An economic assessment of the amenity benefits associated with alternative coastal protection options.

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Abstract

Current government guidelines for the appraisal of coastal protection projects in the UK do not require that non-market amenity benefits to be considered. However, a new option in coastal defence, namely multi-purpose reefs, provides an opportunity to integrate coastal protection with significant amenity provision. This paper reports the findings of a choice experiment study that evaluated the amenity benefits of four alternative coastal protection systems currently being considered in a small town in west Wales. The results indicate that traditional coastal protection options such as timber and rock groynes do not generate amenity benefits, while a multi-purpose reef would generate significant benefits in terms of improvements in the visual appeal of the beach, safer swimming opportunities and improved surfing conditions. Importantly, these benefits were found to be significant for all members of the local community and not just surfers. Based on our findings, we recommend that guidelines for the appraisal of coastal protection projects should be amended to incorporate non-market amenity benefits.

Key words: Choice experiment, amenity benefits, coastal protection, multi-purpose reef

JEL: Q26, Q51, Q58

Introduction

The protection of coastal land and communities from the onslaught of the sea is a major concern throughout the world. Climate change and the predicted rises in sea levels are likely to further exacerbate these concerns in the future. In England and Wales, it has been estimated that over one million properties (valued at over £130 billion) are at risk from coastal flooding and a further 113,000 properties (£7.7 billion) are at risk from coastal erosion (Defra, 2001).

In this paper, we report the findings from a choice experiment study that assesses the economic value of the non-market amenity benefits associated with alternative coastal protection (defence) schemes that have been proposed for the

village of Borth in west Wales. Included in these proposals is a relatively new option for coastal protection, namely multi-purpose reefs which potentially could provide significant amenity benefits. Based on our findings, we argue that non-market amenity benefits and costs associated with alternative coastal protection schemes may be significant and therefore should be included in the economic appraisal of such schemes. Furthermore, we demonstrate that multi-purpose reefs can generate significant amenity benefits to local communities compared to more traditional coastal protection options and therefore should be considered as a possible option in future coastal protection proposals.

Coastal Protection options for Borth

The two mile stretch of coastline that runs alongside the village of Borth, west Wales has been defended from the sea since the 1930's. The current sea defence system at Borth includes a series of wooden groynes, a shingle bank, and a low seawall. Although this form of sea defence has proven to be effective in the past, recent inspection of the defences has established a need for substantial improvements. In response to these concerns, the local Council are currently in the process of appraising the suitability of various options for repairing and upgrading the Borth sea defences. These options included:

- *Timber and Rock Groynes*

Groynes are a proven method of sea defence (Dong, 2004). They can be constructed from timber, stones, concrete or steel and their main purpose is to prevent 'longshore' drift and restore beach volume (Viles *et al.*, 1995). Although they have been extensively used in the past, timber groynes have been found to have a number of unattractive qualities including a susceptibility to create rip channels (Viles *et al.*, 1995), as well as creating higher levels of reflection than rock groynes (Dong, 2004).

Rock has therefore recently become a more popular choice of construction material for groynes. The main disadvantage of groynes and particularly rock groynes is that they are often perceived as unattractive; a potential concern for Borth which relies heavily on tourism.

- *Seawall*

Seawalls are commonly used as sea defence where houses lie directly behind the beach (Clayton, 1993). Seawalls can help prevent overflow; that is when water flows over the beach and onto the land (property) lying behind. The last time severe overflow occurred in Borth was during the last major storm surge of 1976, when water broke through coastal defences and severely flooded the village. In an investigation of the effectiveness of seawalls in Jersey, Komar (1983) found that when used in a defence system with groynes, seawalls successfully harboured erosion problems and reduce the risk of overflow. Seawalls however are often considered to have a negative scenic impact on the beach (Bird, 1996), as well as potentially reducing the views of the sea from people's homes.

- *Multi-purpose reefs*

'Multi-purpose reefs' are a new and subtle development in coastal protection and may be considered as a sophisticated multi-purpose type of submerged breakwater. Pioneered by a New Zealand based company, ASR Ltd., the concept of multi-purpose reefs basically mimics the 'natural' coastal protection found around many tropical islands from coral reefs (Black, 2000). The 'artificial' reefs are constructed using up to 300 large 'TerraFix mega' geotextile bags, each filled with between 160 and 300 tonnes of natural sand. The depth of the reef, its size and its position relative to the shoreline are determined using sophisticated refraction/diffraction, wave-driven circulation and sediment transport numerical models, supplemented and calibrated by

field data collected on site (Black, 2000). The reef achieves coastal protection by dissipating wave energy offshore, refracting the angle at which waves hit the shore and allowing salient growth in the lee of the reef which leads to enhanced shoreline stability and protection. Since the reef is located 'offshore' (as opposed to on the beach as would be the case with groynes) the natural character of the beach is retained and visual amenity is not impaired (Black, 2000). The reef may also be designed to create and enhance surfing conditions. Indeed, observations from existing multi-purpose reefs such as the reef built at Lombok, Indonesia demonstrate that the technology can be used to create world-class waves (Mead *et al.*, 1999). In addition to improving surf conditions, the reef can also be designed to generate opportunities for other recreational and public amenity benefits including diving/snorkelling, sheltered swimming, fishing and other water activities, as well as the enhancement of marine habitat. Multi-purpose reefs therefore unify coastal protection and amenity benefits into a single structure placed offshore .

ASR Ltd. are currently building a number of reefs around the world, including reefs in New Zealand, Australia, India and USA. Despite their growing popularity worldwide, multi-purpose reefs are still very much in the early stages of development in the UK with only two other reef projects currently under consideration (Bournemouth and Newquay); both of which have been proposed primarily for surfing amenity although they are also expected to contribute towards coastal defence (Meager, 2002). The proposed reef at Borth could change this since the Borth reef would be the first UK reef to be considered primarily for coastal protection. This has led to a high level of scrutiny of the proposed Borth reef, particularly in terms of its potential effectiveness for coastal defence. However, results from the feasibility study

indicates that the reef option would provide effective coastal defence for Borth (Black *et al.*, 2003).

The current situation at Borth is that a range of coastal defence options are being scrutinised by the planning authorities. The final decision is likely to be based primarily on the effectiveness of the coastal defence options and the costs of construction and maintenance. Although the planning authorities are aware of the amenity benefits and dis-benefits of the various options, there is currently no requirement for them to account of these benefits, nor to establish the value of these benefits / dis-benefits. This research therefore aims to fill in this knowledge gap.

Research aims

The aim of this investigation is therefore to establish the *amenity value* associated with the various coastal protection options currently being considered for Borth. In this investigation, we restrict our analysis to the amenity benefits derived from Borth residents only. Furthermore, it should be stressed that in this study we are only interested in the amenity values associated with alternative coastal defence options, as opposed to the value of the coastal protection *per se*.

Methodology

The choice experiment (CE) method was utilised in this research to estimate the amenity benefits associated with a range of coastal defence options. The CE method relies on surveys to gather data. Within the survey, respondents were presented with a series of choice tasks in which they were asked to choose their preferred policy option from a list of three options: two options related to hypothetical coastal protection projects and the third related to the maintenance of the status quo. Each choice option was described in terms of attributes; in this case four amenity

attributes and a price attribute. Analysis of respondent choices was undertaken using a random parameters logit model (Train, 2003). The parameters from this model were then used to estimate implicit prices (economic values) for each level of provision of each of the amenity attributes. See Louviere *et al.* (2000) for a detailed discussion of the theory, design and analysis of choice experiments.

The actual questionnaire used in this study was structured as follows. First, the current coastal defence system at Borth was described and respondents were informed that these defences were coming to the end of their useful life and that they needed replacing. Respondents were then informed that the local Council was currently considering a range of options for improving the Borth sea defences and that the Council was interested in considering the views of local residents on the various options. Next, the four main coastal defence options currently being considered (timber groynes, rock groynes, seawall and multi-purpose reef) were described and respondents were informed that the Council could choose either one of these options or any combination of options. In either case, respondents were informed that all possible options or combinations of options would provide effective coastal protection for Borth. Importantly, respondents were also informed that the different options or combinations of options would have varying impacts on Borth in terms of the provision of amenities and that in some cases the provision of amenities might affect the overall level of coastal protection.

Four coastal protection amenity attributes were identified and defined following consultation with coastal protection experts and local residents. Each attribute was specified as either two or three levels of provision, including a status quo level. Figure 1 provides a summary of the descriptions used to describe the four amenity attributes. In addition to these amenity attributes, a fifth attribute relating to

annual increases in local tax over a five year period was also included as the price attribute. The tax attribute was specified according to five levels. A main effects, fractional factorial orthogonal design was used to assign attribute levels to the choice tasks. A blocking procedure was also used to split the choice tasks into four groups of eight choice sets.

	Visual Appearance
No change:	The existing timber groynes with shingle bank would be replaced and therefore the appearance of the beach would be the same as it is now.
Rock Groynes:	The rock groynes would stretch out into the sea replacing the existing timber groynes and would help to hold the shingle bank in place. They would be prominent on the beach and visible from both upper and lower Borth.
Offshore Reef:	A multi-purpose offshore reefs could be used as an alternative to the rock groynes in the area of beach near the lifeboat station (South Borth). Although the reef would be submerged most of the time, it is likely that the reef would be exposed above the surface of the water by around one foot during extremely low tides. The width of the reef would be approximately 100 metres.
	Seawall
No change:	The wall would not be raised and would remain three metres tall. The appearance of the wall would therefore remain the same. The risk of overflow would also remain unchanged.
Raised wall:	The seawall would be raised by one metre. It is likely that adding height to the wall would restrict views of the sea from Borth. The raised wall would reduce (but not prevent) the risk of overflow.
	Surf Conditions
No change:	The design of the sea defence would not aim to improve wave quality and therefore surf conditions would remain the same as they are now.
Improved:	The offshore reefs could be designed to improve the shape of the waves for surfing. Note that improved waves would be 100 metres offshore. Waves near to the shore would not be affected. Also note that designing the reef for surfing may compromise its effectiveness for coastal protection.
	Conditions for Family Beach Activities
No change:	Conditions for family beach activities such as swimming and paddling in the sea would remain the same.
Safer conditions:	The reefs could be designed to dissipate the energy from waves offshore, thus resulting in much calmer conditions along the beach. This would make activities such as swimming, water games, fishing and diving safer.

Figure 1: Coastal protection amenity attribute descriptions.

Each respondent was thus asked to consider eight choice scenarios. The wording used to introduce the choice task is reproduced below, as is a typical example of a choice task.

To allow us to assess your preferences for future improvement options to Borth's sea defences, we will now ask you to examine eight different scenarios that depict alternative sea defence options at Borth. We would like you to indicate for each scenario whether you prefer Option A, Option B or the 'status quo'. Options A and B describe the various options in terms of visual appearance, seawall height, surf conditions and impact on family beach activities. If you choose the status quo option, you should assume that the current sea defence system will remain unchanged. Also note that choosing the current situation will mean that your tax bill will not change from its current level.
In your responses to the following eight choice questions, you need to consider the implications of the improvement options in terms of their effect on coastal defence, amenity impacts and the extra costs to you.

	OPTION A	**OPTION B**	**STATUS QUO**
Visual appearance	Structures made from large rocks would replace the timber groynes.	Existing timber groynes with shingle bank	Existing timber groynes with shingle bank
Height of seawall	No change in the height of the wall	Wall raised by 1 metre to reduce the likelihood of overflow	No change in the height of the wall
Surf conditions	Conditions for surfing would remain unchanged	Conditions for surfing would improve	Conditions for surfing would remain unchanged
Beach conditions for family amenity	Safer conditions for beach activities	Conditions for beach activities would remain unchanged	Conditions for beach activities would remain unchanged
Annual tax increase	You will pay an extra **£15.00** tax annually over a 5 year period	You will pay an extra **£6.00** tax annually over a 5 year period	Your tax bill **will not be increased**
Choice (Please tick your preferred option)	**A** [ ]	**B** [ ]	**SQ** [ ]

Following the choice tasks, respondents were asked to complete a number of debriefing questions. Finally, demographic and attitudinal data was collected.

Survey administration

The village of Borth is split into two parts. Lower Borth is situated in a strip along the shoreline and is thus at risk from flooding from the sea, while Upper Borth is located on a hill overlooking the sea and therefore is not at risk from flooding. Clearly, the location of people's home within Borth is likely to influence their views on the coastal protection options. Thus, in-person interviews were conducted at random households located in both Lower and Upper Borth.

Results

One hundred and twenty Borth residents were interviewed during this research. This represents 22.6 % of all Borth households. Analysis of the demographics from our survey with that from the local census data revealed that our sample was representative of the local population.

The data from the choice experiment were analysed using a random parameters logit model (Louviere *et al.*, 2000, Train, 2003).Table 1 summarises two random parameters logit models for coastal defence options at Borth: a base model (Model 1) and our 'best fit' model that attempts to explain any heterogeneous preferences (Model 2). In the RPL models, the dependent variable is respondent's choice, which the independent variables include the amenity and price attributes of the choice options, as well as respondents socio-economic and attitudinal characteristics. Implicit prices associated with Model 2 can be found in Table 2

Model 1 represents the RPL model in which all of the coastal defence attributes are specified as random parameters in the utility function drawn from normal distributions. This first RPL model is statistically significant (χ^2 = 357 at 14 degrees of freedom). The overall fit of the model is good (Psuedo R^2=0.169) and is an improvement over a basis conditional logit model (which was estimated but not shown here). Examination of the random parameters in the utility function indicates that most parameters were significant ($p<0.05$) and of the expected sign; the exceptions being for the 'Seawall' and 'Improved_surf' parameters. The dispersal (derived standard deviation) of the 'Seawall' parameter was statistically significant ($p=0.00$) suggesting that unobserved heterogeneity of preferences exist for this parameter. The dispersals of the remaining parameters were not statistically significant suggesting that all the information on these attributes could be captured

within the parameter mean. Model 1 thus confirms heterogeneous preferences for the 'Seawall' attribute and also suggests that the 'Improved_surf' attribute could be better specified.

Table 1: Random parameters logit model for coastal defence amenity options at Borth

	Model 1 -Base RPL	Model 2 - 'Best fit' RPL
Random parameters in utility function		
b_{ASC_SQ}	-1.369* (-5.47)	
$b_{Visual\_rock\_groyne}$	-0.519* (-4.56)	
b_{Visual_reef}	0.857* (5.16)	
$b_{Seawall}$	0.024 (0.13)	0.305 (0.987)
$b_{Improved\_surf}$	0.305 (1.93)	-0.029 (-0.181)
$b_{Family\_amenity}$	0.447* (3.25)	
b_{Tax}	-0.016* (-3.47)	
Non random parameters in utility function		
b_{ASC_SQ}		-1.257* (-7.851))
$b_{Visual\_rock\_groyne}$		-0.441* (-6.002)
b_{Visual_reef}		0.746* (7.381)
$b_{Family\_amenity}$		0.495* (4.399)
b_{Tax}		-0.015* (-4.839)
Heterogeneity in Mean, parameter : variable		
$b_{Seawall\_Upper}$		-1.005 (-1.884)
b_{Surf_surfer}		1.116* (3.387)
Derived standard deviations of parameter distributions		
Nsb_{ASC_SQ}	0.092 (0.10)	
$Nsb_{Visual\_rock\_groyne}$	0.481 (1.20)	
Nsb_{Visual_reef}	0.062 (0.12)	
$Nsb_{Seawall}$	2.705* (3.74)	2.381* (8.549)
$Nsb_{Improved\_surf}$	0.949 (1.44)	0.914* (4.806)
$Nsb_{Family\_amenity}$	0.146 (0.11)	
Nsb_{Tax}	0.016 (1.14)	
$Nsb_{Seawall\_Upper}$		0.102 (0.106)
Nsb_{Surf_surfer}		0.067 (0.084)
Number of respondents	120	120
LL model	-875.995	-796.956
LL constants only	-1054.668	-1054.668
LL ratio test (χ^2)	357.34	515.42
p-value	0.000	0.000
Pseudo-R^2	0.169	24.43
Correct predictions	0.453	0.462

Wald test stat in parenthesis. * indicates that parameter is significant at $p<0.05$

In the 'best fit' model (Model 2) only two attributes, the 'Seawall' and 'Improved_surf' attributes, were specified as random parameters. The remaining attributes were specified as non-random parameters since the dispersal of these parameters were found not to be statistically different from the parameter means. In Model 2, we also aimed to explain heterogeneity observed within the mean random parameters and thus offer possible explanations as to why heterogeneity may exist. To achieve this, both random variables were interacted with a number of socio-economic and attitudinal characteristics. Following various specifications, the 'best fit' model included two interactions: the 'Seawall' random parameter was interacted with a dummy variable for residents of Upper Borth, while the 'Improved_surf' random parameter was interacted with a dummy variable for surfers. In the model, all random parameters were specified from normal distributions[1].

Model 2 is statistically significant ($\chi^2 = 515$ at 13 degrees of freedom), and the overall fit of the model is high (Psuedo $R^2 = 0.244$). Examination of the non-random parameters in the utility function indicates that they are all significant ($p < 0.05$) and of the expected sign. The random parameter for the 'Seawall' attribute is positive (0.305), but not significant at $p < 0.05$, while that of the interaction between the 'Seawall' attribute and upper Borth dummy variable is negative (-1.005) and significant at $p < 0.1$ (but not $p < 0.05$). The dispersal of the 'Seawall' attribute is significant, indicating that unobserved heterogeneity still remains within this parameter, while no heterogeneity was found in the interacted parameter. The interpretation of this is that residents of upper Borth have significantly different value preferences for the raising of the seawall (implicit price = -£45) compared to the mean value from other Borth residents (implicit price = +£19). It should also be noted that

[1] Other distributions were also investigated but were found not to significantly improve the model.

unobserved heterogeneity still exists for the other Borth residents. In other words, some people in lower Borth may want the seawall raised while others do not. The coefficient in the 'Improved_surf' random parameter was negative but low (0.029), and also insignificant. The parameter on the interaction between the 'Improved_surf' parameter and the surfer dummy variable is positive (1.116) and significant. The dispersal of the 'Improved_surf' random parameter was significant, suggesting that unobserved heterogeneity still exists in this parameter. However, the dispersal of the interaction random parameter ('Improved_surf' attribute x surfer dummy variable) was insignificant suggesting homogeneous preferences with this group. The interpretation of this is that surfers have consistently high values (implicit price = £70) for improved surf conditions, while the other Borth residents have values that are close to £0 for improved surf conditions (in other words, they appear to be indifferent with regards to whether surf conditions are improved or not).

Table 2: Implicit prices for coastal defence amenity attributes at Borth.

Attributes	**Model 2 RPL**
Visual_timber_groynes (all residents)	-£19.82 (7.23)
Visual_rock_groyne (all residents)	-£28.66 (8.06)
Visual_reef (all residents)	£48.49 (12.84)
Seawall (all residents)	£19.81 (20.12)
Seawall (Upper Borth only)	*-£45.45 (30.49)*
Improved_surf (all residents)	-£1.95 (10.85)
Improved surf (Surfers only)	*£70.59 (21.02)*
Family_amenity (all residents)	£32.14 (10.09)

Standard errors in parenthesis

Implicit prices for the non random parameters in Model 2 (Table 2) were similar to those from a basic conditional logit model (not reported here), but were

generally more conservative in value. It should also be noted that the standard errors in the RPL models are generally smaller than those found in the conditional logit models; this suggests that more precise measures were attained in the RPL model. The use of the random parameters logit models enabled sources of heterogeneity to be identified and evaluated within an econometrically robust modelling framework.

Implications for future coastal defence strategies

Traditionally, coastal defence design has focused (as it should) on maximising the effectiveness of coastal defence systems. Although, many projects also attempt to minimise the impacts of the project on local amenity, coastal defence projects generally have not attempted to maximise amenity benefits. A multi-purpose reef option could potentially change this since it allows coastal defence to be directly integrated with amenity provision. Multi-purpose reefs may be designed to provide a range of amenity benefits including opportunities for surfing, diving, snorkelling, fishing, sheltered swimming, and the preservation of the natural character of a beach. The surfing benefits of multi-purpose reefs have been well documented; for example, experiences from New Zealand, Australia and Indonesia indicate that multi-purpose reefs can create world-class waves that attract significant numbers of surfers and therefore benefit local economies (Mead *et al.*, 1999). The values of the other non-surfing benefits, however, have not previously been quantified, and this study demonstrates that these may be significant. Furthermore, this study has also demonstrated that these benefits may be enjoyed by the wider community, and not simply restricted to the relatively small, specialist surfing community.

Evidence from this study has clearly demonstrated that there are significant differences in the value of the amenity benefits associated with alternative types of coastal defence options. We therefore argue that these values should not be

disregarded in the appraisal of coastal defence projects, which is the current situation in most countries including the UK. We therefore recommend that planning authorities modify their guidance for the appraisal for coastal defence projects to include a requirement to consider the non-market benefits / dis-benefits of alternative options. These non-market benefits should include the amenity benefits to local residents (as highlighted in the current study), as well as the benefits attained by existing (and potentially new) tourist visitors (particularly, in locations where tourism plays a significant contribution to a local economy). The incorporation of amenity benefits in coastal defence appraisals will help to ensure that best value for money is attained.

Finally, the case for a multi-purpose reef at Borth is different from most of the other reefs that have been proposed or constructed in that the Borth reef is primarily being considered for coastal protection; the case for most of the other reefs have all primarily focused on creating world-case waves which would attract surfing tourists, boosting the local economy. The local conditions at Borth, however, mean that the reef is unlikely to create world-class waves. However, if it is demonstrated that the Borth reef can effectively integrate coastal defence and amenity, then it is likely that the reef will represent a landmark case in terms of changing the way coastal defence systems are considered in the future. Thus, the implications of the Borth proposal could have far reaching consequences that could change the appearance of our coastlines in the future; arguably for the better.

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