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Methodology Development for Cost-Benefit Analysis of Policy Implementation

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SIXTH FRAMEWORK PROGRAMME

Contents

Abstract

This study develops a procedure for cost-benefit analysis of alternative land use policies. The developed procedure can be used to assess socio-economic impacts of urban, peri-urban and rural land use changes in the rural-urban region (RUR). Starting from the concept of Functional Urban Region, the RUR includes an urban core and its peri-urban belt that can extend to include peri-urban and rural regions. The procedure takes into consideration functional relationships between land use changes and changes in the rural, peri-urban and urban service supply from a socio-economic and environmental perspective. The role of land use diversity in shaping the production of goods and services and interregional linkages are taken explicitly into consideration. The cost-benefit procedure reflects a real option perspective dividing cost and benefits in reversible (e.g. changes in GDP), and irreversible (e.g. changes in ecosystem functioning). Volatility of reversible costs and benefits is taken into consideration when aggregating the different impacts. Our procedure is designed to be applied to data from the CORINE and EUROSTAT databases.

1. Introduction

The idea of summing social costs and benefits of a policy program to determine its socio-economic viability stems from an article written by Jules Dupuit in 1848. Rigourous theoretical foundations for this approach were contributed later by Alfred Marshall. Costs-benefit analysis relies on a few basic principles. First, costs and benefits must be expressed in monetary terms, in a particular currency and year. Second, values should be based on producers and consumers preferences, that is values should derive from actual transactions in which people trade off money to purchase the good or service being evaluated or from a stated value elicited following one of the state of the art non-market valuation methods (i.e. contingent valuation, conjoint analysis etc.). Third, gross benefits of an increase in consumption are measured in terms of changes in consumer surplus, i.e. the area under the demand curve (Marshallian or Hicksian) to which the change pertains. Fourth, cost-benefit analysis should take into consideration and evaluate in monetary terms impacts on the natural environment and human health. Fifth, the value of a program is given by the difference between the value of a situation with and without the program, thus both values should be identified. Sixth, the cost-benefit valuation study should be well-defined in time and space. Seventh, double counting of costs and benefits must be avoided.

To these standard principles we add a ninth one that has to do with uncertainty in ex-ante projects' valuations: a cost-benefit analysis should include a discussion of the size of uncertainty in the obtained results by means of sensitivity analysis of crucial assumptions made during the monetary valuation.

For the particular purpose of valuing alternative land use policy programs implying changes of land allocated from use *i* to use *j*, a double accounting procedure of costs and benefits has to be developed: one for net-costs of decreasing the amount of land allocated to use *i*, and one for the net-benefits of increasing the amount of land allocated to use *j*. In ex-ante program valuations, furthermore, the changes in the probability that a particular change in land use will occur due to actions taken within the program, should be taken into consideration. This implies that, while in ex-post analysis the result of the cost-benefit analysis will be a measure of society's willingness to pay for the program, in ex-ante studies, such results will just give an option price for committing to the program immediately. If the possibility of postponing the adoption of the program to a later point in time is taken into consideration, the result of the cost-benefit analysis will give the option value of such waiting; should this value be zero, the program should be adopted immediately.

The development of such cost-benefit analysis procedure faces several challenges. The first and most important is data availability. Because costs-benefit analysis requires a quantification of impacts in monetary terms, only impacts for which data or a literature base to perform benefit transfer analysis exist can be evaluated. This put some constraints on the structure and the scope of the cost-benefit valuation procedure.

A second challenge is the identification of the policy program the cost-benefit analysis (CBA) procedure should evaluate. CBAs are usually applied to well defined policy programs, projects or commodities and tailored ad hoc for their purpose. The development of a CBA procedure able to deal with different and yet undefined policy programs has to be dynamic in nature and be able to adapt as more specific information about the specific need of the policy maker becomes available. Such ability comes at the costs of a fully detailed procedure specification.

In the next section, a general approach is described that can be used to perform a CBA of a policy program dealing with land use.

2. General Conceptual Framework

The general conceptual framework developed in this section takes into consideration two fundamental factors usually associated to costs and benefits of land use policy programs. The first factor is uncertainty: changes in land use may have, for example, predictable and unpredictable environmental and health impacts. The second factor is irreversibility: changes in land use often require sizeable up front investments that can be considered sunk costs and impact, for example, existing ecosystems irreversibly.

One approach that allows researchers to consider irreversibility and uncertainty (both predictable and unpredictable) in a cost-benefit analysis framework is the MISTICs approach developed by Wesseler, Scatasta and Nillesen (2007). The MISTICs (Maximum Incremental Social Tolerable Irreversible Costs), represented by I^*, is a threshold for unpredictable irreversible costs. This threshold derives directly from the real option theory by Dixit and Pindyck (1994) and Trigeorgis (1996) and it is represented by the sum of predictable irreversible net benefits (R) and reversible net benefits (W) weighted by a hurdle rate commonly expressed in the form of $\beta/(\beta\text{-}1)$. The MISTICs can be represented as follows:

(1) $$I^* = \frac{W}{\beta/(\beta-1)} + R$$

If the policy maker has reasons to believe that the true value of unpredictable irreversible costs, I, is greater than the MISTICs threshold I^*. then the option value of waiting to implement the policy program is positive and such action should be postponed. Both the values of I and I^* vary over time due to the information flow. The optimal timing of implementation of the policy program will be the point in time at which $I = I^*$.
Thus, the MISTICs approach allows the policy maker to complement a quantitative analysis with an expert qualitative judgement in a theoretically consistent framework.

Traditional cost-benefit analysis (CBA) differs from the MISTICs in three ways. First, unpredictable impacts are quite often not taken into consideration. Second, the decision outcome is of the type “now or never”, failing to consider flexibility and the option to delay the decision. Third, no distinction is made between reversible and irreversible impacts, implying a hurdle rate equal to 1.

Another way to see that real option analysis allows accounting for flexibility more than a traditional CBA under uncertainty would is that, while in the traditional CBA analysis the decision maker maximizes the present value of expected payoffs of the policy program, in a real option context, she acts based on the present value of expected maximized payoffs. The difference between these two values gives the value of flexibility to act at a later point in time.

The value of flexibility is sometimes referred to as the option value of implementing the policy program. Once the program is implemented, the option value of implementing the policy program is lost. The total value of the program, therefore, is the value of implementing the program plus the option value of implementing the program. It may seem counterintuitive to include both values, e.g. the value to act and the value of the option to act, in the decision maker optimization problem, but it makes sense if we think of the value of the option to act as the value of all those other actions we will not be able to take after the program is implemented (i.e. the option value to act is the value of lost opportunities once the action is taken).

Coming back to the MISTICs approach, the hurdle rate depends on the risk-adjusted discount rate, μ, the risk-free rate of return, r, and the type of stochastic process followed by those benefits. If the stochastic process followed by the reversible net benefit is a geometric Brownian motion with drift rate α and variance σ^2, for example, the hurdle rate can be computed as:

(2.1) $$\beta = \frac{1}{2} - \frac{r-(\alpha-\mu)}{\sigma^2} + \sqrt{\left[\frac{r-(\alpha-\mu)}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma^2}}$$

For a mean reverting motion with speed of reversion η and W reversion level $\overline{W}$ instead it is:

(2.2) $$\beta = \frac{1}{2} + \frac{\mu - r - \alpha + \eta\overline{W}}{\sigma^2} + \sqrt{\left[\frac{r-\mu+\alpha-\eta\overline{W}}{\sigma^2} - \frac{1}{2}\right]^2 + \frac{2r}{\sigma^2}}$$

(See Wesseler 2002 and Dixit and Pindyck, 1994).

3. CBA Procedure

To apply the MISTICs approach to the evaluation of land use policy programs two sets of impacts need to be identified:

1. Direct impacts of the policy program;
2. Indirect impacts of the policy program through implied changes in land use;

As direct impacts of the policy program we consider the program's administrative direct costs. Indirect impacts will instead depend on the changes in land use caused by the policy program. Both sets of impacts will be classified as reversible and irreversible. Irreversible impacts will be those that will persist once the program is abandoned and land use changes reversed to their original status. Examples of irreversible impacts are those associated to the loss of ecosystems due to land development or environmental and health impacts from changes in greenhouse gas emissions and pesticide use. Irreversible impacts are also costs that society would have to bear to reverse land use changes due to the program. Reversible impacts can be yearly program maintenance costs or profits arising from land use changes implied by the program.

The CBA procedure follows a double accounting procedure considering impacts of converting land from use i to use j. Figure 1 shows the conceptual structure of the CBA procedure:

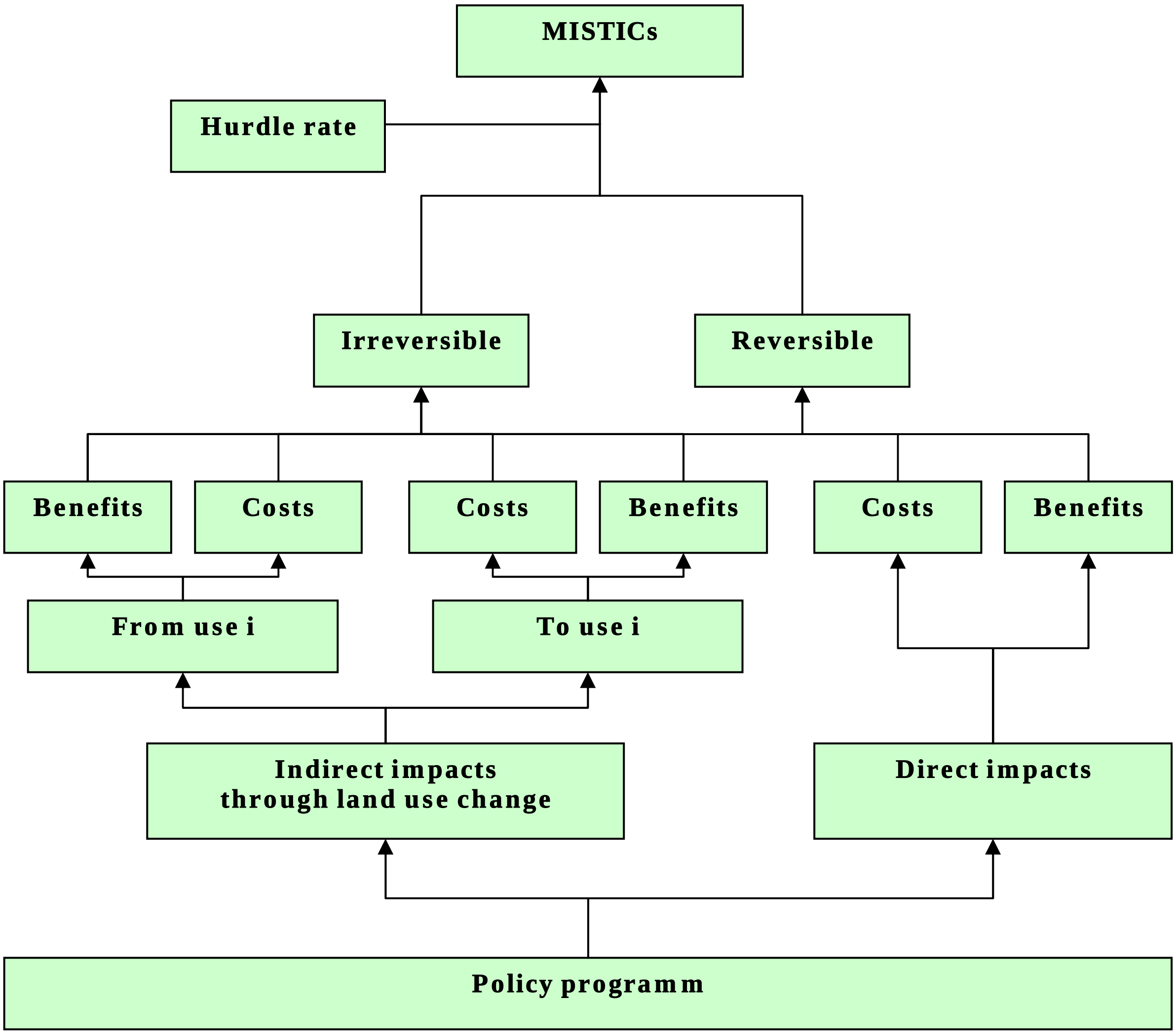

Figure 1: Conceptual Structure of the CBA procedure

The implementation of the CBA Procedure will be based on land use categories used in the CORINE database.

Impacts being evaluated may or may not give rise to market transactions. Reversible impacts giving rise to market transactions in terms of changes in transactions in financial assets and liabilities, changes in transactions in goods and services, and changes in other accumulation entries (see Table 1 for a description of items in this category) will be approximated by changes in the regional GDP (see Dapena, 2004). Irreversible impacts will be evaluated based on existing studies.

If some GDP impacts include accounting of irreversible impacts giving rise to market transactions, double counting issues could arise when aggregated with irreversible impact values from existing studies. Our CBA procedure in this case would overestimate or underestimate irreversible impacts. The size of this bias is shown below:

$$(3)\quad \frac{W+R_{pr}}{\beta/(\beta-1)}+\left[R_{pu}+\alpha R_{pr}\right]-\frac{W}{\beta/(\beta-1)}-R_{pr}-R_{pu}=\left(\frac{1}{\beta/(\beta-1)}+\alpha-1\right)R_{pr}$$

Where R_{pr} represents private irreversible impacts (i.e. impacts giving rise to a market transaction and therefore of the type that would cause a change in regional GDP); R_{pu} represents public irreversible impacts or impacts that do not give rise to market transactions such that $R = R_{pu} + R_{pr}$; and α is the percentage of private irreversible impacts that would be double counted. Eq. (3) shows that our CBA procedure is likely to overestimate or underestimate private irreversible impacts. To understand the size of this bias it will be important to indicate whether studies used to evaluate irreversible impacts measure these impacts in terms of changes in revenues/costs or more sophisticated measures of economic welfare such as the Marshallian and Hicksian Surpluses.

On the other side standard CBA (i.e. a MISTICs approach with a hurdle rate assumed value of 1) would also suffer from the same double counting issues and bias the results as shown below

$$(4)\quad W+R_{pr}+\left[R_{pu}+\alpha R_{pr}\right]-\frac{W}{\beta/(\beta-1)}-R_{pr}-R_{pu}=\frac{W}{\beta}+\alpha R_{pr}$$

Eq. (4) means that using a standard cost-benefit analysis will overestimate the importance of both reversible and irreversible impacts.

The most suitable approach for the CBA will depend on the relative size of private irreversible and reversible impacts (which are assumed to be all private here). When reversible impacts are relatively more important, the GDP based MISTICs approach should be followed. When irreversible impacts are relatively more important, the standard CBA should be preferred. For completeness we will presents results from both methodologies.

If $W = R_{pr}$ then standard CBA and the GDP based MISTICs approach will give the same results.[1]

[1] Provided that the results from the standard CBA are interpreted as a MISTICs threshold and not as the net present value of the policy program.

4. Quantification Procedure for reversible impacts

As mentioned in the previous section, reversible impacts will be approximated by changes in GDP due to changes in land use and land use mix. For this purpose response functions of regional GDP will be estimated based on land use data at NUTS 3 level from the CORINE database and regional GDP data at NUTS 3 level from Eurostat. Response functions will be estimated in a spatially explicit model (spatial-lag model) taking into consideration regional typologies developed in Module 2 of the Plurel Project.

The regional typologies considered will be: Deep Rural, Large City Monocentric, Metropolitan Monocentric, Regional Centre Monocentric, Rural Polycentric, and Urban Polycentric. For each region a distinction will be made between shrinking regions and non shrinking regions, where a region is considered shrinking if the region has a negative population dynamic (both for resident and immigrant population).

For each of the six regions above the following spatially explicit model will be estimated:

(5) $$GDP_i = \alpha_0 + \sum_{n=1}^{N} \alpha_n L_{ni} + \alpha_{N+1} D_i + \alpha_{N+2} SHRINK_i + \rho W D_{-i} + \varepsilon$$

where GDP_i is GDP in region *i*; L_n is a land use class of level 1, 2 or 3 in the Corine database (see Table 2) for region *i*, D_i is a variable representing the land use mix or diversity in region *i*; D_{-i} is a k by 1 vector of land use mix datapoints for regions other than I; *W* is a 1 by k vector of weights assigned to each of the other regions according to the inverse distance to region *i*; SHRINK is a dummy variable indicating shrinking regions; ε is an i.i.d. error term; α and ρ are coefficients to be estimated.[2]

Land use mix or diversity is represented following Di Falco and Perrings (2004). The authors show that land use diversity (crop diversity) can have a positive impact on agricultural production. In their model land use diversity is represented by a Simpson Diversity Index. The Simpson's Index (D) is used in ecology as a measure of biodiversity. This index measures the probability that two individuals randomly selected from a sample will belong to different species (or some category other than species):

(6) $$D_i = 1 - \sum_{n=1}^{N} \left(\frac{L_{ni}}{L_i} \right)^2$$

Where L_i is the total amount of land available in region *i*. To identify the impact of land use change on land use diversity, it is sufficient to identify the difference in the value of this index before and after the change.

Analysis of GDP time series data will be used to determine whether the geometric Brownian motion or the mean reverting motion are most appropriate for computing hurdle rates as given in (2.1) and (2.2).

The potential temporal scope of the analysis depends on the availability of CORINE land use data meaning the years 1990 and 2000.

[2] For a description of spatially explicit models and their advantages see Anselin (2008).

The potential geographical scope of the analysis is the NUTS3 region of EU27. A first analysis carried out on economic data available on Eurostat for these regions reveals potential scope for analysis in the regions listed in table 3.

5. Quantification Procedure for irreversible impacts

We identify the following areas of potential irreversible impacts:

I. Air (air quality, ozone depletion and greenhouse gas emissions)
II. Water (Quality and Quantity)
III. Noise
IV. Culture and Recreation
V. Security and Safety
VI. Commuting time
VII. Ecosystem Services
VIII. Depletion of non-renewable resources
IX. Costs of long-term environmental damage

Impacts in these areas can be considered irreversible if they involve changes in the environment and health that can act cumulatively. In this respect all impacts except those on water quantity, as irreversible. We chose the structure of these accounts of costs and benefits to resemble the structure of the Index of Sustainable Economic Welfare (ISEW) developed by Daly and Cobb (1989).

6. Conclusion

In the previous sections we outlined the CBA procedure that will be used to quantify impacts of policy programs involving land use changes. Monetarization coefficients are identified for selected impacts. The next step of this analysis will be to identify the policy program to be evaluated, to identify possible sources of direct costs and benefits. Response functions connecting land use changes to the key sources of impacts identified in this report also need to be identified.

Table 1. Other Accumulation Entry List for GDP

Sector code	Label
K.1	Consumption of fixed capital
K.2	Acquisitions less disposals of non-financial non-produced assets
K.21	Acquisitions less disposals of land and other tangible non-produced assets
K.22	Acquisitions less disposals of intangible non-produced assets
K.3	Economic appearance of non-produced assets
K.4	Economic appearance of produced assets
K.5	Natural growth of non-cultivated biological resources
K.61	Depletion of natural assets
K.62	Other economic disappearance of non-produced assets
K.7	Catastrophic losses
K.8	Uncompensated seizures
K.9	Other volume changes in non-financial assets n.e.c.
K.10	Other volume changes in financial assets and liabilities n.e.c.
K.11	Nominal holding gains/losses
K.11.1	Neutral holding gains/losses
K.11.2	Real holding gains/losses
K.12	Changes in classifications and structure
K.12.1	Changes in sector classification and structure
K.12.21	Monetization/demonetization of gold
K.12.22	Changes other than monetization/demonetization of gold in classifications of assets or liabilities

Table 2. Three-layered Land Cover Classes (CORINE)

First Layer	Second Layer	Third Layer
Artificial Surfaces	Urban Fabric	Continuous Urban fabric Discontinuous Urban Fabric
	Industrial, Commercial or transport units	Industrial or commercial units Road and rail networks and associated land Port areas Airports
	Mine, dump and construction sites	Mineral extraction sites Dump sites Construction sites
	Artificial, non-agricultural vegetated areas	Green urban areas Sport and leisure facilities
Agricultural areas	Arable land	Non-irrigated arable land Permanently irrigated land Rice fields
	Permanent crops	Vineyards Fruit trees and berry plantations Olive groves
	Pastures	Pastures
	Heterogeneous agricultural areas	Annual crops associated with permanent crops Complex cultivation patterns Land principally occupied by agriculture, with significant areas of natural vegetation Agro-forestry areas
Forest and semi natural areas	Forests	Broad-leaved forest Coniferous forest Mixed forest
	Scrub and/or herbaceous vegetation associations	Natural grasslands Moors and heathland Sclerophyllous vegetation Transitional woodland-shrub
	Open spaces with little or no vegetation	Beaches, dunes, sands Bare rocks Sparsely vegetated areas Burnt areas Glaciers and perpetual snow

Table 2. Continued: Three-layered Land Cover Classes (CORINE)

First Layer	Second Layer	Third Layer
Wetlands	Inland wetlands	Inland marshes Peat bogs
	Maritime wetlands	Salt marshes Salines Intertidal flats
Water bodies	Inland waters	Water courses Water bodies
	Marine waters	Coastal lagoons Estuaries Sea and Ocean

Table 3. Potential Geographical Scope of the Analysis

Country	Nuts Level	Number of regions in the database (1165 Regions in Total)	Additional Comments*
Austria	3	35	Homogenous
Belgium	3	43	Homogenous
Bulgaria	3	28	Only code changes
Czech Republic	3	14	Homogenous
Germany	3	426	DEG0P (Wartburgkreis) is not included Dee06 Jerichower Land and Dee0e Wittenberg were merged Dee09 Harz and Dee0c Salzland were merged Sachsen Anhalt underwent major restructuring
Estonia	3	5	Homogenous
Spain	3	48	ES630 (Ceuta) is not included ES640 (Melilla) is not included ES707 (La Palma) is not included ES709 (Tenerife) is not included
France	3	90	FR 9 Department d'otre meer is excluded
Greece	3	51	Homogenous
Hungary	3	20	Homogenous
Ireland	3	8	Homogenous
Italy	3	102	ITC2 Valle d'Aosta is not included
Lithuania	3	10	Homogenous
Luxembourg	3	1	Homogenous
Latvia	3	5	LV007 Periga is not included
Netherlands	3	40	Homogenous
Poland	2	16	Major restructuring at NUTS 3 but homogenous at NUTS 2
Portugal	3	28	Homogenous
Romania	3	42	Code Changes
Slovenia	3	12	Code Changes
Slovakia	3	8	Homogenous
United Kingdom	3	133	Homogenous

* Comments refer to NUTS classifications used by Eurostat to publish GDP regional data for the year 2000 and Corine land use year 2000.

Table 4. Monetization procedure for selected irreversible impacts

Impact	Value	Unit	Description	Source
AIR				
Agricultural Areas	91	2007 €/hectare	Marginal Social Costs	Pretty et al. (2000)*
Sulfur Oxide SO2	5245.4	1995 €/Ton	Marginal Social Costs	Nourry (2008)
Nitrogen Oxide NOx	8093.4	1995 €/Ton	Marginal Social Costs	Nourry (2008)
Carbon Monoxide CO	969.5	1995 €/Ton	Marginal Social Costs	Nourry (2008)
Particulate Matter PM10	7264.57	1995 €/Ton	Marginal Social Costs	Nourry (2008)
Volatile Organics VOC	5762.3	1995 €/Ton	Marginal Social Costs	Nourry (2008)
Carbon Dioxide CO2	20	2007 €/Ton	Marginal Social Costs	Danish Energy Authority (2007)
Water				
Agricultural Areas	18.48	2007 €/hectare	Marginal Social Costs from damages to water quality	Pretty et al. (2000)
Waste Disposal	0.0025	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Recreation/Fish and Wildlife Habitat	0.0397	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Navigation	0.1208	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Hydropower	0.0207	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Irrigation	0.0621	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Industrial Processing	0.2334	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Thermoelectric Power	0.0281	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)
Domestic	0.1606	2007 €/m³	Marginal Social Benefits from water quantity	Frederick et al. (1997)

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Noise				
Airport Noise	0.0058*decibel	%	Discount on property value	Nelson (2004)
Noise in General	$0.4*137.2*[(GDP_t-GDP_{92})/GDP_{92}]$	1992 €	Social cost per capita at time t	Nourry (2008)
Culture and Recreation				
Scenic Roads	0.0001	%	Gain in Property Value	Gravel et al. (2006)
Open Land	0.0091	%	Gain in Property Value	Gravel et al. (2006)
Monument	0.0010	%	Gain in Property Value	Gravel et al. (2006)
Shop	0.0404	%	Gain in Property Value	Gravel et al. (2006)
Auditorium	0.0121	%	Gain in Property Value	Gravel et al. (2006)
Playground	0.0063	%	Gain in Property Value	Gravel et al. (2006)
Security and Safety				
Crime Rate per 1000 People	0.0000004	%	Discount on property value	Acharya and Bennett (2001) Saphores and Benitez (2005)
Agricultural Land	63.08	2007 €/hectare	Marginal Social Cost	Pretty et al. (2000)
Slight Injury	22,000	2006 €/Accident	Marginal Social Cost	Nourry (2008)
Serious Injury	150,000	2006 €/Accident	Marginal Social Cost	Nourry (2008)
Fatal Accidents	1,000,000	2006 €/Accident	Marginal Social Cost	Nourry (2008)
Commuting Time				
Travel Time Savings	82.92 (63.63) 101,18 (84.92)	% wage/hour in North Europe Centre-South Europe	Marginal Social Benefit (Standard Deviation)	Zamparini and Reggiani (2007)
Ecosystem Services				
Agricultural Areas	98 397.19 -10.16	2007 €/hectare 2000 €/acre 2007 €/hectare	Marginal Social Benefit	Sutton and Costanza (2002) Nourry (2008) Pretty et al. (2000)

Forests	1035	2007 €/hectare	Marginal Social Benefit	Sutton and Costanza (2002)
Natural Grasslands	248	2007 €/hectare	Marginal Social Benefit	Sutton and Costanza (2002)
Inland Waters	9073	2007 €/hectare	Marginal Social Benefit	Sutton and Costanza (2002)
Estuaries	24378	2007 €/hectare	Marginal Social Benefit	Sutton and Costanza (2002)
Sea and Ocean	269	2007 €/hectare	Marginal Social Benefit	Sutton and Costanza (2002)
Depletion of Non-Renewable Resources				
Depletion of non-renewable resources (from coal, electricity, oil and gas consumption)	75+0.03*(t-1988)	1988 $ per barrel of oil equivalent consumed	Marginal Social Cost at time t.	Nourry (2008)
Long-Term Environmental Damage				
Long –Term Environmental Damage	1.98	2000 € per barrel of oil equivalent consumed	Marginal Social Cost	Nourry (2008)

* Pretty et al. (2000) measures impacts in terms of changes in revenues/costs (e.g. cleanup costs).

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