



Valuation of climate change mitigation co-benefits.

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Valuation of climate change mitigation co-benefits

A non-technical guide written by Fatemeh Bakhtiari (UNEP DTU Partnership)

About this document

This document describes tools for valuating in monetary terms the co-benefits associated with climate change mitigation actions. The term co-benefits refers to outcomes of those actions other than their primary outcome (reducing greenhouse-gas emissions). Such non-primary outcomes can fall under a broad range of economic or, more likely, environmental and social issues. Examples of positive environmental impacts that may not be the primary outcome of a climate change mitigation policy include reduced local air pollution or restored ecosystem health. Examples of positive social impacts include improved human health or increased access to clean energy.

Consider, for example, a climate change mitigation action aimed at increasing the fuel efficiency of private motor vehicles. It is likely that such measure, in addition to limiting greenhouse-gas emissions, would reduce emissions of particulate matter from motor vehicle exhausts. This benefit, which can be seen as ancillary to the main goal of the policy, would have positive impacts on human health, as fine particulate matter is hazardous to humans. Similarly, a climate change mitigation action aimed at expanding forest cover in a certain area will most likely have multiple ancillary benefits, ranging from increase in the amenity value of the area, the level of flood protection offered, or the income generation opportunities.

The rationale for valuating this kind of benefits is twofold: firstly, valuation helps decision-makers justify the climate change mitigation action, the implementation of which results in the aforementioned benefits; secondly, understanding the nature and size of these co-benefits gives decision-makers valuable additional information, which allows them to fine-tune the mitigation action, with a view to increasing the impact of the action's ancillary impacts.

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This document complements one other related guide, focused on decision-support tools. Both guides aim at presenting in non-technical language a set of analytical tools that can support the planning of climate change mitigation actions by national and sub-national government agencies. To the extent that developing country government agencies have comparatively less human and technical capacities than their developed country counterparts, these guides are primarily directed at supporting developing country government agencies.

Structure of the document

The remainder of this document is structured around three main elements, as follows:

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Economic valuation provides a means for measuring the benefits of climate change mitigation activities, beyond greenhouse-gas mitigation itself. It does so by assigning monetary values to the full range of goods and services provided by those activities, whether or not market prices are available. As such, economic valuation can be a powerful tool to justify and ultimately promote climate change mitigation activities.

TYPES OF ECONOMIC VALUATION METHODS

On the basis of the approach used to monetise benefits, valuation methods can be divided in three categories: direct market valuation, non-market valuation and benefit transfer.

Direct market valuation

Direct market valuation methods monetise benefits on the basis of production or cost data. Therefore, they can only be applied to goods or services (the benefits being monetised) for which markets exist.

Three main approaches to direct market valuation are commonly used, depending on the type of data employed to derive monetary values: market prices, costs, and production functions. Cost data can refer to avoided costs, replacement costs, or mitigation and restoration costs. Table 1 illustrates common situations in which each approach can be used.

Table 1: Direct market valuation – illustrative sources of data, by type of approach

Approach	Illustrative sources of data
Market prices	Energy markets: For example, savings from reduced imports of fossil fuels, associated with increased reliance on domestic renewable energy endowments.
Costs	Project costs: For example, the value of averted heating costs due to improved building insulation (avoided costs), or the value of expensive system upgrades associated with the lack of energy audits in a factory (replacement costs), or the value of building flood barriers further to deforestation (restoration costs).
Production function or income factor	Income factors: For example, the income level of communities whose livelihoods depend on the preservation of a certain forested area.

Non-market valuation

Non-market valuation methods are used to monetise the benefits of goods and services for which there are no markets. To this end they rely on indirect measures of the value of those goods and services. Two main approaches exist, depending on the type of indirect measure employed: stated-preference (or direct) methods, and revealed-preference (or indirect) methods.

Stated-preference methods operate by asking individuals how much they would be willing to pay for a given good or service, should it be marketed. The most commonly used techniques to do so are called 'contingent valuation' and 'choice experiment'.

Revealed preference methods draw on observations of individual choices in existing markets that trade goods and services that are related or in some way comparable to the non-market goods and services of interest. So called travel-cost methods and hedonic-pricing methods are the two most commonly used techniques.

Benefit transfer

There are instances when, due to lack of time or resources, undertaking new analysis is not possible. In these situations, the results from related studies may provide useful proxies. The system that has been analysed carefully is often termed 'policy site', whereas the system of interest is referred to as the 'study site'. When care is taken to closely match policy and study sites, or to adjust values to reflect important differences between sites, benefit transfer can provide reasonably accurate estimates.

STRENGTHS AND WEAKNESSES OF ECONOMIC VALUATION METHODS

Compared to non-market valuation methods, direct market methods use actual market data that reflect real consumer preferences – that is, individuals' actual willingness to pay for goods or services that are bought and sold in markets. For this reason, the method can be more reliable. Nonetheless, the method is not without limitations. Firstly, market data only are available for a limited number of goods and services. Secondly, market prices may not reflect the true economic value of a particular good or service.

Compared to revealed-preference methods, stated-preference methods are better suited for analyses of the total economic value of a non-market good or service. This is because only stated-preference methods can take account of non-use values. A typical example of a non-use value is someone's willingness-to-pay to protect a remote forested area, even if the person has no intention and maybe even no desire to ever travel to that area, but values the fact that the area exists. In general, stated-preference methods are highly flexible and applicable to a wide variety of good and services, and can provide estimates of both ex-ante use and non-use values.

Notwithstanding, revealed-preference methods are sometimes preferred by decision-makers. A key reason for this is that such methods rely on actual choices, as opposed to the hypothetical choices on which stated-preferences are based. A further advantage of revealed-preference methods is the possible

biases associated with stated-preference methods, notably the so-called hypothetical bias by which respondents to a questionnaire might report a willingness-to-pay that exceeds what they may actually pay in reality.

The appeal of benefit-transfer methods lies in its affordability and quick delivery: in general they are cheaper, compared to conducting a new valuation study, and deliver results more quickly. However, in some cases good studies for the policy or issue in question may not be available. Not least, benefit-transfer may not be accurate enough – except for making gross estimates of recreational values – unless the system under study shares most characteristics with the proxy systems.

USAGE IN A CLIMATE CHANGE CONTEXT

Economic valuation methods are powerful tools to illustrate the full range of benefits associated with a climate change mitigation action. It is worth noting that, in some contexts, notably with regard to efforts to increase the efficiency with which energy is transformed, distributed and used, economic valuation can reveal that ancillary benefits such as reduced local air pollution or employment creation, are at least equally important, from a monetary point of view, than the greenhouse-gas reduction benefits which were the primary objective of the climate change mitigation action.

In the context of national-level planning for climate change mitigation, economic valuation methods can be used to uncover the broader sustainable development benefits associated with, for example, a given nationally-appropriate mitigation action (NAMA, for short). In addition to helping justify the merits of the NAMA, economic valuation methods can help fine-tune the design of the NAMA, with a view to making it compatible with broader development objectives, and indeed strengthening those objectives. For example, non-market valuation approaches can be used to ensure that, while meeting its intended greenhouse-gas reduction targets, a reforestation project supports the livelihoods of the communities living in the area.

● Direct market valuation methods

Direct market valuation methods are used to estimate the economic value of environmental goods or services that are traded in markets. To do so, these methods use standard economic techniques which rely on information

about quantities purchased and supplied at different prices. Table F1.1 summarises the main strengths and weaknesses of direct market valuation methods.

Fiche 1

Table F1.1: Generic strengths and weaknesses of direct market valuation methods

STRENGTHS	<ul style="list-style-type: none"> • using actual market data increases the reliability of the results • data are easily available • reliance on standard economic theory increases the credibility of the results
WEAKNESSES	<ul style="list-style-type: none"> • market transactions may not reflect the true economic value of the (environmental) goods or services of interest • only a limited number of (environmental) goods and services are traded in markets • seasonal variations and other effects on price have to be factored in the final results • the method is not amenable to large-scale applications • the method may overstate benefits, as it fails to reflect negative spill-over effects on related natural resources required

Source: adapted from TEEB, 2010

The methods' rationale – that market prices reflect the value of one additional unit of the good or service of interest – is based on the assumption that the market of interest is perfectly competitive (that is, consumers have full information about their purchases, competing products are on offer, and goods and services are neither taxes, nor subsidised). While this condition can seldom be met fully, the estimates obtained through direct market valuation methods are comparable with one another, thus giving a measure of the relative value of the environmental goods and services.

Three main approaches to direct market valuation are commonly used, depending on

the type of data employed to derive monetary values: market prices, costs, and production functions. Cost data can refer to avoided costs, replacement costs, or mitigation and restoration costs. To illustrate direct market valuation approaches, the following paragraphs summarise the main characteristics of approaches relying on replacement cost data.

As the name indicates, replacement cost data correspond to the estimated costs associated with building a human-engineered system that offers the same environmental good or services as the natural systems offering those goods or services. Note that the benefits offered by the natural system are at least as

large as the monetary value obtained in this way. Note also that, in a situation where, for example, demand is low, society may not be prepared to pay for human-engineered systems as substitutes to natural systems. In these situations, using replacement costs data would result in overestimates of the economic value of environmental goods or services of interest.

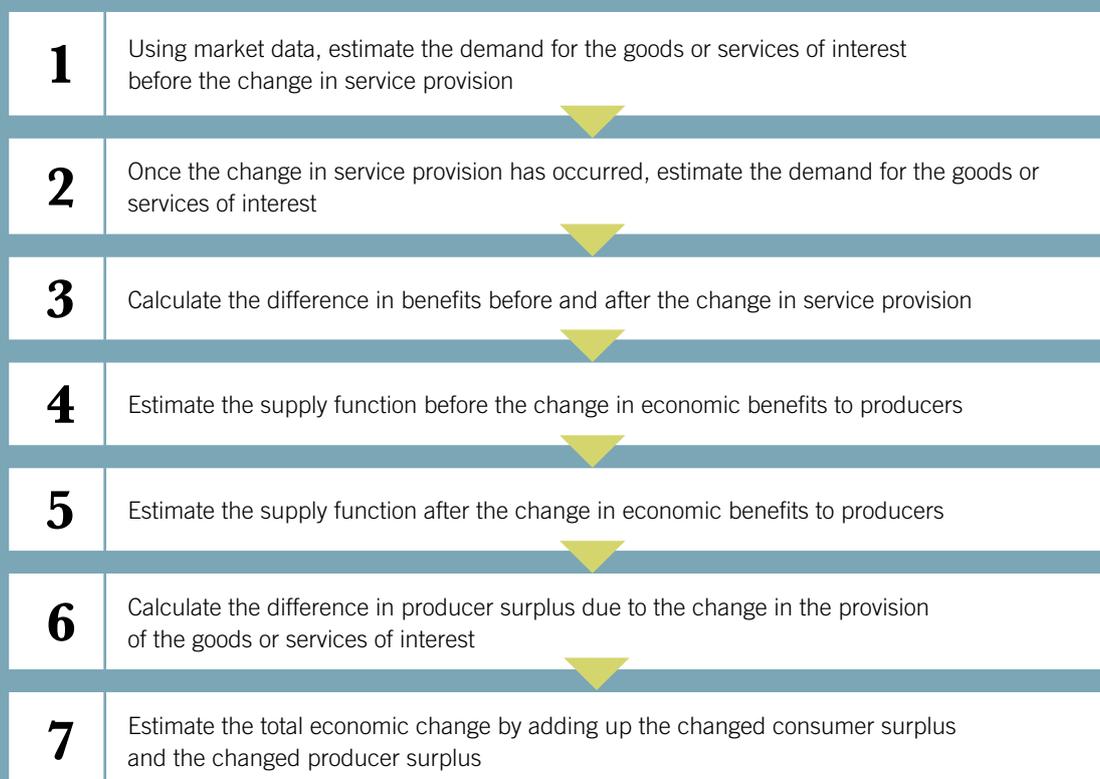
Replacement cost data can only be used if the following conditions are met:

- the goods or services provided by the human-engineered system are fully comparable in quality and magnitude to those provided by the natural system;
- the human-engineered system represents the least costly substitute to the natural system (from the point of view of the provision of the goods and services of interest);
- society chooses to paying the substitution costs, rather than foregoing the service.

Key steps in applying direct market valuation methods

Figure F1.1 below summarises the main steps involved in applying direct market valuation methods. Although this is a generic representation, most applications would follow all these steps.

Figure F1.1: Steps involved in applying direct market valuation methods



Source: adapted from Mavsar et al. 2013

Stakeholder involvement

Stakeholder engagement is essential in almost all steps of the valuation procedure. Stakeholders help frame the research (that is, to help determine the question being answered and the object being valued) and, with their responses to the survey, provide the raw data that will ultimately result in a monetary value for the good or service of interest.

Stakeholder involvement can be supported by so-called participator analysis tools, which promote an inclusive approach to stakeholder selection. 'Deliberative monetary valuation' is one such tools (more accurately, it is a set of approaches aimed at fostering participatory, deliberative, political and/or social-learning processes).

Budgets and time frames

The time and expense associated with any one application of direct market valuation methods depends mainly on both data availability and accessibility. In general, it can be said that budgets and timeframes would not exceed those involved in conducting a cost-benefit analysis.

Typical applications

Most applications are found the area of natural resources management. Nonetheless, the basic tenets of the direct market valuation methods can be used in the energy sector and, more generally, in efforts to plan mitigation actions in other sectors of society.

Some examples follow, purely for illustrative purposes:

- data on market prices of fossil fuels can be used to value the goods and services associated with increased reliance on renewable sources of energy, thereby providing a more complete assessment of the benefits of renewable energy;

- data on the income levels of communities whose livelihoods depend on the preservation of a certain forested area can help estimate the goods and services provided by that area.

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● Non-market valuation methods: stated-preference approaches

Stated-preference approaches are one type of non-market valuation method. As such, they are used to assign monetary values to goods and services for which there are no markets (for example, reduced local air pollution associated with shifts from fossil fuels to renewable sources of energy). To do this, and in contraposition to revealed-preference approaches, stated-preference approaches rely on constructed or hypothetical markets: potential beneficiaries of the non-market goods and services of interest are asked what economic value they attach to the benefits they obtain from those goods and services.

Contingent valuation and choice modelling are the two main survey based techniques used in stated-preference approaches. Contingent valuation works by asking individuals about their willingness to pay for a certain good or service. Choice modelling relies on a broader set of tools, such as rankings or ratings of alternative options/scenarios presented to respondents which called choice sets.

Table F2.1 summarises how the two techniques compare against one another for a number of key implementation considerations.

Fiche 2

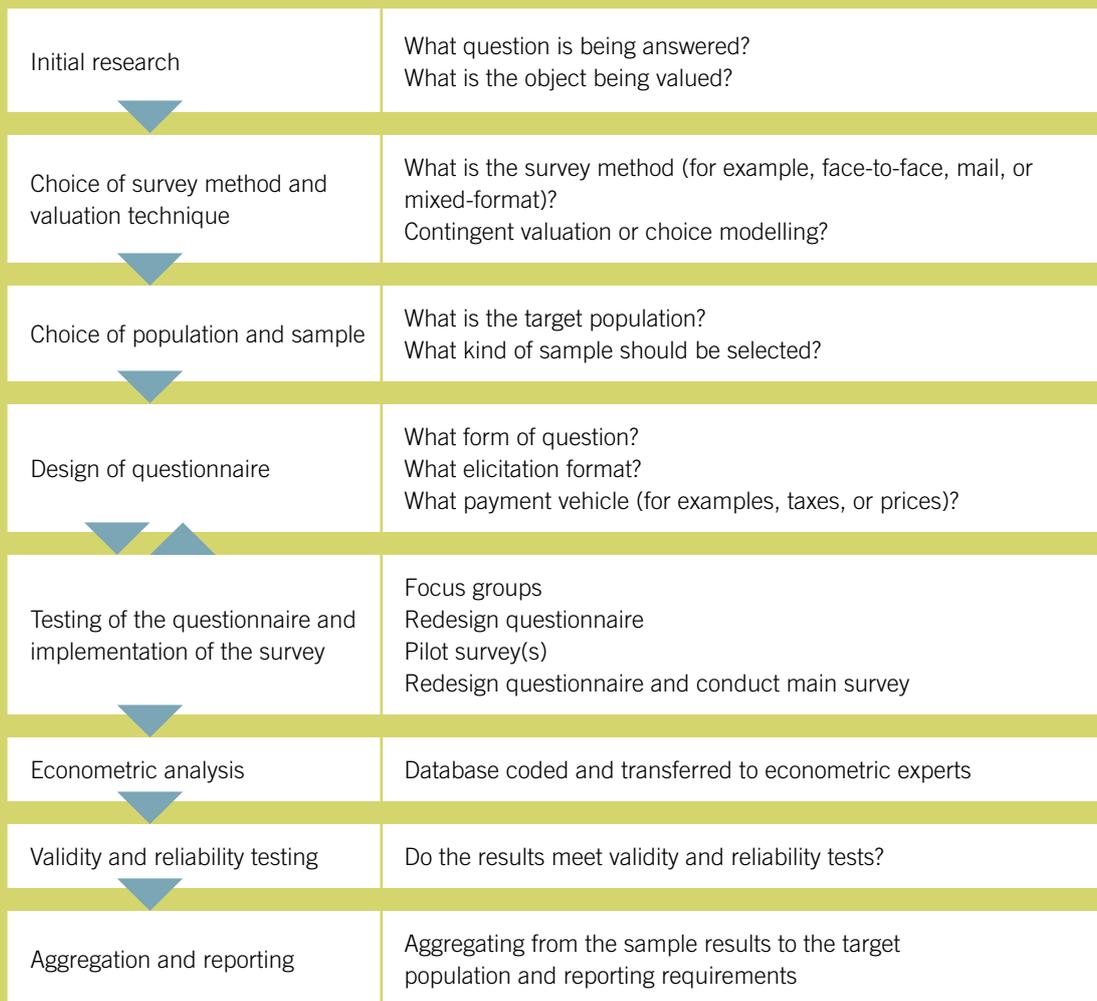
Table F2.1: Comparison between contingent valuation and choice modelling

ISSUE	RELATIVE PERFORMANCE
Survey costs	Lower for contingent valuation
Timescales	Shorter for contingent valuation
Valuation	Choice modelling can value individual attributes, whereas contingent valuation can only value an aggregation of attributes
Design complexity	Simpler in the case of contingent valuation
Requirements	Choice modelling requires specialised software and skills for the design of the questionnaire, whereas contingent valuation does not
Other	Choice experiment (a form of choice modelling) can estimate marginal effects and attribute values simultaneously, whereas contingent valuation cannot

Key steps in applying stated-preference approaches

Figure F2.1 below summarises the main steps involved in applying stated-preference approaches. Although this is a generic representation, most applications would follow all these steps.

Figure F2.1: Steps involved in applying stated-preference approaches



Source: adapted from Bateman et al. 2002

Stakeholder involvement

Stakeholder engagement is essential in almost all steps of the valuation procedure. Stakeholders help frame the research (that is, to help determine the question being answered and the object being valued) and, with their responses to the survey, provide the raw data that will ultimately result in a monetary value for the good or service of interest.

Stakeholder involvement can be supported by so-called participator analysis tools, which promote an inclusive approach to stakeholder selection. 'Deliberative monetary valuation' is one such tools (more accurately, it is a set of approaches aimed at fostering participatory, deliberative, political and/or social-learning processes).

Budgets and time frames

The time and expense associated with any one application of stated-preference methods depends mainly on both data availability and accessibility. These two determinants also influence the choice of technique – choice modelling or contingent valuation. In general, it can be said that budgets and timeframes are similar to those involved in conducting a cost-benefit analysis.

Typical applications

Stated-preference techniques can be used to monetise the non-market co-benefits associated with the implementation of climate change mitigation actions, both ex-ante and ex-post. The focus on non-market goods and services makes these techniques particularly suitable to the analysis of issues such as reduced local air pollution (for example, in the context of mitigation planning efforts focused on the transport or energy sectors), or in mitigation analyses for the forestry and agriculture sectors, where ancillary (non-market) benefits are often neglected.

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● Non-market valuation methods: revealed-preference approaches

Revealed-preference approaches are one type of non-market valuation method. As such, they are used to assign monetary values to goods and services for which there are no markets (for example, reduced local air pollution associated with shifts from fossil fuels to renewable sources of energy). To do this, and in contraposition to stated-preference approaches, revealed-preference approaches rely on people's behaviours in markets for goods and services that are related to the non-market goods and services of interest.

Travel cost and hedonic prices are the two main techniques used in revealed-preference approaches. The techniques are related in that, to derive monetary values for the non-market goods and services of interest, both rely on the prices of certain marketed goods and services.

Travel cost techniques equate the value of accessing a site (typically, a scenic landscape) to the time and travel cost expenses that people incur when visiting the site. The higher the (indirect) value of access, the larger the co-benefit of the climate change mitigation action that, as an ancillary effect to its main purpose, contributes to preserving the site.

Hedonic price techniques equate the value of non-market goods and services (typically, noise, water pollution, or air pollution) to the difference in price between two marketed products (for example, real estate) that differ only with regard to the non-market goods and services of interest. The hedonic price thus estimated makes it possible to attach a monetary value to the co-benefit of the climate change mitigation action that, as an ancillary effect to its main purpose, contributes to the provision of the non-market good or service of interest (for instance, reduced noise levels).

Valuation of climate change mitigation co-benefits

- 1 | Direct market valuation methods
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Table F3.1 summarises the main strengths and weaknesses of each technique. The list of weaknesses has to be seen from the perspective of the uniqueness of these techniques: because there are no alternative techniques, most applications are conducted

in spite of the limitations of the techniques. Understanding those limitations and interpreting results in light of them is arguably more important than seeking to limit the impact of the various shortcomings.

Table F3.1: Generic strengths and weaknesses of revealed-preference methods

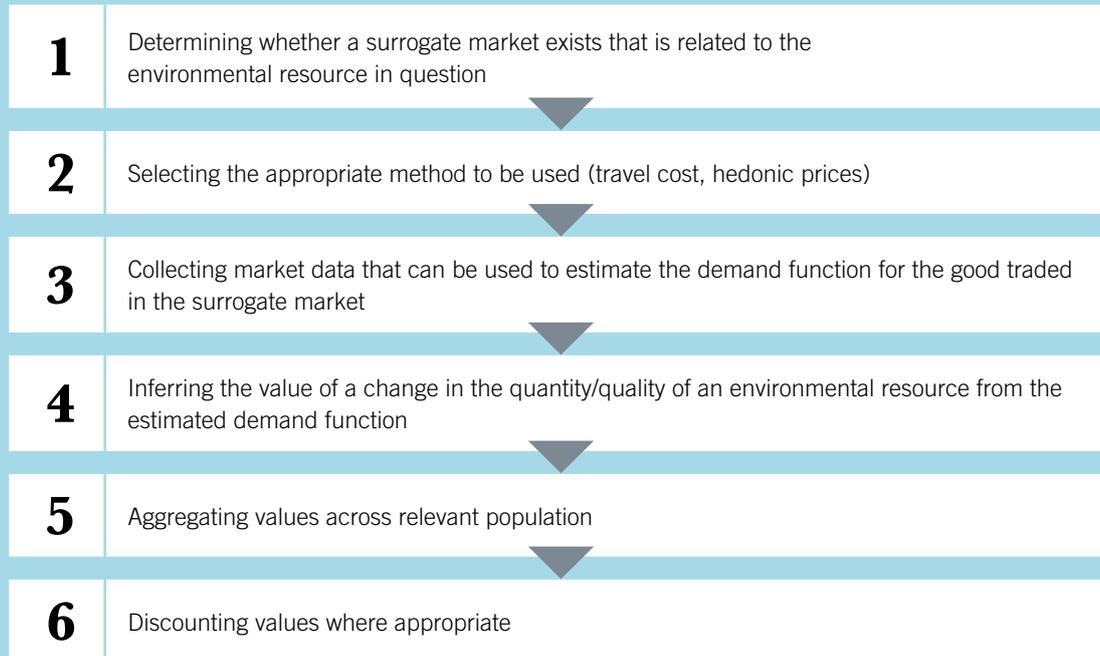
TECHNIQUE	STRENGTHS	WEAKNESSES
Travel cost	<ul style="list-style-type: none"> • similar to conventional valuation approaches that rely on market prices • based on actual (as opposed to hypothetical) behaviour and thus more reliable • large sample sizes are possible through on-site surveys • relatively inexpensive 	<ul style="list-style-type: none"> • changes in travel cost might not be fully aligned with access values • requires active user participation • standard applications provide information about current conditions, but not about anticipated (future) changes • the premise that trips are single-purpose may not always hold • results are affected by the availability of substitute sites
Hedonic price	<ul style="list-style-type: none"> • values based on actual choices • real estate markets react quickly to information and thus are good indicators of value • versatility and adaptability • reliable data sources (property records) 	<ul style="list-style-type: none"> • mostly applicable to non-market goods and services that can be valued through changes in real estate prices • subjective individual perceptions about environmental attributes may introduce biases • results depend strongly on model specifications • data intensive and requiring specialised knowledge

Source: adapted from Freeman, 2003 and TEEB, 2010

Key steps in applying revealed-preference approaches

Figure F3.1 below summarises the main steps involved in applying revealed-preference approaches. Although this is a generic representation, most applications would follow all these steps.

Figure F3.1: Steps involved in applying revealed-preference approaches



Source: adapted from TEEB, 2010

Stakeholder involvement

Stakeholder engagement is essential in almost all steps of the valuation procedure. At one level stakeholders help frame the research (that is, to help determine the question being answered and the object being valued). Not least, through their indirect choices and, when relevant, by responding to purpose-developed surveys, they provide the raw data that will ultimately result in a monetary value for the good or service of interest.

Stakeholder involvement can be supported by so-called participator analysis tools, which promote an inclusive approach to stakeholder selection. 'Deliberative monetary valuation' is one such tools (more accurately, it is a set of approaches aimed at fostering participatory, deliberative, political and/or social-learning processes).

Budgets and time frames

The time and expense associated with any one application of revealed-preference methods depends mainly on both data availability and accessibility. In general, it can be said that budgets and timeframes would not exceed those involved in conducting a cost-benefit analysis.

Typical applications

Travel cost techniques can be used to estimate the economic benefits or costs resulting from (i) changes in access costs for a recreational site; (ii) elimination of an existing site, or addition of a new one; and (iii) changes in the environmental quality of a site. Hedonic prices techniques can be used to estimate the economic benefits or costs associated with changes in environmental quality in sites other than recreational sites, and changes in the availability of environmental amenities.

To make use of these techniques in the context of planning for climate change mitigation requires that some kind of attribution can be established between the changes referred to above and the climate change mitigation action under study. Stated differently, one has to be able to characterise the extent to which implementing the mitigation action will cause changes in a recreational site, or changes in the environmental quality of other sites. While accurate measures can seldom be provided, it is nonetheless possible to determine the sign (cost or benefit) and the order of magnitude of the associated change.

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● Benefit-transfer methods

Benefit-transfer methods are used to estimate the economic value of certain environmental goods or services of interest, by relying on pre-existing economic valuation studies conducted in different, but comparable, settings.

Benefit-transfer methods are applied when an estimate of benefits or costs is needed, but the

budget and/or the time required to conduct an original valuation study are not available. Table F4.1 summarises the main strengths and weaknesses of benefit-transfer methods.

Fiche 4

Table F4.1: Generic strengths and weaknesses of benefit-transfer methods

STRENGTHS	<ul style="list-style-type: none"> • typically less costly and faster than conducting an original valuation study • can be used as a screening technique to determine if a more detailed, original valuation study should be conducted • widely applicable with regard to valuating the recreational benefits of a site
WEAKNESSES	<ul style="list-style-type: none"> • limited accuracy, unless the target goods or services are very similar to those used as proxies • reliable studies that are comparable may not be available and relevant studies may not report enough details • the adequacy of the candidate studies may be difficult to assess • the quality of the studies used as proxies determines the quality of the resulting estimates

Source: adapted from Mavsar et al., 2013

Two main techniques are available to put benefit-transfer methods to work: unit-value transfer and function transfer. Unit-value transfer refers to the direct transfer of one or more estimates from pre-existing studies. In some instances these estimates need to be adjusted – for example, to correct for differences in income levels. Function transfer involves a more elaborated analysis of the original data, a process that is typically accomplished through one of three main approaches: using the original data to

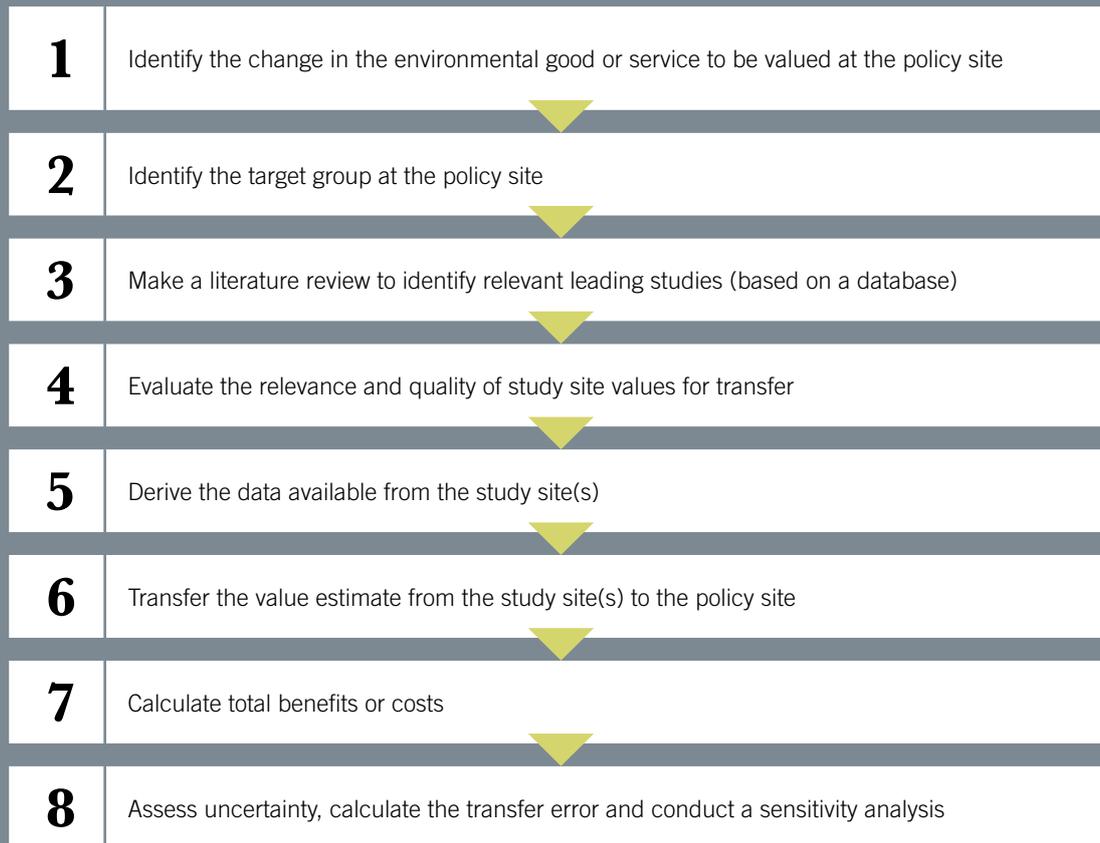
estimate a function that describes those data, conducting a meta-data analysis that synthesises results from several prior studies, or constructing a structural utility model using results from several prior studies.

Function transfer techniques tend to be more accurate than unit-value transfer techniques. Nonetheless, when the target and proxy sites are very similar, unit-value transfer techniques perform satisfactorily.

Key steps in applying benefit-transfer methods

Figure F4.1 below summarises the main steps involved in applying benefit-transfer methods. Although this is a generic representation, most applications would follow all these steps.

Figure F4.1: Steps involved in applying benefit-transfer methods



Source: adapted from Navrud, 2007 and Mavsar et al., 2013

Stakeholder involvement

Stakeholder engagement is essential in almost all steps of the valuation procedure. Stakeholders help frame the research (that is, to help determine the question being answered and the object being valued) and, with their responses to the survey, provide the raw data that will ultimately result in a monetary value for the good or service of interest.

Stakeholder involvement can be supported by so-called participator analysis tools, which promote an inclusive approach to stakeholder selection. ‘Deliberative monetary valuation’ is one such tools (more accurately, it is a set of approaches aimed at fostering participatory, deliberative, political and/or social-learning processes).

Budgets and time frames

The time and expense associated with any one application of revealed-preference methods depends mainly on both data availability and accessibility. In general, it can be said that budgets and timeframes would not exceed those involved in conducting a cost-benefit analysis.

Typical applications

Benefit-transfer methods are commonly used to estimate in monetary terms the recreational value of a natural site. The accuracy of the estimates thus obtained depends on the extent to which the sites are similar (from an ecological point of view but also with regard to accessibility or climate, for example), and the extent to which the recreational experiences are comparable.

In the context of planning for climate change mitigation, public authorities may choose to regulate the preservation of certain forested areas, to prevent emissions from deforestation.

In addition to this primary benefit, such a regulation would indirectly contribute to maintaining the recreational value of the area. Benefit-transfer methods can be used to quantify those indirect impacts. These estimates help put in context the overall economic merits of the regulation.

For further reading

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○ Using replacement-cost techniques to quantify the developmental benefits of carbon-sequestering agricultural practices

Topic	Using direct market valuation methods to characterise increased agricultural productivity associated with preservation of carbon-sequestering ecosystems.
Key message	Direct market-valuation methods can be used to attach a monetary value to a given ecosystem service, which in turn can be seen as the monetary value of the co-benefit associated with the carbon sequestration function of the ecosystem.
Source	Hussain, S. A., Badola, R. (2008). Valuing mangrove ecosystem services: linking nutrient retention function of mangrove forests to enhanced agroecosystem production. <i>Wetlands ecology and management</i> , 16(6), 441-450

India's Bhitarkanika National Park, formed by the estuary of the Brahmani, Baitarani, and Dhamra rivers, boasts 145 km² of mangrove formations. Mangrove-forest soils retain more nutrients than non-mangrove forests. For this reason, the productivity of agricultural land in and around mangrove forests is higher than that of non-mangrove areas. Differences in agricultural productivity between mangrove and non-mangrove soils have helped reduce the extent to which agricultural land encroaches upon mangrove forests land.

Reflecting agricultural productivity levels, mangrove-forest land is more expensive by a factor of 1.5 to 2.3, compared to agricultural land in non-mangrove areas. Direct market valuation methods (replacement-cost techniques in particular) can be used to obtain a monetary measure that is specific to the value associated with the nutrient retention property of mangrove-forest land. Such measure captures in monetary terms the economic value of the co-benefits associated

with the carbon sequestration function played by mangrove forests.

Approach followed to estimate and value nutrient-content levels

Sixty soil samples were collected from relatively pure strands of different mangrove species and from areas lacking mangrove forests. Care was taken to eliminate samples from areas where chemical fertilizers had been used. To characterise the nutrient content in each sample, standard tests were run for the following parameters: soil texture, soil pH, organic carbon content, total nitrogen content, available phosphorus and available potassium.

As expected, non-mangrove forest soils contained lower levels of nutrients, compared to mangrove-forest soils. The monetary value of the nutrients available in mangrove-forest soils was estimated by calculating the difference in nutrient levels between

mangrove-forest and non-mangrove forest soils, and multiplying that difference by the market price of a fertilizer with similar chemical composition, as per the basic tenets of replacement-cost techniques.

In addition, the study sought to gauge local farmer perceptions with regard to the nutrient retention function of mangrove-forest soils. To this end a total of 140 households in six different villages were interviewed, to gather information about, among other issues, options to improve the productivity of their lands*. A second round of interviews among a sample of the households in 35 villages shed light on farmers' perceptions about the benefits provided by mangrove forests.

Results of the analysis

Each hectare of mangrove forests contained additional nutrients worth USD 232, compared to soils in non-mangrove forests. Since the total surface of mangrove forests was 145 km², the total soil nutrient benefit associated with mangrove-forest soils can be placed at USD 3.37 million.

The survey of households confirmed that the productivity was much higher in land adjoining mangrove forests: when asked about options to increase productivity, farmers answered moving to landlocked agricultural land near mangrove forests. These are lands that benefit from the nutrient-retention property of mangrove-forest soils, and are safe from wildlife damage and saline water intrusion during storm surge.

Farmers value mangrove forests primarily because they protect adjacent land from storms and cyclones, and from erosion. Nutrient retention was perceived as a secondary benefit of mangrove forests. Most villagers were in favour of mangrove restoration and against mangrove forest clearing.

Discussion

Characterising the development functions provided by ecosystem helps make the case for ecosystem conservation measures, and broader environmental goals, notably carbon sequestration in biomass. Studies that value ecosystem services are particularly useful in this regards, in that they speak to the general public and are directly useful to decision-makers.

Estimating the monetary value of nutrient retention by mangrove-forest soils provides a good example of the argument above. The valuation exercise helps highlight the positive impacts of mangrove forests on livelihoods and security. In doing so it strengthens the case for mangrove restoration and, indirectly, carbon sequestration in mangrove forests.

*None of these households were using chemical fertilizers.

○ Using stated-preference methods to design subsidy programmes for cleaner energy technologies

Topic	Using contingent valuation and choice experiment techniques to estimate household's willingness to share the costs of purchasing stoves that are more energy-efficient than the regular stoves used by households in southern Chile.
Key message	When market data are lacking, stated-preference methods such as contingent valuation and choice experiment can help design economic incentives for replacing household-level polluting technologies.
Source	Gómez, W., Salgado, H., Vásquez, F., Chávez, C. (2014). Using stated preference methods to design cost-effective subsidy programs to induce technology adoption: An application to a stove program in southern Chile. <i>Journal of environmental management</i> , 132, 346-357.

Suspended fine particulate matter resulting from households' wood combustion for heating and cooking is the main environmental problem in several cities in Southern Chile¹. Regulating particulate matter emissions is challenging for at least four reasons: (i) the vast number of individual sources, which calls for a non-point source approach to treating the problem; (ii) the variability in weather conditions, which introduces variability in the severity of the problem; (iii) the heating preferences of individual households, which differ, thus ruling out overly generic solutions; and (iv) the quality of the fuel used, which affects the type of particulate matter emitted and, therefore, its hazardousness.

Economic incentives have been used to regulate environmental problems that share attributes (ii), (iii) and (iv) above. However, their use in connection with non-point sources (attribute (i) above) is much less common: it is argued that the dispersed nature of non-point sources makes it difficult to design effective economic incentives, thus ruling them out as a regulatory option. By estimating the probability that dispersed actors (individual households, in this case) invest in cleaner technologies and assessing the most suitable types of technologies, stated preference methods can help overcome the difficulties associated with dispersion. This makes it possible to design economic incentives (a subsidy programme) suited to the non-point source nature of the emissions from individual households.

1) For example, in 2012 the city of Temuco, in central-southern Chile, exceeded during 92 days the national limit for 24-hour average concentration of suspended fine particulate matter (PM2.5). The national limit has been set at 50 µg/m³, whereas the equivalent level recommended by the World Health Organisation is 25 µg/m³.

Designing the contingent valuation and choice experiment models

Contingent valuation techniques (a dichotomous choice model) were used to estimate the extent to which households might be willing to replace their stoves with more modern equipment, given several possible subsidy levels. Choice experiment techniques were used to estimate the type of technology that a household might choose.

Data for the model were collected through a survey questionnaire structured around four sections:

- presentation: description of the work and of the survey itself;
- current technology: questions about the stove used (for example, its age, the costs associated with using it, or the amount of wood consumed), and the household's perceptions about local air quality;
- contingent valuation: questions about the attributes of the current technology and the use of it by the household;
- debriefing: questions about the socio-demographic characteristics of the household and related issues that helped evaluate the quality of the responses.

The survey used the one-and-one-half-bound approach to contingent valuation. This approach consists of proposing the respondent two prices up-front, noting that “although the exact final price of the item is not known for sure, it is known that it lies within the range bounded by these two prices”.

Questions pertaining to the choice experiment were also included in the survey. Households were asked to decide about their preferences with regard to keeping the stove they had, or purchasing one among two possible cleaner options.

Results of the analysis

The results for the contingent valuation show that a reduction of CLP 100,000 (about USD 200) in the final cost of the new equipment increases the probability of adoption by 27 percent. However, the same increase on income rises the probability of adoption by 2 percent only. The average willingness to pay is close to CLP 160,000 (about USD 320). This level of self-financing would require a subsidy for the amount of 55 percent of the price of the cleaner stove.

The results for the choice experiment valuation show that, the greater the expected duration of the equipment in use, the lower the probability of adoption. The use of other sources of fuel, large family sizes, high education levels, and a positive outlook on a household's financial situation, all increase the probability of switching to a cleaner stove. Older people are less likely to change their stove.

○ Using hedonic-price techniques to estimate global warming-driven welfare changes in Great Britain

Topic	Using hedonic-price techniques to estimate the amenity value of climate to households in Great Britain.
Key message	Studying the amenity value of temperature and precipitation is useful to understand household decisions and societal perceptions of public policy to manage climate change, thus complementing other initiatives aimed at guiding mitigation or adaptation decisions.
Source	Rehdanz, K. (2006). Hedonic pricing of climate change impacts to households in Great Britain. <i>Climatic Change</i> , 74(4), 413-434.

Mean annual sea-level temperature in Great Britain varies from about 7 °C on the Shetland Islands, to 11 °C near the coast of Cornwall, whereas average annual rainfall ranges from 2000 mm in the Lake District and other wet regions, to 500 mm in South-east England. Global warming is expected to bring about changes in temperature and precipitation patterns: mean values are forecast to increase across all regions and periods, except for precipitation in July, which is expected to decrease. The more severe the global warming scenario considered, the more marked the departure from current patterns is expected to be. Like with any other amenity, changes in precipitation and temperature levels will influence welfare levels.¹ Examining global warming-driven changes in welfare makes it possible to anticipate demographic and labour market developments spurred by global warming. Further, it helps understand societal perceptions about measures to manage climate change.

Approached followed to estimate hedonic prices

Consumers compete for environmental goods in, among others, the housing and labour markets: a typical consumer will be willing to pay higher real estate prices and accept lower wage rates in exchange for living in a preferred area. Provided that enough variation in climate variables is registered, the value of marginal changes in climate, represented as changes in precipitation and temperature, can be derived from real estate prices and wage regressions (through hedonic-price techniques).

Estimating two hedonic equations (one for property prices and one for wages) is analytically cumbersome. To overcome this challenge, a dependent variable can be constructed: expected after-tax household labour income net of housing. This approach assumes that prices of all other goods not related to housing or labour income are the same in all locations, which is considered reasonably realistic in the context of Great

1) It is acknowledged that, in addition to changes in temperature and precipitation levels, other consequences of climate change have impacts on welfare. These include, for example, the impacts associated with sea-level rise or with more frequent extreme-weather events. None of these consequences are considered.

Valuation of climate change mitigation co-benefits

- A1 | Direct market valuation methods
- A2 | Stated-preference methods
- A3 | Revealed-preference methods
- A4 | Benefit-transfer methods

Britain. Nonetheless, to explore the possibility of segmented markets, Great Britain was divided in eleven regions.

Deriving the dependent variable mentioned above requires that three indices are calculated – for real estate prices, wages, and employment. The real estate price index is defined as the ration between the average house price in a given location, and the average house price of all locations considered. The wage, and employment indices are calculated in a similar manner.

To calculate the dependent variable – expected after-tax household labour income net of housing – the following steps are taken:

- the expected average household income after tax is calculated (by multiplying the wage index, the employment index, and the average after-tax household labour income);
- the house price index is multiplied by the average annual housing costs;
- the two figures above are subtracted.

The large number of variables to be considered causes problems of multi-collinearity. To overcome these problems, the climate variables – mean temperature and precipitation – were summarised as January and July averages, minimum and maximum values within a twelve-month period, and

annual averages and ranges. In addition, these variables were analysed as both linear and squared terms, as the latter makes it possible to test if households prefer a mild climate instead of one characterised by extremes.

In addition to climate variables, other factors influence household decisions with regard to real estate prices and wage rates that are acceptable for a given location. Ignoring these variables introduces biases in the analysis. For this reason, four model specifications were designed (labelled 1, 2, 3, and 4), considering progressively larger sets of variables, interaction terms for some variables, and geo-spatial information.

Results of the analysis

The implicit prices of temperature and precipitation were calculated by differentiating the above hedonic price function with respect to each climate variable for seventeen regions of Great Britain, and for the average of all locations. The analysis shows that, for all regions, precipitation and temperature are statistically significant in the real estate-price regression, but not in the wage regression.

Table A3.1 summarises the results of the analysis. It presents data for each of the four model specifications, for one average location. A negative sign indicates a disamenity.

Table A3.1: Implicit prices for climate variables

VARIABLE	MODEL 1	MODEL 2	MODEL 3	MODEL 4
January temperature	270 (2.09)	443 (2.89)	426 (2.87)	426 (2.87)
July temperature	259 (2.10)	96 (0.81)	272 (1.74)	296 (2.18)
January precipitation	-9 (-3.17)	-10 (-3.03)	-10 (-2.89)	-11 (-3.15)
July precipitation	-9 (-1.24)	-2 (-0.31)	-6 (-0.79)	9 (1.21)

Source: Rehdanz, K. (2006)

Notes: - Unit: GBP per household per year
 - Location: average of all locations
 - t-statistic is given in parenthesis

A3

The analysis highlights that households are willing to pay for a one-degree increase in average temperature in January. Considering all model specifications, the amount ranges from between GBP 207 and GBP 344, to between GBP 512 and GBP 668. Not surprisingly, regions with lower average temperatures in January are willing to pay higher amounts, compared to regions with higher average temperatures.

Increased precipitation is regarded as a disamenity and households are willing to receive varying amounts for one extra millimetre of rain per year. Considering all model specifications, the amounts range from between GBP -4 and GBP -9, to between GBP -12 and GBP -14. Regions with higher mean precipitation in January are willing to receive less for one extra millimetre of rain per year.

Estimates for higher precipitation in July are not statistically significant, irrespective of the model specification considered. Estimates of the willingness to pay for higher average temperature in July are statistically significant in regions such as Greater London or East Anglia, where the overall willingness to pay is higher.

Discussion

A similar study investigated the amenity value of climate to Italian households. The study examined the following main variables: January and July average temperatures, precipitation and fraction of clear sky. It concluded that Italians prefer a drier climate in winter and lower temperatures in the summer. The latter contrasts with the results obtained for Great Britain and highlights that the amenity value of climate varies depending on the latitude of the region under study.

As mentioned above, global warming introduces welfare-changing elements that go far beyond variations in temperature and precipitation. Studying the amenity value of temperature and precipitation is useful to understand household decisions and societal perceptions of public policy to manage climate change. As such, this kind of studies support national climate change planning efforts, complementing other initiatives aimed at guiding mitigation or adaptation decisions.

○ Using benefit-transfer methods to estimate the economic value of ecosystem services

Topic	Using benefit-transfer methods to quantify the recreational value of several candidate areas for afforestation.
Key message	Estimating the net social benefits of afforestation projects puts carbon sequestration benefits in the larger perspective of other economic, social and environmental benefits, thus helping make the case for climate change mitigation policies that rely on afforestation.
Source	Moons, E., Saveyn, B., Proost, S., & Hermy, M. (2008). Optimal location of new forests in a suburban region. <i>Journal of Forest Economics</i> , 14(1), 5-27.

The region of Gent, in East Flanders (Belgium), has a low forest cover. To benefit from the ecosystem services associated with forests, in the late 2000s local authorities sought to add 550 ha of new forests to the existing forest cover. To this end a large number of candidate sites were identified. Maximising net social benefits was the criterion chosen to select the sites that would be afforested. Net social benefits are the balance between the costs and benefits associated with afforesting a given site. Costs considered include planting and management costs, and opportunity costs (for example, foregone agricultural production, or reduced land surface available for manure deposition). Benefits considered include profits from use values (notably timber sales and hunting permit payments), carbon sequestration, recreational values, and non-use values (namely existence and bequest values).¹

Estimates could be produced easily for all cost and benefit components, except for recreational values. Estimates for recreational values were obtained using benefit-transfer methods (through function-transfer techniques in this case) and geo-referenced data.² The resulting net social benefit estimate helps strengthen the climate change mitigation rationale for afforestation projects, in as much as it highlights that benefits accrue at many different levels, beyond reducing greenhouse-gas emissions.

1) Ecological function values such as biodiversity conservation, watershed protection, or reduced air pollution, among others, could not be taken into account due to lack of data.

2) When estimates are lacking, and the time and resources required to obtain them are not available, benefit-transfer methods can be applied. Through these methods, estimates from a comparable site can be 'transferred' to the site of interest.

Using benefit-transfer methods in combination with geo-referenced data

As mentioned above, estimates of costs and benefits – with the exception of the benefits associated with recreational values – are drawn from the literature.³ This section focuses on the method used to derive estimates of recreational values.

Function transfer techniques are used, to better reflect the characteristics of the site under study and its visitors. Since distance to the site and travel time data are key elements in the transfer function, geo-referenced data are used to increase the level of detail of the resulting estimates.

At the time the analysis was conducted, recreational benefits had only been estimated for the Heverleebos-Meerdaalwoud forest.⁴ This is the largest forest in Flanders, covering an area of 1,890 ha. The estimates of recreation demand for this forest are transferred to the candidate sites for afforestation. This is done through a travel cost model specifying a travel demand function that predicts visit rates for the base site (the Heverleebos-Meerdaalwoud forest). The function is defined as follows:

Visit rate = f [Price, socio-demographics, substitutes]

where

- Visit rate = (total visits/total visitors) x (total visitors/total population)
- Price = cost per visit (monetary and travel time costs)
- Socio-demographics = age, education, professional activity, population density

- Substitutes = availability and characteristics of other forest sites

The price variable is calculated on the basis of (geo-referenced) data about the cost of travelling a certain distance using a given mode of transport, weighted by the frequency with which that mode is used. The value of the time spent travelling is derived from a comparable Dutch study.

Data for the socio-demographic variables are available from the Flemish statistical office. The data are disaggregated enough to allow for the preparation of geo-referenced datasets at the level of 1 ha.

A substitution index is calculated, which reflects the extent to which available substitute sites affect the level of visits to the base site. The data used to calculate the index is geo-referenced, thus making it possible to incorporate the spatial dimension in the calculation.

The substitution index of an origin zone is calculated as follows for M distances and N different travel modes:

Substitution index =

$$\sum_{m=1}^M \frac{WL_m}{\sum_{n=1}^N P_{mn} TT_{mn}}$$

where

- Substitution index = measure for total area of substitutes (ha per minute of travel time)
- WL_m = area of substitute woodland (ha)
- P_{mn} = proportion of visitors using a particular travel mode
- TT_{mn} = travel time from origin zone to substitute at distance using a particular travel mode (minutes)

3) With regard to carbon sequestration, it is assumed that one hectare of forested land stores 2.5 tonnes of carbon annually, at a value of EUR 10 per tonne. This includes both above- and below-ground storage.

4) To estimate the recreational value of the forest, travel cost methods were used.

The recreational demand regression function above predicts an average number of 12.5 visits per inhabitant and year for the base site. This compares well with the results of an on-site recreation survey for that site, which reported an actual average of 11 visits per inhabitant and year. A statistical analysis of the detailed model results shows that there is no statistically significant difference between the model outputs and the survey results. For this reason, the recreational demand function is considered suitable for use with the site of interest, through benefit-transfer methods.

The net social benefit of the candidate sites is calculated as follows:

$$NSB_{Z_j}^{lim/full} = \frac{\sum_{i \in Z_j} Benefits_i - Costs_i}{\sum_{i \in Z_j} S_i}$$

where

- I includes all forest sites $i (i \in I)$
- Z is the set of all possible subsets, Z_j , that respect the area constraint ($Z_j \subset Z$)
- S_i denotes the (surface) area of site i

Two types of net social benefits are calculated: NSB^{lim} (without recreation) and NSB^{full} (with recreation). The NSB^{lim} of a single forest site is independent of the subset it belongs to. The variation in NSB^{lim} between forests is solely due to the variation in opportunity costs (foregone agricultural production and reduced land surface available for manure deposition), as all other costs and benefits are taken constant per hectare for all forests. The NSB^{full} of a forest site depends on the subset that the new forest site belongs to. This is due to the variation in the set of substitutes determining the recreational value.

Discussion

Benefit-transfer methods are used to estimate the economic value of certain environmental goods or services of interest, by relying on pre-existing economic valuation studies conducted in different, but comparable, settings. Benefit-transfer methods are applied when an estimate of benefits or costs is needed, but the budget and/or the time required to conduct an original valuation study are not available.

The application described in the previous paragraphs assumes that all marginal costs are constant and all costs are additive. Nonetheless, in spite of their shortcomings, benefit-transfer methods make it possible to incorporate the recreational value a given site in the calculation of the net social benefits associated with that site, which is considered preferable to overlooking recreational values.

At EUR 10 per tonne of carbon (the rate used in this application), carbon sequestration makes a small contribution to the overall net social benefits associated with an afforestation project. Including as many types of factors in the calculation of net social benefits helps draw connections between the multiple positive impacts of the project and its trade-offs. From the point of view of planning for climate change mitigation, a measure of the overall net social benefits (rather than a measure of the carbon sequestration potential only) helps strengthen the case for afforestation as a carbon mitigation tool.

Valuation of climate change mitigation co-benefits

About the author



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