results from a European study on forests

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Abstract

In the scenario of global change, it becomes increasingly urgent to find more cost-effective solutions to halting the loss of biological species, for if current trends continue, an estimated 24 percent of mammal species and 12 percent of bird species face a 'high risk of extinction in the near future' (FAO, 2001). In turn, biodiversity loss will be transformed into welfare losses to human due to its important ecological functioning, in terms of supporting the provisioning of ecosystem goods and services. The value of biodiversity thus lies in the value of the ecological services supported by the interaction between the organisms, populations and communities of the natural environment, and the value of biodiversity loss reflects the sensitivity of ecological service to both the depletion and deletion of species (Ehrlich, 1988). For this reason, the present paper is aimed to test formally the econometric significance of the effect of biodiversity on the economic value of forest ecosystem goods and services in Europe in the context of climate change. Therefore, the undertaken analysis shall be operationalized by the calculation of the reduced/gained quantity, and quality, of these forest ecosystem services resulting in loss/gain of human welfare under alternative IPCC scenarios. If the empirical evidence rejects the null hypothesis, then we proceed in estimating the magnitude of the loss/gain of human welfare

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involved in alternative IPCC scenarios. However, it should be noticed that the present paper is more an experimental exploration than a theoretical or an empirical investigation.

1. Introduction

It is widely recognized that biodiversity conservation is essential not only for biological stability but also for its impacts on economic activities either directly or indirectly. However, like all other policies, conservation policy implementations incur various types of costs, such as operational costs and opportunity costs. Economic reasoning is not to arbitrarily allocate the limited resource for conservation purpose, but to pursue the cost-effective policy options within certain budget constraints. For this reason, it is important to incorporate the value of biodiversity into a cost-benefit analysis of the conservation decisions. The intention of revealing the true value of biodiversity is not new in environmental economics. As a matter of fact, many specific economic tools, such as cost-benefit analysis and valuation methods have been developed and greatly practiced over the last decades to estimate monetary and non-monetary values of the biodiversity of interests. The main focus of the literature has been concentrated on the estimation of people's willingness to pay for conserving a certain type of biological species due to its important ecological existing value (e.g. the rare and extinction biological species for research or educational use) or due to its high commercial value (e.g. the pharmaceutical development). However, due to the fact that the relation between the diversity of organisms and ecosystem functions is highly non-linear (Perrings et al. 1995), it becomes problematic to reach a good understanding of the complex linkages between biodiversity and the associated welfare effects, which makes the results from the previous valuation exercises a continuing debate.

In the scenario of global change, it becomes increasingly urgent to find more cost-effective solutions to halting the loss of biological species, since if current trends continue, an estimated 24 percent of mammal species and 12 percent of bird species face a 'high risk of extinction in the near future' (FAO, 2001). In turn, biodiversity loss will be transformed into welfare losses to human due to its important ecological functioning, in terms of supporting the provisioning of ecosystem goods and services. The value of biodiversity thus lies in the value of the ecological services supported by the interaction between the organisms, populations and communities of the natural environment, and the value of biodiversity loss reflects the sensitivity of ecological service to both the depletion and deletion of species (Ehrlich, 1988). For this reason, the present paper is aimed to test formally the econometric significance of the effect of biodiversity on the economic value of forest ecosystem goods and services in Europe in the context of climate change. Therefore, the undertaken analysis shall be operationalized by the calculation of the reduced/gained quantity, and quality, of these forest ecosystem services resulting in loss/gain of human welfare under alternative IPCC scenarios. If the empirical evidence rejects the null hypothesis, then we proceed in estimating the magnitude of the loss/gain of human welfare involved in alternative IPCC scenarios. However, it should be noticed that the present paper is more an experimental exploration than a theoretical or an empirical investigation.

The paper is organized as follows. Section 2 describes the construction of a database for the undertaken analysis. Section 3 explains the choice of the econometric model in the paper. Section 4 reports the preliminary results from the econometric analysis. Section 5 discusses the limitations of present analysis and the possibilities to improve the study.

2. Data description

In the present research, the first hand data are obtained from a previous CLIBIO project, which provides the value estimation of three categories of ecosystem goods and services provided by European forests under different IPCC scenarios. About 34 European countries have been included in the CLIBIO project, but we will tackle here only the 17 most economic developed countries due to limited data on some of the indicators described below.

- **Climate change impact**

To investigate the potential economic effects of climate change and different policy scenarios on forest ecosystem values in European countries we rely on the IPCC storylines. The four scenario families of the Fourth Assessment Report (A1, A2, B1 and B2) are assessed[2], which differ for their assumptions on carbon dioxide emissions, global average surface temperature increase and patterns of economic development (see Table 1). Scenario A1 and A2 are the more economic oriented scenarios. In Scenario A1 different combinations of fuel are also considered (scenario A1F1). Scenario A2 represents a world differentiated into a series of consolidated economic regions characterized by low economic, social, and cultural interactions, uneven economic

[2] Scenarios from the A1 family could not be evaluated for lack of data on the trends of GDP per capita and total population in the IIASA GGI Scenario Database.

growth and with the income gap between industrialized and developing countries that does not narrow. Scenario A2 is often used by the European Commission as the baseline scenario to which the other scenario analyses are compared. In scenario B1, environmental and social consciousness is combined in a more sustainable development. Although no specific climate policy is included, the technological shift towards renewable energy plays an important role. A more equitable income distribution than in scenario A2 is achieved. Similarly to scenario B1, scenario B2 is environmentally oriented with a focus on both environmental and social sustainability.

Table 1. The specifications of the four IPCC scenario families

Scenarios by 2050	Climatic model (HadCM3)			
	A1FI	A2	B1	B2
Storyline	Global economic	Local economic	Global environmental	Local environmental
CO_2 concentration (ppm)	779	709	518	567
Δ Temperature (°C)	4,4	2,8	3,1	2,1
Socio-economic dimensions	High savings, high rate of investments & innovation	Uneven economic growth, high per capita income	High investment in resource efficiency	Human welfare, equality, environmental protection

Source: adapted from: IPCC 2001; Schroeter et al. 2005

Government policies and business strategies show a trend toward local self-reliance and stronger communities while international institutions decline in importance. Technological development plays a smaller role than in scenario B1 and innovations are also regionally more heterogeneous. For the four scenarios, the average global surface air temperature increase ranges between 2.1 and 4.4 °C for scenarios B2 and A1F1 respectively.

- **The mapping of the geo-climatic regions**

In the present paper, the 17 European countries are mapped in terms of three geo-climatic zones, i.e. Mediterranean Europe (4 countries), Central-Northern Europe (10 countries) and Scandinavian Europe (3 countries), corresponding to different latitude intervals. The country classification is reported in Table 2.

Table 2. Geographical grouping of the 34 European countries

Geographical groupings	Latitude classification	Countries included
Mediterranean Europe	Latitude N35-45°	Greece, Italy, Portugal, Spain
Central-Northern Europe	Latitude N45-65°	Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, Switzerland, Denmark, United Kingdom
Scandinavian Europe	Latitude N65-71°	Finland, Norway, Sweden

Source : Ding et al. (2009)

The underlying idea of this grouping is based on the assumption that particular types of forests in each country are closely determined by the specific climate conditions, which have been classified in four main groups according to the range of latitude. This way thus allows us to identify the predominant tree species as well as the respective contributions to the local economy at both national and larger regional scales. From an ecological view point, different tree species can play different roles in ecosystem regulating and life supporting functions, which will ultimately influence the provision of forest ecosystem goods and services. Whereas from an economic perspective, different tree species may deliver very different flows of ecosystem goods and services, which thus refer to the various levels of economic importance and respective welfare impacts. Finally, and from a geo-climatic perspective, this way of grouping may also allow us to explore how sensitive are different tree species when reacting to the changes of climate, including increase of temperature and precipitation rate in the countries under consideration.

- **Socio-demographic characteristics of the country**

The changes in GDP density and population are derived from the work of the Center for International Earth Science Information Network (CIESIN, 2002), one of the main IPCC data distribution centers. Thus, both of their GDP and population projections are computed with previous assumptions on the climatic variables under different scenarios. Furthermore, we elaborated data and obtained a variable of GDP density to be introduced in the regression model. This variable is used as a proxy of the value of each hectare of the country's land can produce, which is assumed to have impacts on the composition of the revenues derived from forest ecosystem goods and services in a country's economy. Table 3 contains the values of context variables that are calculated based on the countries' socio-demographic characteristics under different IPCC scenarios.

Table 3. Values of context variables in climate change scenarios (2050)

Country	Population ('000)[a]				GDP density, US$/ha			
	A1	A2	B1	B2	A1	A2	B1	B2
Greece	10,042	10,042	10,042	9,013	119,937	90,878	58,372	48,353
Italy	48,538	48,538	48,538	42,092	427,560	337,305	244,122	189,860
Portugal	9,910	9,910	9,910	8,701	105,822	82,384	56,373	44,260
Spain	35,270	35,270	35,270	31,755	137,962	108,373	76,387	59,670
Austria	7,290	7,290	7,290	7,430	99,156	79,157	80,711	60,761
Belgium	10,677	10,677	10,677	9,763	1,217,250	915,841	733,113	481,065
France	68,487	68,487	68,487	58,370	260,737	191,225	156,571	113,581
Germany	79,429	79,429	79,429	69,542	554,191	431,200	350,406	251,120
Ireland	5,790	5,790	5,790	3,809	346,525	315,385	191,691	147,679
Luxembourg	773	773	773	461	440,115	351,880	273,439	238,066
Netherlands	17,474	17,474	17,474	14,956	6,340,847	1,777,251	2,301,494	1,468,069
Switzerland	6,317	6,317	6,317	6,935	372,534	301,518	279,548	220,593
Denmark	5,588	5,588	5,588	5,234	1,043,923	497,384	794,426	325,565
United Kingdom	65,243	65,243	65,243	58,733	1,609,791	1,162,652	918,542	581,978
Finland	5,200	5,200	5,200	5,172	24,298	19,192	21,416	16,406
Norway	5,391	5,391	5,391	4,694	57,691	46,448	58,075	41,048
Sweden	8,701	8,701	8,701	9,574	33,922	27,066	23,769	21,465

Notes: [a] Source: CIESIN (2002)

- **Values of ecosystem goods and services**

Values of ecosystem goods and services are obtained from a previous study[3] on European forest and classified into three categories: i.e. provisioning, regulating and cultural services suggested by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005). In particular, forest provisioning services contains the benefits derived from production of timber and other wood forest products, regulating services provides non-monetary benefits from CO2 sequestration in the forest, and cultural services provides humans with direct incomes from the related tourism industries and non-monetary benefit from the enjoyment of existing forests. These values have been estimated using a hybrid valuation approach that combines various valuation techniques and expressed in 2005 $. All value categories are

[3] All these results are embedded in Ding et al. (2009).

expressed in 2005$. The economic valuations of each three type of EGS are summarized in Table 4-6.

Table 4. Total Values of WFPs in Europe: Projections for 2050

Note: TV means Total Value (unit: 1000$/yr)

Countries	Initial 2005	A1 Storyline	A2 Storyline	B1 Storyline	B2 Storyline
Greece	141,392	100,958	103,944	165,710	158,460
Italy	3,225,397	1,465,385	1,447,371	1,883,929	2,082,211
Portugal	1,858,800	1,759,507	1,843,519	2,279,211	2,300,916
Spain	3,337,363	2,211,767	2,196,647	2,870,406	3,232,732
Austria	5,990,309	7,509,746	7,236,331	5,186,138	6,896,760
Belgium	4,807,036	4,831,506	3,342,974	3,512,916	4,305,723
France	7,203,747	4,909,314	5,280,568	5,683,882	6,210,732
Germany	16,636,208	12,740,815	12,711,840	12,619,732	14,905,826
Ireland	505,887	299,256	249,506	303,507	384,188
Luxembourg	216,228	107,068	104,397	137,171	124,939
Netherlands	3,692,598	2,568,423	9,288,827	5,134,256	6,375,137
Switzerland	2,003,354	2,119,888	2,038,861	2,094,878	1,847,261
Denmark	465,205	438,826	1,066,933	410,418	713,966
United Kingdom	2,665,438	2,997,286	2,925,477	2,543,039	3,360,900
Finland	12,067,126	15,912,943	15,332,695	12,984,700	14,183,474
Norway	1,863,442	2,020,537	1,625,117	1,476,321	1,707,585
Sweden	13,199,556	17,606,054	16,984,380	17,310,323	16,051,787

Table 5. The total value of Forest Carbon-Mitigation in Europe: projection for 2050

(Million $ 2005)

Country	Initial 2005	A1 2050	A2 2050	B1 2050	B2 2050
Greece	9,051.88	2,695.08	2,774.84	4,423.72	4,230.10
Italy	4,768.42	2,617.49	2,628.34	3,235.96	3,075.40
Portugal	613.50	272.97	263.57	363.79	336.72
Spain	2,911.01	1,796.10	1,783.60	2,268.68	2,217.54
Austria	3,372.24	3,690.15	3,748.32	3,985.23	3,900.20
Belgium	363.97	185.04	202.82	222.24	212.11
France	7,019.92	6,408.27	6,749.74	7,465.75	7,096.90
Germany	6,703.30	3,971.90	4,144.03	4,968.52	4,751.76
Ireland	198.05	139.58	135.55	169.34	173.89
Luxembourg	196.97	89.06	86.99	114.89	104.04
Netherlands	184.38	71.39	166.14	113.96	124.09
Switzerland	1,034.97	1,349.45	1,357.10	1,502.47	1,428.08
Denmark	186.02	111.48	207.77	135.24	159.94
United Kingdom	1,232.40	667.96	796.38	913.03	923.88
Finland	5,486.66	2,459.20	2,428.93	2,831.26	2,538.66
Norway	1,740.41	692.55	669.51	730.88	723.54
Sweden	7,815.69	3,878.60	4,042.99	5,746.20	4,369.99

Table 6. Total Cultural Value of forest in Europe *1000$ 2005*

Countries	Initial 2005	A1 2050	A2 2050	B1 2050	B2 2050
Greece	390,479.14	238,544.04	246,695.05	565,811.95	489,873.63
Italy	1,038,537.13	868,614.18	862,772.01	1,756,185.73	1,619,486.06
Portugal	393,705.38	225,828.49	227,304.63	489,369.74	447,026.03
Spain	1,864,454.62	1,254,298.70	1,251,227.60	2,615,143.98	2,400,993.54
Austria	401,927.09	221,914.12	206,490.25	308,292.81	217,677.28
Belgium	69,416.20	22,031.32	21,751.37	41,365.98	33,508.31
France	1,618,740.00	632,262.69	640,386.92	1,190,646.03	872,430.03
Germany	1,152,704.40	420,927.76	401,860.51	752,818.45	558,369.16
Ireland	69,624.34	18,508.55	15,106.10	37,835.50	26,104.99
Luxembourg	9,054.29	3,366.94	3,128.19	6,128.23	3,741.45
Netherlands	37,986.38	6,328.83	16,772.91	19,717.65	16,430.86
Switzerland	127,072.23	83,135.59	76,300.31	125,282.66	84,391.30
Denmark	52,036.13	17,435.51	27,206.91	30,213.34	37,678.76
United Kingdom	296,085.59	83,734.95	86,197.46	193,520.16	156,099.31
Finland	2,341,625.95	462,413.82	458,793.75	1,039,355.52	833,063.88
Norway	976,926.35	164,371.37	159,994.30	323,482.97	281,011.54
Sweden	2,864,901.29	576,080.03	565,823.59	1,628,809.84	1,107,477.20

- **Forest ecosystem and biodiversity indicators**

The diversity of life is generally defined at three levels: genetic species, ecosystem and functional (Nunes and van den Bergh, 2001). In the present paper, term “biodiversity” refers to five different species, including trees, plants, birds and reptiles that can be found within the boundary of forest ecosystems in Europe. The variation in biodiversity was included in the scenario analysis through the estimates of the variation of the total number of tree species, bird species, plant species and reptiles in EU countries as estimated in the frame of the Advanced Terrestrial Ecosystem Analysis and Modelling project (Schroeter, et al. 2004). However, due to the fact that ATEAM only explored their biodiversity investigation in the 17 most developed European countries and that the characteristics of biodiversity are always site-specific, we will only include these countries into our database. This matter of fact, however, results in a 50 percent reduction of the total number of observations that we may obtain. For example, Table 7 shows the variation of tree species in 17 European countries in the IPCC scenarios with respect to the baseline.

Table 7. The Variation of tree species in the IPCC scenarios with respect to baseline in 2000

Countries	A1	A2	B1	B2
Greece	88.95%	120.71%	107.62%	126.47%
Italy	101.10%	130.24%	121.77%	136.15%
Portugal	59.38%	73.24%	69.22%	68.00%
Spain	71.14%	86.58%	89.37%	93.93%
Austria	112.88%	149.33%	152.23%	154.06%
Belgium	104.69%	154.65%	174.24%	175.65%
France	63.20%	98.81%	106.47%	120.45%
Germany	110.21%	140.45%	155.86%	151.05%
Ireland	132.03%	157.17%	176.53%	177.28%
Luxembourg	72.73%	127.27%	152.84%	155.12%
Netherlands	156.80%	172.12%	182.55%	182.39%
Switzerland	87.83%	126.61%	133.80%	132.89%
Denmark	131.55%	146.08%	158.86%	155.29%
United Kingdom	132.58%	152.98%	164.82%	164.99%
Finland	144.13%	156.20%	170.62%	167.82%
Norway	144.93%	158.44%	163.56%	167.16%
Sweden	136.37%	148.28%	160.40%	157.52%

3. The construction of composite biodiversity indicator

3.1 The NCI approach

The construction of composite biodiversity indicator is built-up on the idea of Natural Capital Index (NCI), an indicator for the biodiversity of habitats developed by Ten Brink (2000). One of the main advantages of NCI is that it entails both the changes in "nature quality" as the change in area of ecosystems. In other words, NCI considers biodiversity of an ecosystem as the stock of its characteristic species including their corresponding abundances. The loss of biodiversity is characterized by the decrease in abundance of many species and increase of a few others, due to human interventions. NCI is a function of changes in the area of ecosystems and the changes in abundance of a core set of species within the remaining ecosystem. The latter is called "nature quality", the former factor "ecosystem quantity". Therefore, the NCI is calculated by the following formula:

$$NCI = ecosystem\ quantity \times ecosystem\ quality$$

where both quality and quantity are expressed relative to an “optimal” or “intact” baseline. The concept is based on the assumption that biodiversity loss can be modelled as a process driven by two main components: habitat loss due to conversion of natural areas into agricultural fields or urban area, and the degradation of the remaining habitat patches, caused by overexploitation, pollution, fragmentation, invasive species, etc. Thus, NCI summarizes the extent to which a landscape has preserved its original (baseline) natural capital. Combining habitat quality and quantity into one indicator, NCI relies on a hypothetical equivalence between smaller intact, and larger, but degraded patches in terms of ecological value.

3.2 A Composite Forest Biodiversity Indicator (CFBI) vs. A Synthetic Biodiversity Indicator (SBI)

As in our analysis, we first adopted NCI approach as a framework for constructing ecological state indicators with existing implementations for global change driver data (i.e. the climate change impacts). Based on the data available, we first calculated separately the quality change (in terms of species abundance) of all five species that projected in the four IPCC scenarios against the current situation in 2005, and then aggregate them into a general indicator, which describes the overall ecological state of the forests embedded with the detailed information on species. The computation results are therefore equal to the "nature quality" in the NCI term. On the other hand, we are also able to compute the changes of forest areas in the future scenarios against the present situation. This is used as a proxy of the "ecosystem quantity" in the NCI, assuming that forest ecosystem will extend or shrink in the same proportion as the size of forest. Finally, an average status of biological conditions of forests in different IPCC scenarios in 2050 with respect to 2005 can be estimated by multiplying quality and quantity indicators. In mathematical terms, this calculation is expressed in equation 1.

$$CFBI_{Aggregated}^{IPCC} = \prod \left(FBI_{Tree}^{IPCC}, FBI_{Bird}^{IPCC}, FBI_{Plant}^{IPCC}, FBI_{Herptile}^{IPCC} \right) \times \Delta ForestArea^{IPCC} \qquad (1)$$

where the FBI_{Tree}^{IPCC} refers to the Forest Biodiversity Indicator (*FBI*) on tree species. It is calculated in terms of the change of abundance of tree species in the 2050 IPCC scenarios with respect to 2005. In a similar fashion, $FBI_{Bird}^{IPCC}, FBI_{Plant}^{IPCC}$ and $FBI_{Herptile}^{IPCC}$ are calculated as *FBIs* on bird species, plant species and herptile species, respectively. Moreover, changes in forest areas are calculated by taking into account the difference between the forest areas in the four different future scenarios and in the present. Both changes of biodiversity and forests are expressed in percentage changes, so thus the aggregated Composite Forest Biodiversity Indicator (CFBI).

Alternatively, we compute a synthetic biodiversity indicator, a production of the percentage changes of each of the four biodiversity indicators with respect to the initial year, 2005 – see equation 2. Different from the *CFBI*, the *SBI* is a sole quality indicator for describing the changes of biological species over time. Therefore, if we run the regression model using the CFBI and the SBI separately, we are able to explain whether our own created indicators can give the most compress information on the variance of indicators. The computed CFBI and SBI are reported in Table 8.

$$SBI_{Aggregated}^{IPCC} = \prod \left(FBI_{Tree}^{IPCC}, FBI_{Bird}^{IPCC}, FBI_{Plant}^{IPCC}, FBI_{Herptile}^{IPCC} \right) \qquad (2)$$

Table 8. The projection of CFBI and SBI under the IPCC scenarios

	the CFBI				the SBI			
Country	A1	A2	B1	B2	A1	A2	B1	B2
Greece	12.2%	20.0%	101.7%	105.6%	87.3%	127.8%	100.6%	124.9%
Italy	43.9%	61.8%	211.8%	266.2%	89.6%	132.1%	113.0%	131.9%
Portugal	7.7%	9.4%	41.8%	40.1%	70.8%	85.8%	76.4%	70.7%
Spain	14.5%	17.4%	78.9%	84.5%	70.8%	87.2%	88.9%	90.0%
Austria	474.7%	675.1%	662.2%	831.2%	134.1%	209.1%	201.6%	206.4%
Belgium	35.8%	69.1%	215.5%	434.0%	92.5%	154.6%	180.1%	170.8%
France	42.9%	102.6%	275.2%	431.1%	48.3%	90.3%	99.1%	109.2%
Germany	62.6%	84.3%	250.2%	339.5%	92.3%	123.1%	144.9%	131.8%
Ireland	27.7%	20.3%	191.5%	206.2%	145.3%	197.5%	231.4%	222.9%
Luxembourg	44.4%	78.5%	337.5%	210.5%	60.9%	118.9%	169.5%	154.3%
Netherlands	4.6%	328.8%	131.1%	301.7%	155.9%	186.6%	190.3%	184.2%
Switzerland	399.7%	613.5%	975.7%	931.5%	57.3%	101.8%	108.8%	102.3%
Denmark	61.0%	522.3%	110.1%	1375.1%	130.4%	155.3%	193.7%	173.4%
United Kingdom	33.0%	57.8%	179.4%	407.4%	139.1%	178.7%	196.6%	182.8%
Finland	113.5%	103.3%	81.7%	85.6%	263.8%	252.3%	281.4%	257.9%
Norway	55.6%	44.0%	19.8%	30.4%	244.9%	220.1%	219.8%	214.4%
Sweden	83.7%	76.5%	160.7%	90.2%	181.0%	180.9%	205.6%	195.0%

As we shall see in Table 8, climate change impact on the change of biodiversity varies depending on the IPCC scenario and on the country where biodiversity is hosted. Despite the difference in the magnitude of biodiversity changes, the table depicts some general patterns for the countries that are located in the same geo-climatic regions. For instance, under an A1 scenario Mediterranean countries, including Greece, Italy, Portugal and Spain will suffer from a stronger decrease in the *CFBI* indicator than in the *SBI*. This means that the land use change of forests can have a strong impact on the overall ecosystem health.

4. The Econometric Model

4.1 The Model specification

The value of the type of ecosystem goods and services has been considered as the dependent variable (standardized to 2005US$ per annum) to be explained as a function of a set of explanatory variables, including the GDP density (i.e. GDP per square kilometers), population, the size of forest and the status of forest biodiversity in each of the specific geo-climatic regions. The dataset is arranged in a panel data fashion[4] with full set of information consistent with four IPCC scenarios. The equation below was a generalized form of the econometric model. In practice, we ran the model separately, in terms of the three different types of ecosystem goods and services under consideration. This was due to the fact that the three value components provided by forests have been estimated with different microeconomic tools, ranging from market-based methods to nonmarket-based methods. Pooling all data in one regression exercise could lead to biased results. Moreover, as regards the model specification, we considered a semi-logarithmic model – see equation 3, expecting that one percentage change in biodiversity variable in the IPCC scenarios with respect to the baseline, will result in proportional changes in the value of considered ecosystem services. Thus, the coefficients represent elasticities.

$$\begin{aligned}\ln(y_{it}^{EGS}) = {} & GDP\_Density_{it} \cdot \beta_1 + Population_{it} \cdot \beta_2 + Forest\_Area_{it} \cdot \beta_3 + \\ & + CFBI\_GeoDUMMY_{it} \cdot \beta_4 + \varepsilon_{it}\end{aligned} \qquad (3)$$

[4] Strictly speaking, data for all variables in the model were not collected on a regular time intervals, rather they are point estimates in one future time, 2050, but under different scenarios.

where EGS refers to the type of ecosystem services under consideration. It can be either, provisioning service, regulating service, or cultural service. GDP_Density is a proxy variable to measure the average land productivity of geo-climatic region *i* in scenario *t*, i.e. how much of GDP can be produced by each hectare of the land. In other words, it tells how valuable is the country's land in terms of its contribution to the GDP. *GeoDUMMY* is a dummy variable indicating, in which of the three geo-climatic regions, forests are located. Thus, $CFBI\_GeoDUMMY_{it}$ makes the composite forest biodiversity indicator very 'site specific' at a aggregated regional level. Finally, the equation also contains an error term ε_{it} that is assumed to be well-behaved.

$$\ln(y_{it}^{EGS}) = GDP\_Density_{it} \cdot \beta_1 + Population_{it} \cdot \beta_2 + Forest\_Area_{it} \cdot \beta_3 + \\ + SBI\_GeoDUMMY_{it} \cdot \beta_4 + \varepsilon_{it} \quad (4)$$

4.2 The null hypothesis testing

Assessing the impact of biodiversity on the different economic values of forest ecosystem goods and services, i.e. (i) the value of forest provisioning services (PS), (ii) the value of forest regulation services (RS) and (iii) the value of forest cultural services (CS), we are interested in the null hypothesis stating that biodiversity does not have impacts on the proportional changes of the respective values, i.e. $\hat{\beta}_4^{EGS} = 0$. Therefore, if the empirical evidence rejects the null hypothesis, the obtained $\hat{\beta}_4^{EGS}$ coefficient can be used to explain the role of biodiversity (in terms of either the composite biodiversity indicator or the synthetic biodiversity indicator) on the value of forest EGS. For instance, $\hat{\beta}_4^{EGS} \succ 0$ signals a positive link between biodiversity and human wellbeing. In this context, human wellbeing expressed in monetary and evaluated in forest services, regardless the different IPCC storylines. From the economic point of view, $\hat{\beta}_4^{EGS} \succ 0$ means that biodiversity is responsible for a positive impact on human wellbeing. Therefore, the policy implication is that more management efforts should be placed on the biodiversity conservation activities as it can result in positive impacts on overall social economy independent of the continual change of climatic conditions.

4.3 Preliminary results and regression diagnostics

Despite the limited data availability, our results have shown some interesting results. For instance, changes in biodiversity status may have significant impacts on the marginal value of ecosystem services, but the magnitudes are expected to vary depending on the type of ecosystem services under consideration and corresponding geo-climatic regions. Given our initial interests on the two different biodiversity indicators, we run separately the two econometric models described in equation (3)-(4), using ordinary least squares (OLS), for each of the ecosystem goods and services region by region. As a consequence, we may compare the two biodiversity indicators to see which is more relevant to explain the change of value of ecosystem goods and services caused by climate change impact on biodiversity. Since the expressed value terms are directly or indirectly associated to the level of human welfare, the obtained coefficients of biodiversity variable can play a role in explain the gain/loss of human welfare under different climate change scenarios.

Table 9 reported the econometric results for the four Mediterranean countries. A series of diagnostic tests are performed in order to investigate the robustness of the regression results. The normality of residuals was checked by means of the Kernel density plot of the residuals (see Figure 1) and then a standardized normal probability (P-P) plot (Figure 2) was used to plot the quantiles of a variable against the quantiles of a normal distribution (Figure 3).

Table 9. The econometric results for the four Mediterranean countries

Source	SS	df	MS
Model	17.8963723	4	4.47409309
Residual	13.0444339	15	.869628926
Total	30.9408062	19	1.62846349

Number of obs	20
F(4, 15)	5.14
Prob > F	0.0082
R-squared	0.5784
Adj R-squared	0.4660
Root MSE	.93254

logpv_medi	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
gdpd_medi	.0063543	.0213488	0.30	0.770	-.0391497	.0518583
pop_medi	.0000252	.0000357	0.71	0.491	-.0000509	.0001014
fa_medi	.0000715	.0000726	0.98	0.340	-.0000833	.0002263
sbi_medi	-3.067757	1.144983	-2.68	0.017	-5.508231	-.6272825
_cons	8.590998	1.119647	7.67	0.000	6.204528	10.97747

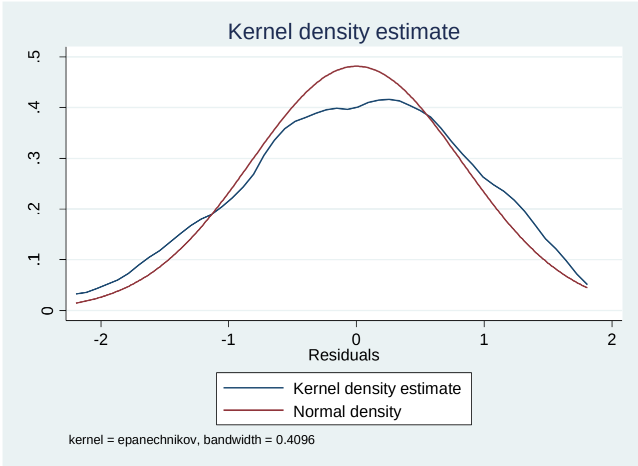

Figure 1. kernel density plot of residuals

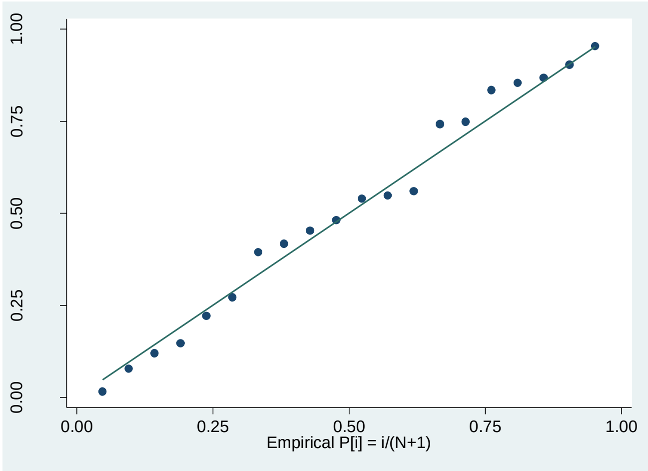

Figure 2. Standardized normal probability plot

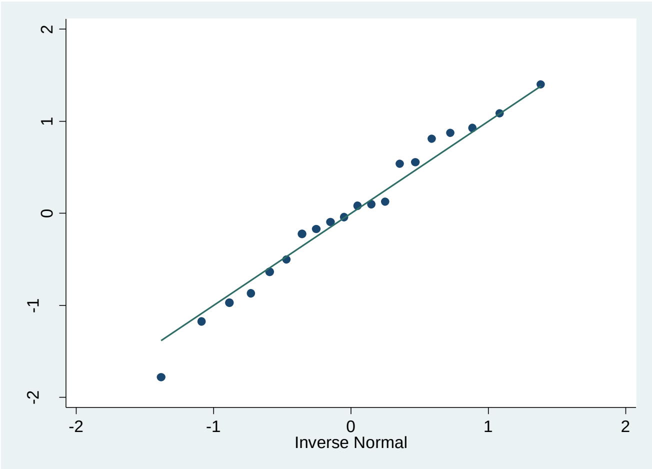

Figure 3. Quantiles of residuals plotted against quantiles of normal distribution

The Kernel density plot and quantiles of residuals show a certain deviation from the normal distribution in the middle range of data and in the lower tail. Nevertheless the distribution seems quite close to a normal distribution. This result is also confirmed by the Shapiro-Wilk test, from which a Prob>z=0.92836 is large enough to indicate that we cannot reject that **sbi_medi** is normally distributed.

Despite our experimental investigation is still at a very early stage, the biodiversity variable of our interests in the model, i.e. the synthetic biodiversity indicator, does show statistical significance in explaining the value of forest provisioning services (e.g. timber products). What is more interesting in the result is that the negative coefficient on biodiversity indicator suggests that one percentage of improvement in biodiversity quality is associated with a 2.68 percentage decrease in the value of forest provisioning services. This result is not surprising because increasing in biodiversity quality is usually the result of a series of sustainable management strategies. For example, one of the policy implications for forest conservation is to enlarge the original forest protection area of a country, which means that some of the commercial forests will be banned from harvesting and thus fewer revenues will be generated by the forestry sector. This finding also indicates that there is always a trade-off between the economic growth and conservation, a classic topic in the literature of development economics and environmental economics. However, this result reveals only one perspective of the entire complex picture. Alternatively, we may expect that the impact of biodiversity will be positively related to the values of other ecosystem services, such as cultural services with future investigation in the current experiment. This refers to a welfare gain. Therefore, the magnitudes of the positive and negative impacts of biodiversity quality, or better, environmental quality improvement will help a social planer to better understand the consequences of a new piece of environmental policy and the trade-off is therefore useful for determining the most cost-efficient solution to today's biodiversity conservation.

5. Discussion and Further research

As we have seen the preliminary results, biodiversity seems to have an important role in explaining the value of provisioning service provided by Mediterranean forests. However, our current position is too far to make any solid conclusions. Further investigations in both methodological and practical terms are needed. Below, we list a number of tasks to be undertaken for the paper.

- We need to extend the econometric analysis to the remaining ecosystem services for total three geo-climatic regions under consideration.
- The whole exercise for the *sbi* shall be repeated for the *cfbi*, in which we may expect to see that quantitative changes of ecosystems can be a supplementary explanatory element to explain the values of ecosystem goods and services, in addition to the qualitative biodiversity indicatory.
- Finally, there is also a need to improve the robustness of the econometric results.

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