Economic valuation of water quality improvements: a quick tour of methods available.

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Economic values for water quality (eg in coastal areas) come through two routes:

- Ways in which improved water quality contributes directly to peoples' well-being (utility – measured by willingness to pay)
- Water quality improvements contribute to the production of other goods or services which are then bought and sold (indirect values)

➔ In both cases, market prices do not reveal the full economic value of water quality changes due to the problem of "missing markets".

➔ For example, there is no market price for marine mammals or sea birds which we could use to measure the benefits of increases in their populations due to a reduction in pollution.

Methods which can be used:

Methods	Ecosystem Service Type	Examples
Market prices	Provisioning services – eg commercial fish species. Carbon?	Use price per tonne of fish, or profits per tonne
Avoided costs	Regulatory services – flood mitigation, water quality. Carbon?	Use value of avoided damages *or* value of avoided spending on flood defences; avoided spending on water treatment. Avoided costs of carbon mitigation
Stated preferences	Cultural services	Beach aesthetics, non-use values of wildlife, recreation
Revealed preferences (1): travel cost models	Cultural services	Recreation benefits eg kayaking, surfing
Revealed preference (2): hedonic pricing	Cultural services, regulating services (water quality)	water quality benefits which get picked up in house prices.
Environment-as-input	Supporting services	Role of coastal wetlands in commercial fish/crustacean life cycles

Avoided damages and avoided costs

- Idea is that some ecosystem services protect us from incurring damages
- Example is flood protection service supplied by coastal wetlands
- Value of this service could be either (i) what is the value of avoided damages (economic costs due to flooding) *or* (ii) what costs do we avoid spending, for example on hard flood defences, thanks to the natural flood defence capacity of wetlands
- A similar argument could be applied to pollution treatment services provided by coastal wetlands.
- Main problem – not all of these avoided cost values may reveal people's maximum willingness to pay for these changes.

Some examples from UK NEA

Table 22.10 Estimated average, total and marginal values for inland flood control provided by wetlands in the UK.* All values are given in £, 2010 prices. Source: Morris & Camino (2010).

Ecosystem service-related goods	No. of sites†	Total area (ha)	Average value of service where present (addition to default value)‡ (£/ha/yr)	Total value of service, assuming it is present in all UK inland wetlands¶ (£ million/yr)	Marginal value of service when provided by an additional hectare of new wetland§ (£/ha/yr)
UK inland wetlands	1,519	601,550	608	366	407

* Values are area-weighted estimates for all UK inland wetland sites using the Brander *et al.* (2008) benefit function and CORINE land use data sets.
† Data on the number and area of wetlands were drawn from the European CORINE Land Cover Maps (Morris & Camino 2010).
‡ Default average values (where all of the ecosystem services specified in this table do not apply) are £303/ha/yr for UK inland wetlands.
¶ In contrast, the default total value of the existing inland wetland stock, assuming that none of the ecosystem services in the table apply, is £182 million/yr for UK inland wetlands.
§ The per hectare value of services associated with additional new wetlands is lower than the average per hectare value of existing wetlands. This reflects the diminishing marginal value of additional wetlands.

Table 22.11 Estimated average, total and marginal values for storm buffering and flood control provided by coastal wetlands in the UK.* All values are given in £, 2010 prices. Source: Morris & Camino (2010).

Ecosystem service-related goods	No. of sites†	Total area (ha)	Average value of service where present (addition to default value)‡ (£/ha/yr)	Total value of service, assuming it is present in all UK inland wetlands¶ (£ million/yr)	Marginal value of service when provided by an additional hectare of new wetland§ (£/ha/yr)
UK coastal wetlands	693	274,613	3,730	1,534	2,498

* Values are area-weighted estimates for all UK inland wetland sites using the Brander *et al.* (2008) benefit function and CORINE land use data sets.
† Data on the number and area of wetlands were drawn from the European CORINE Land Cover Maps (Morris & Camino 2010).
‡ Default average values (where all of the ecosystem services specified in this table do not apply) are £1,856/ha/yr for UK coastal wetlands.
¶ In contrast, the default total value of the existing inland wetland stock, assuming that none of the ecosystem services in the table apply, is £509 million/yr for UK coastal wetlands.
§ The per hectare value of services associated with additional new wetlands is lower than the average per hectare value of existing wetlands. This reflects the diminishing marginal value of additional wetlands.

Stated Preference Methods

We will look at two such methods:

- Contingent Valuation (CV)
- Choice Experiments (CE)

Both aim to produce estimates of willingness to pay for changes in environmental quality, in terms of direct impacts on utility.

CONTINGENT VALUATION

Aim: seek Willingness To Pay (WTP) for environmental increase or decrease in a *hypothetical* market.

Method very widely used, but still much controversy.

Based on survey of the population of interest (eg internet panel surveys, in-person visitor questionnaires….)

Stages of analysis

(example: valuing a planned improvement river water quality)

1. Construct hypothetical market: how to pay, who pays, for what. *(planned improvement in pollution treatment imposes higher costs on citizens - fund by higher local taxes)*

2. Sample from a population of people (survey): Seek bids on WTP (*imagine the only way this improvement could go ahead was for local taxes to rise by 25%: would you be in favour of such a policy?)*

3. Average bids (*identifying of protests; mean versus median*)

4. Aggregate values (*how big is the population of those who benefit from the improvement?)*

5. Perform validity tests

An example: benefits of protecting nature sites

- Hanley et al, *Jnl Environ. Management*, 2003
- Ecological benefits being valued are in terms of better ecological quality of rivers
- Benefits to (i) users and (ii) non-users of measures to improve flow rates in rivers in Southern England
- Bid vehicle = payments for water services
- Find (i) WTP of users > WTP of non-users; (ii) but non-users still have WTP>0; (iii) distance-decay effect for users stronger than for non-users.

Table 2
Simple mean WTP by scenario in £/household/year

	Mean WTP, users	Mean WTP, non-users
All low flow rivers in Thames region	40.45	29.76
Full alleviation scheme for Mimram only	12.90	2.78
Partial alleviation scheme for Mimram	11.51	2.20

Notes: Based on sample of $n = 488$, which excludes protest bids but includes genuine zeros.

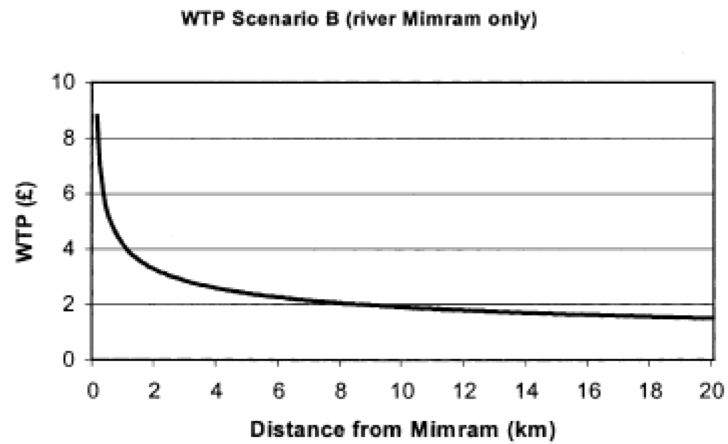

Fig. 1. Household WTP as a function of the households' distance from the river Mimram.

CHOICE EXPERIMENTS

Another stated preference method.

Based on characteristics theory of value: the value of a good is equal to the sum of the value of its characteristics, or attributes. Choice experiments try to value, in money terms, these attributes.

- Do this via experimental design which forces people to trade off different attributes against each other and against price
- This gives us three "answers":

1.- Which attributes significantly influence choices

2.- What is the marginal WTP for a change in any of these

3.- What is the total WTP for a programme which changes more than one attribute level simultaneously

Method is now very widely used world-wide.

- Need to describe the resource to be valued in terms of its attributes, or characteristics
- Construct choice sets out of these attributes, and the different levels they can take
- Ask people to choose their most preferred option in each choice set based on *random utility model*;

- Making assumptions about the nature of this randomness allows us to statistically estimate a model explaining choices

Suppose the environmental resource we wish to value is a river. We could say that this resource has 4 attributes:

- biodiversity in the river (poor, moderate, good)

- appearance of the water (no improvement, some improvement, big improvement)

- What recreational activities you can undertake in the river (walking, boating, fishing, swimming)

- The condition of river banks, in terms of vegetation and erosion (visible erosion; natural condition)

To run an economic choice experiment, we would introduce an additional attribute, namely the cost of improving the river (eg higher local taxes).

	No Change	Option A	Option B
River life: fish, insects, plants	Poor	Moderate	Good
Water appearance	No improvement	Some improvement	A lot of improvement
Recreational activities	Walking Boating ~~Fishing~~ ~~Swimming~~	Walking Boating Fishing ~~Swimming~~	Walking Boating Fishing Swimming
Condition of river banks	Visible erosion that needs repairs	Natural looking banks	Visible erosion that needs repairs
Increase in annual tax payments by your household for the next 10 years	€0	€5	€80
Which do you like best?	☐	☐	☐

Another example: water quality in rivers in Eastern Scotland

Which plan would you prefer for your local river?

Policy Option / Impact	Do Nothing	A	B
Number of agricultural jobs lost or gained in the local area	No loss no creation	Loss of 2 jobs	No loss no creation
Visual impact: number of months of low flow condition	5 months	2 months	2 months
Ecological condition	Worsening	Big improvement	Slight improvement
Increase in your water rates per year	£0	£30	£10
Please tick the option you prefer	□	□	□

(Hanley et al, ERAE, 2006)

- Using econometric analysis, we can then translate peoples' between options into an equation which shows the value they place on each attribute
- These parameters can then be used to calculate willingness to pay for a change in any attribute

Implicit prices (willingness to pay) for catchment management attributes in 2 Scottish lowland rivers.

(all values in £/year/household)

	Implicit Price	**95% confidence interval**	**Implicit Price**	**95% confidence interval**
	Motray River		*Brothock River*	
Low Flows: reduction in number of months experienced	3.87	2.52-5.07	2.70	0.90-4.21
Slight Improvement in river ecology	8.97	5.41-12.38	10.53	4.57-17.19
Big improvement in river ecology	24.03	18.53-31.08	28.26	19.65-40.57

Revealed preference approaches

Main idea – uncover environmental values using peoples' behaviour in markets that are somehow related to the environmental good.

Can only measure use values, rather than non-use values, since non-use values leave no "behavioural trail".

MAIN APPROACHES:

- Travel cost model
- Hedonic Pricing

1. The Travel Cost method

Uses expenditures on outdoor recreation (eg travel) to value public outdoor recreational resources (eg beaches, wetlands).

Procedure: typically, sample visitors at a site such as a national park. Then estimate statistical relationship between visits (V) and cost of visiting (C), plus other relevant variables (eg income).

For instance, visits (V) to a local recreation site per year by individuals could be determined according to:

e.g. $V = f(C, Y)$

where Y is income and C are Travel costs.

Travel Costs C are defined as C = f (distance, travel time)

Produces estimates of *consumers' surplus* per visit day, by estimating the rise in travel costs needed to drive trips to zero (or some arbitrary amount).

➔ gives the use value of the site under current conditions (value of access).

Random utility travel cost model

- These models predict how many trips people will take to alternative recreational sites (eg all fishing rivers in Ireland) as a function of the characteristics of these sites. One of these characteristics is the "price" – travel costs from respondent's home.
- Can use to measure how the use value (consumers surplus per trip) will change if (i) there is a change in site characteristics (eg improvement in water quality) and (ii) if one of the sites is closed.
- Very powerful method for understanding recreation demand, but need to combine with some other method if want to understand what happens to the total number of trips.
- Analysed the same way as choice experiments – only difference is the source of data (actual behaviour compared with stated choice)

A random utility travel cost model for whitewater kayaking on rivers in Ireland – note the site characteristics and the travel cost variables.

Variable	Parameter (t-statistic)
Travel Cost	-0.121 (-19.33)**
Quality of Parking	-0.096 (-1.24)
Crowding	0.101 (1.45)
Star quality of the whitewater site	0.409 (3.25)**
Water Quality	-0.186 (-1.79)
Scenic quality	0.289 (2.99)**
Availability of Information on water levels prior to visiting the site	-0.077 (-0.88)
Clifden Play Hole	-1.38 (-3.78)**
Curragower Wave on the Shannon	-1.838 (-6.80)**
The Boyne	-2.003 (-6.51)**
The Roughty	-2.134 (-5.34)**
The Clare Glens	-4.016 (-10.11)**
The Annamoe	-2.597 (-7.55)**
The Barrow	-3.491 (-10.93)**

The Hedonic Price Method

- **Basic assumption: housing market tells us something about how people value environmental quality.**

- Need to find link between environmental good (eg river quality) and a market good (eg housing)

- Assume house prices depend on "characteristics" of housing. One or more of these may be environmental, such as noise or water quality.

- Estimate a regression equation relating house prices to housing characteristics. Include environmental characteristic(s) of interest in this regression.

We try to estimate:

$P = f\,(S_i \ldots S_m;\, N_j \ldots N_n;\, Q_k \ldots Q_r)$

where S are *m* Site characteristics (eg number of bedrooms), N are *n* neighbourhood characteristics (eg crime rate, school quality); and Q is a set of *r* environmental characteristics, such as water quality.

- We then find the partial effect of Q on house prices, P. This "implicit price", P*q*, is the marginal cost of Q; it may well vary with the level of Q.

Method - continued

- We assume that people will buy houses which allow them to balance this marginal cost against the marginal benefit to them of an improvement in water quality.
- Applications: air and water pollution, noise, urban green space, value of beach front, externalities associated with solid waste sites.

<u>Production function methods: the value of ecosystem services as "inputs"</u>

Environmental services or resources (E) can enter the *production function* of some marketed good (Q):

$$Q = Q\ (L, K, E)$$

where L is labour, K is capital.
- Change in E can be thought of as shifting the supply curve for Q ➔ impacts on input use/output, impacts on prices.

"Valuing the environment as an input" (Barbier)

- Estimate changes in consumers and producers surplus due to changes in ecosystem,

or

- Estimate changes in value of output (assuming no price change)

Example: Barbier and Strand (Environment and Resource Economics, 12 (2))

Looks at the links between mangrove area and shrimp production, using case study from Campeche in Gulf of Mexico. Aims to estimate one element of indirect use values for mangroves by looking at link between area of mangrove swamp remaining and coastal shrimp fishery.

- Mangrove area falling due to urban development and aquaculture.
- Mangroves operate as nursery and breeding ground for fish and shrimp.
- Shrimp harvest has been falling as number of boats has risen, and as mangrove area has fallen.

Barbier and Strand (continued)

Model: $X_{t+1} – X_t = F(X_t, M_t) – h(X_t, E_t)$

where X is stock, F (.) is growth, M is mangrove area, h(.) is catch and E is effort.

Empirical model: $h = 4.4491\ M.E – 0.04297E^2$

- Implies marginal product of mangroves, evaluated at mean level of effort, is 24.7 tonnes per km sq.
- Most of fall in catch is due to rise in effort rather than fall in M
- Value of mangroves : each km sq. lost has a cost of \$86,345 - \$153,300 in terms of shrimp fishery.

conclusions

- Economic values (benefits) arise from water quality improvements to rivers, coastal areas etc; and from biodiversity improvements such as protection of marine mammals.
- But market prices do not adequately value these benefits.
- A range of methods have been developed which allow us to estimate the value in ££s of a change in environmental quality, based on the fundamental concept of Willingness to Pay.

- Changes in health risks – eg by reducing coliform levels in bathing waters - can be measured using similar approaches (for example, as part of a choice experiment).