An Economic Assessment of the Amenity Benefits Associated with Alternative Coastal Defence Options

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ABSTRACT

Current government guidelines for the appraisal of coastal defence 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 defence with significant amenity provision. This paper reports the findings of a choice experiment study that evaluated the amenity benefits of four alternative coastal defence systems currently being considered for Borth in west Wales. The results indicate that traditional coastal defence 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 defence projects should be amended to incorporate non-market amenity benefits.

ADDITIONAL INDEX WORDS: *Choice experiment, amenity benefits, coastal defence, multi-purpose reef*

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 a fifty year forecast, the same report estimates that, if nothing is done to maintain and improve existing coastal defence systems, damages to property from coastal flooding will cost on average over £1.5 billion per annum (*ibid.*). To maintain existing levels of protection, the UK government would have to invest £210 million per annum (*ibid.*). The bulk of this expenditure is ultimately met by taxpayers, many of whom may derive little personal benefit from the money spent on their behalf. Good project appraisal is therefore essential to ensure that taxpayers receive value for money from coastal defence projects.

In the UK, DEFRA (then MAFF) has produced a series of six guidance documents for the appraisal of flood and coastal defence projects (MAFF, 2001), including a document on the economic appraisal of such projects (MAFF, 2000). Since the publication of these documents, the HM Treasury has revised it's 'Green Book' on 'Policy appraisal in Central Government'(HM TREASURY, 2003), indicating that project appraisal should now adopt lower discount rates, examine distributional effects, be more risk adverse, account for optimism bias, and importantly incorporate non-market and environmental benefits and costs associated with policies and projects. DEFRA is currently updating it's '*Economic appraisal of flood and coastal defence*' guidance document to reflect the changes made in the 'Green Book' and has produced a supplementary note in the interim (DEFRA, 2003). Although, this supplementary note does address most of the changes made in the revised 'Green Book', the interim guidance does not explicitly address one of the key changes made in the revised 'Green Book', namely the incorporation of values for the non-market and environmental benefits and costs associated with flood and coastal defence projects.

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 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 defence options and therefore should be considered as a possible option in future coastal defence 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. The concern over the state of the existing sea defences has been such that the Environment Agency has been opposing nearly all new building development in the village (CAMBRIAN NEWS, 2003). In response to these concerns, the local Council (Ceredigion County Council) are currently in the process of appraising the suitability of various options for repairing and upgrading the Borth sea defences. Initially, the Council were examining ten options, including various variations on: replacing the existing timber groynes; replacing the timber groynes with rock groynes / structures; and raising the height of the existing seawall. However, during its investigations, an eleventh option of an 'artificial' or multi-purpose reef was also put on the table. Multi-purpose reefs are constructed using large sand bags that are placed just under the surface of the water around 100 meters offshore. The reef provides coastal defence security by dissipating the wave energy offshore, similar to what happens with the natural coral reefs found around tropical islands. Multi-purpose reefs also have the added attraction of providing amenity benefits including improvements in conditions for surfing. Multi-purpose reefs, however, are a new concept in coastal defence and to date no reefs have been built in the UK; although a small number of reefs have been constructed elsewhere primarily to improve surfing conditions, but also enhance coastal defence. A feasibility study is currently being undertaken to establish whether a multi-purpose reef would be a viable coastal defence option for Borth. Thus, the local Council is currently considering a range of coastal defence options for Borth. We now describe the main options being considered.

Timber and Rock Groynes

Groynes are a proven method of sea defence. They have been used extensively throughout the world to tackle coastal erosion (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 and SPENCER, 1995). Wave action has been linked to the 'longshore' transport of sediment (KOMAR, 1983, KOMAR and INMAN, 1970, LONGUET-HIGGINS, 1972). Therefore groynes are constructed at right angles to the shore and are designed to reduce longshore drift. Despite their effectiveness, groynes can have a negative impact on neighbouring beaches if the groynes completely prevent any 'longshore' transport whatsoever and consequently, starves another beach of new sediment inputs (KOMAR, 1983, VILES and SPENCER, 1995). Despite these criticisms of groynes, BRAY (1992) has proved that groynes play a key role in coastal protection systems on shingle beaches and VILES and SPENCER (1995) conclude that despite certain problems, groynes can be a successful form of coastal management.

Currently the two main materials used to construct groynes are timber and rock. Timber used to be the main construction material for groynes, however the introduction of beach nourishment schemes has lead to a decline in their use (VILES and SPENCER, 1995). Furthermore, timber groynes have a number of unattractive qualities including a susceptibility to create rip channels (VILES and SPENCER, 1995), as well as creating higher levels of reflection than rock groynes (DONG, 2004). Rock has recently become a more popular choice of construction material for groynes. DONG (2004) suggests the main reason for this is their intrinsic properties to dissipate wave energy and low levels of reflection. In addition, recent research carried out by DONG (2004) clearly demonstrates that rock groynes are generally more effective than timber groynes, specifically on mixed sand and shingle beaches such as at Borth. 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. Overflow is most likely to occur during unusually high tides and intense storms. 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. The proposal to raise the height of the seawall at Borth is likely to lessen but not remove the risk from 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. Furthermore, some sea walls have been found to exacerbate coastal erosion problems. PENNING-ROWSELL *et al.* (1992) however suggest that there may be some recreational benefits from seawalls if a walkway is created on top of it.

Multi-purpose reefs

'Multi-purpose reefs' are a new and subtle development in coastal defence 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 and BLACK, 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 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). Thus, the proposed reef at Borth could change this since the reef would be the first UK reef to be considered primarily for coastal protection. This has lead 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 considered and the Council is currently negotiating possible sources of funding from the Welsh Assembly Government (WAG). The Council / WAG will have to decide which option to choose including the possibility of a combination of options. 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 Council/ WAG 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 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

Environmental economists have developed a range of environmental valuation techniques that could be used to evaluation the amenity benefits associated with coastal protection projects. These methods include both revealed preferences techniques (e.g. the travel cost method and hedonic pricing) and stated preference methods (e.g. contingent valuation and choice experiments) (CHAMP, *et al*., 2003). The choice experiment (CE) method has been chosen for this application since (i) it is the best method to value component attributes of an environmental good, i.e. different types of amenity benefits and (ii) it is very flexible in terms of what it can be used to value (LOUVIERE, et al., 2000).

Choice experiments: theoretical background

The choice experiment technique is a survey based method in which survey respondents are presented with a series of choices, each describing (usually three) policy alternatives. Each alternative is described in terms of a bundle of attributes relating to the good in question: in this application, the attributes describe different types of amenity associated with the various coastal defence options. Respondents are required to consider the policy alternatives and then choose their most preferred alternative from a choice set presented. These choice processes can be modelled using a random utility model (RUM) (HANEMANN, 1984). According to RUM, the respondent's utility from alternative *i*, U_i, is composed of a deterministic, observable component, V_i, and a random, unobservable component, ε_i. It is important to point out that the respondent has full knowledge of their utility function: utility is only random from the point of view of the researcher. Let the utility of alternative i from choice set C be represented by

$$U_i = V_i + \varepsilon_i . \tag{1}$$

The selection of alternative i implies that the utility of alternative i is greater than the utility of any other alternative, j. Thus, the probability of an individual choosing alternative i from choice set C can be expressed as

$$\begin{aligned} \Pr\left[i \mid C\right] &= \Pr\left[U_i > U_j\right], \forall j \in C \\ &= \Pr\left[\left(V_i + \varepsilon_i\right) > \left(V_j + \varepsilon_j\right)\right] \\ &= \Pr\left[\left(V_i - V_j\right) > \xi\right], \end{aligned} \tag{2}$$

where $\xi = \varepsilon_j - \varepsilon_i$. By assuming that the error term, ξ, is distributed according to a Type 1 extreme value (Gumbel) distribution, the probability of choosing alternative i can be expressed as

$$\Pr\left[i \mid C\right] = \frac{\exp\left(\mu V_i\right)}{\sum_{j \in C} \exp\left(\mu V_j\right)}, \tag{3}$$

where μ represents a scale factor, which may be normalised to one.

In CE, the choice probabilities may have a convenient closed-form solution known as the conditional logit model. The conditional logit model is structured such that the probability of individual *n* choosing alternative i depends on the utility of that alternative relative to the utility of all other alternatives. The CE utility function can be expressed as

$$U_{in} = \beta_n' X_{in} + \varepsilon_{in} \tag{4}$$

Where: X_{in} is a vector of explanatory variables that include attributes of the alternatives (including a monetary attribute) and socio-economic and attitudinal characteristics of the respondents, β_n is the parameters of the explanatory variables, and ε_{in} is the stochastic error term.

Welfare estimates, in the form of compensating surplus, can be derived from the conditional logit models using the following formula

$$CS = -\frac{1}{\beta_{Bid}}\left[\ln\left(\sum_{j=1}^{J}\exp(V_0)\right) - \ln\left(\sum_{j=1}^{J}\exp(V_1)\right)\right] \quad (5)$$

where β_{Bid} is the marginal utility of income (assumed to be equal to the negative of the coefficient of the monetary variable), and V_0 and V_1 represent the indirect utility functions before and after the change under consideration. Since we are dealing with a 'states of the world' issue, Equation (5) can be reduced to

$$CS = -\frac{1}{\beta_{Bid}}\left(V_0 - V_1\right). \quad (6)$$

Finally, assuming that V_0 and V_1 are linear in attributes, 'implicit prices' for changes in the quality of individual attributes may be estimated as a ratio of coefficients

$$IP = -\frac{\beta_{Attribute}}{\beta_{Bid}}. \quad (7)$$

An important assumption in the condition logit model is that errors are independently and identically distributed (IID) following a type 1 extreme value distribution. IID has an equivalent behavioural association with a property known as the Independence of Irrelevant Alternatives (IIA). The IIA property states that the ratio of the choice probabilities of any pair of alternatives is independent of the presence or absence of any other alternative in a choice set. Violation of the IIA assumption is a major concern in choice modelling since the cross substitution effects observed between pairs of alternatives are no longer equal given the presence or absence of other alternatives within the model (LOUVIERE, *et al.*, 2000). HAUSMAN and McFADDEN (1984) proposed a specification tests for conditional logit models to test the IIA assumption. The HAUSMAN test requires the analyst to first estimate an unrestricted model complete with all alternatives and then estimate a restricted model that excludes one of the alternatives. The test statistic is:

$$q = [b_u - b_r]' [V_r - V_u]^{-1} [b_u - b_r] \quad (8)$$

Where: b_u and b_r are column vectors of parameter estimates for the unrestricted and restricted models respectively; and V_u and V_r are the variance-covariance matrices for the unrestricted and restricted models. The test statistic, q, is given as a chi-square statistic with degrees of freedom equal to the number parameters estimated in either model. Rejection of the HAUSMAN test suggests that the IIA assumption has been violated and that a less restrictive model specification such as a nested logit or random parameters logit model should be considered.

The random parameters logit (RPL) model relaxes the IIA assumption by partitioning the stochastic component additively into two parts (TRAIN, 1999). One part is correlated over alternatives and heteroskedastic, and another part is IID over alternatives and individuals. The RPL utility function, U_{in}, can now be specified as:

$$U_{in} = \beta_n' X_{in} + [\eta_{in} + \varepsilon_{in}] \quad (9)$$

Where $\eta_{in} \sim f(\eta_n|\Omega)$ is a random term with zero mean and a general distribution[1], with a general density function f and Ω are fixed parameters of the distribution (e.g. mean and variance), ε_{in} is a random term with zero mean that is IID over alternatives and does not depend on underlying parameters or data. As ε is IID extreme value, the *conditional* probability in η of individual n choosing alternative i corresponds exactly to the conditional logit model:

$$P_n(i/\eta) = L_{in}(\eta) = \frac{e^{(\beta_n' X_{in} + \eta_{in})}}{\sum_j e^{(\beta_n' X_{in} + \eta_{in})}} \tag{10}$$

This expression is the simple conditional logit model, but with the proviso that, for each sampled individual, we have an additional piece of information on unobserved preference heterogeneity defined by η_{in}. Thus, the unconditional probability of choosing the alternative corresponds to the integral of the conditional probability over all values of η_{in}, which depends on the parameters characterizing the distribution (TRAIN, 2003):

$$P_{in} = \int_\eta L_{in}(\eta_n) f(\eta_n | \Omega) d\eta_n \tag{11}$$

Unlike the conditional logit model, the RPL choice probabilities do not have a mathematical closed form. The integral is approximated through simulation. R values of η_n are obtained from its density function $f(\eta_n|\Omega)$. Using this draw, the logit formula (10) for $L_{in}(\eta)$ is calculated. Accordingly, the mean of the resulting $L_{in}(\eta)$'s is taken as the approximate choice probability giving the following simulated probability

$$\tilde{P}(i) = \frac{1}{R}\sum_{r=1}^{R} L_{in}(\eta^r) \tag{12}$$

Assuming that the monetary attribute is not specified as random, compensating surplus and implicit prices from the RPL model can again be estimated using the formula reported in Equations 6 and 7.

The choice experiments survey instrument

The 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 reproduces the descriptions

[1] η_{in} can take on a number of distributional forms such as normal, lognormal, uniform or triangular depending the underlying parameters and observed data relating to alternative i and individual n..

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[2]. 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.

Each respondent was asked to consider eight choice scenarios

> *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.*

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. 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.

[2] Due to the sensitivities of this case, it is important to highlight the following. Although an increase in local taxation was used as the preferred payment vehicle in the valuation study, it is stressed that increases in local taxes will not be used to fund Borth's coastal defences. To curb possible concerns from local residents, all respondents were informed of this after completing the survey.

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.

	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	**A** [ ]	**B** [ ]	**SQ** [ ]

RESULTS

One hundred and twenty Borth residents were interviewed during this research. This represents 22.6 % of 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.

Choice Experiment Analysis

The data from the choice experiment were analysed using both conditional logit and random parameters logit models. Five conditional logit models are reported in
Table 1. Model 1 was generated using all 120 survey respondents. The reported model shows only the coastal defence amenity attributes and an alternative specific constant (ASC) for the status quo option. The overall fit of Model 1 is moderate with a pseudo R^2 value of 0.067 and 45% correct predictions. A log-likelihood (LL) ratio test indicates that the model has a better fit than a constants only model. In terms of the attributes, the 'Visual_rock_groyne' parameter is significant and negative indicating that the visual appearance of rock groynes would reduce Borth residents' utility, while the visual appearance of the reef option 'Visual_reef' is significant and positive indicating that this option would increase utility. The parameter on the 'Seawall' attribute is negative but highly insignificant. This indicates that Borth residents considered collectively appear to be largely indifferent to raising the height of the seawall. The parameter on the 'Improved_surf' attribute is positive but again is not significant. Thus, Borth residents appear to be indifferent to improvements in local surfing conditions. The 'Family_amenity' attribute is positive and significant indicating that residents would gain

utility from calmer waters for family beach activities. Finally, as expected the tax coefficient is negative and significant; respondents are less likely to choose an option that has a higher tax associated with it.

Implicit prices can be estimated for the attributes in Model 1 following Equation 7 and are reported in Table 2. The highest value was found for the improved visual amenity associated with replacing the existing timber groynes with the reef (+£84). Replacing the timber groynes with either timber or rock groynes respectively reduced utility by £35 and £48. It would thus appear that, in terms of visual appeal, Borth residents would greatly value a beach absent of groynes compared to one with any type of groyne; although they are largely indifferent to the material used to construct the groynes. Improving sea conditions for 'Family_amenity' was also found to increase utility by £45. The seawall and improved surf attributes were insignificant and therefore the implicit prices are meaningless in this model.

In Model 1, it was noted that both the 'seawall' and 'improved_surf' attributes were insignificant. A possible cause of this may be divergences in the utility functions of different groups of Borth residents. To investigate this, four further models were generated. Models 2 and 3 respectively split the data according to whether the respondent lives in lower or upper Borth, while Models 4 and 5 respectively split the data according to whether respondents were non-surfers or surfers. Models 2 to 5 are presented in
Table 1, while the estimated implicit prices are presented in Table 2.

Turning first to examine Models 2 and 3. In both models, we find that the 'Seawall' parameter is now significant. In the case of lower Borth residents the parameter is positive (implicit price = £25), while it is negative for upper Borth residents (implicit price = -£88). Thus, there are clear divergences in the preference of Borth residents for increasing the height of the seawall. Those currently living in lower Borth have positive preferences for the seawall (presumably because raising the seawall would reduce the risk from overflow), while those in upper Borth are against raising the seawall (presumably because they do not want their sea views impaired and also their houses would not affected by overflow flooding). However, the 'Improved surf' parameter is still not significant in either Model 2 or 3. Comparing Models 2 and 3 with Model 1 using a LL ratio test, we find that the LL values of both models are significantly closer to zero than Model 1 (χ^2 =567 and 1224 respectively). Thus, splitting the sample between upper and lower Borth improved the fit of the models.

Models 4 and 5 provide similar analysis to Models 2 and 3, but this time we respectively split the data between non-surfers and surfers. The non-surfer model (Model 4) is similar to Model 1 in terms attribute signs and significance; although a LL ratio test indicates that Model 4 provides a significant improvement in fit (χ^2 = 443). In the 'Surfer' model (Model 5) we find that the 'Improved surf' attribute is now significant and positive (implicit price = £85). Thus as one might expect, it is only people who currently surf that value the improved surf. It is also interesting to note that the fit of the 'Surfer' model is significantly higher than the other models; the pseudo R^2 values from the surfer model = 0.18 compared to around 0.06 in the other models.

The conditional logit models described in
Table 1 provide a simple illustration of the different values that different groups of residents have for alternative amenity benefits associated with coastal defence options. However, simply splitting the datasets in this way is a rather crude approach to examining preference

heterogeneity. Furthermore, the HAUSMAN IIA tests indicate that three of the five conditional logit models reported in
Table 1 violate the IIA assumption; Models 2 and 4 pass the test. To address these concerns, we also utilised a random parameters logit model.

Table 3 summarises two random parameters logit models for coastal defence options at Borth. Both models are based on all survey respondents. Model 6 represents a base RPL model in which we explore possible sources of heterogeneity by specifying all coastal defence amenity attributes as random variables. Model 7 represents our 'best fit' model in which we attempt to explain the heterogeneity underlying the random variables. It should be noted that due to the random parameter specification, both models are not affected by the IIA assumption. Implicit prices associated with Model 7 can be found in Table 4

Model 6 represents a 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 the previous conditional logit models. 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 'Improved_surf' and 'Seawall' 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 6 thus confirms heterogeneous preferences for the 'Seawall' attribute and also suggests that the 'Improved_surf' attribute could be better specified.

In the 'best fit' model (Model 7) 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 7, 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[3].

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

Table 1: Conditional logit models for coastal defence amenity options at Borth

Attributes	**Model 1 All Borth residents**	**Model 2 Lower Borth only**	**Model 3 Upper Borth only**	**Model 4 Non surfers only**	**Model 5 Surfers only**
β_{ASC_SQ}	-0.971*	-0.856*	-1.217*	-0.964*	-0.894*
	(-7.12)	(-5.18)	(-4.98)	(-6.09)	(-3.21)
$\beta_{Visual\_rock\_groyne}$	-0.403*	-0.353*	-0.522*	-0.230*	-1.038*
	(-6.54)	(-4.73)	(-4.67)	(-3.27)	(-6.93)
β_{Visual_reef}	0.700*	0.675*	0.766*	0.564*	1.138*
	(8.10)	(6.44)	(4.95)	(5.69)	(5.76)
$\beta_{Seawall}$	-0.015	0.245*	-0.572*	0.028	0.045
	(-0.15)	(2.00)	(-3.18)	(0.24)	(0.20)
$\beta_{Improved\_surf}$	0.154	0.135	0.198	-0.066	1.070*
	(1.58)	(1.15)	(1.11)	(-0.60)	(4.55)
$\beta_{Family\_amenity}$	0.377*	0.409*	0.329	0.439*	0.231
	(3.98)	(3.56)	(1.91)	(4.00)	(1.14)
β_{Tax}	-0.008*	-0.009*	-0.006	-0.008*	-0.013*
	(-3.70)	(-3.45)	(-1.60)	(-3.10)	(-2.58)
LL model	-887.58	-603.98	-275.48	-665.59	-199.40
LL constants only	-950.25	-649.87	-297.16	-704.57	-244.06
LL ratio test (χ^2)	125.34	91.78	43.36	77.96	89.32
p-value	0.000	0.000	0.000	0.000	0.000
Pseudo-R^2	0.066	0.071	0.073	0.055	0.183
Correct predictions	0.45	0.45	0.46	0.44	0.54
Number of respondents	120	82	38	89	31
HAUSMAN IIA test (χ^2)	19.80	13.21	21.16	9.01	17.56
(p-=value)	(0.006)	(0.067)	(0.003)	(0.252)	(0.014)

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

Table 2: Implicit prices for coastal defence amenity options at Borth

Attributes	Model 1 All Borth residents	Model 2 Lower Borth only	Model 3 Upper Borth only	Model 4 Non surfers only	Model 5 Surfers only
Visual_timber_groynes	-£35.69	-£33.90	-£37.85	-£41.61	-£7.99
	(13.58)	(14.06)	(32.74)	(17.92)	(13.00)
Visual_rock_groyne	-£48.49	-£37.19	-£81.14	-£28.55	-£82.50
	(15.47)	(13.81)	(54.57)	(13.198)	(34.19)
Visual_reef	£84.17	£71.09	£118.99	£70.16	£90.49
	(25.90)	(24.32)	(80.46)	(27.03)	(39.17)
Seawall	-£1.75	£25.85	-£88.88	£3.43	£3.55
	(12.09)	(13.65)	(64.43)	(14.22)	(17.23)
Improved_surf	£18.48	£14.24	£30.76	-£8.24	£85.02
	(11.52)	(12.04)	(29.45)	(14.46)	(31.14)
Family_amenity	£45.30	£43.08	£51.08	£54.62	£18.36
	(17.25)	(17.64)	(43.94)	(22.90)	(17.76)

Standard errors in parenthesis

Model 7 is statistically significant (χ^2 = 515 at 13 degrees of freedom). The overall fit of the model is the highest out of all models examined (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 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 3: Random parameters logit model for coastal defence amenity options at Borth

	Model 6 *Base RPL*	*Model 7* *'Best fit' RPL*
Random parameters in utility function		
β_{ASC_SQ}	-1.369* (-5.47)	
$\beta_{Visual\_rock\_groyne}$	-0.519* (-4.56)	
β_{Visual_reef}	0.857* (5.16)	
$\beta_{Seawall}$	0.024 (0.13)	0.305 (0.987)
$\beta_{Improved\_surf}$	0.305 (1.93)	-0.029 (-0.181)
$\beta_{Family\_amenity}$	0.447* (3.25)	
β_{Tax}	-0.016* (-3.47)	
Non random parameters in utility function		
β_{ASC_SQ}		-1.257* (-7.851))
$\beta_{Visual\_rock\_groyne}$		-0.441* (-6.002)
β_{Visual_reef}		0.746* (7.381)
$\beta_{Family\_amenity}$		0.495* (4.399)
β_{Tax}		-0.015* (-4.839)
Heterogeneity in Mean, parameter : variable		
$\beta_{Seawall\_Upper}$		-1.005 (-1.884)
β_{Surf_surfer}		1.116* (3.387)
Derived standard deviations of parameter distributions		
$Ns\beta_{ASC\_SQ}$	0.092 (0.10)	
$Ns\beta_{Visual\_rock\_groyne}$	0.481 (1.20)	
$Ns\beta_{Visual\_reef}$	0.062 (0.12)	
$Ns\beta_{Seawall}$	2.705* (3.74)	2.381* (8.549)
$Ns\beta_{Improved\_surf}$	0.949 (1.44)	0.914* (4.806)
$Ns\beta_{Family\_amenity}$	0.146 (0.11)	

Nsβ_{Tax}	0.016 (1.14)	
Ns$\beta_{Seawall_Upper}$		0.102 (0.106)
Nsβ_{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 $p<0.05$

Table 4: Implicit prices for coastal defence amenity attributes at Borth.

Attributes	**Model 7 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

Table 5: Compensating surplus amenity values for alternative coastal defence options at Borth.

Coastal defence option	Compensating surplus value (£ per household)
Replace existing groynes with timber groynes	0
Replace existing groynes with rock groynes	-8.84
Replace existing groynes with a multi-purpose reef (excluding surf improvements)	98.5
Replace existing groynes with a multi-purpose reef (including surf improvements)	171.04
Raising the height of the seawall (lower Borth).	19.81
Raising the height of the seawall (upper Borth)	-45.45

Implicit prices for the non random parameters in Model 7 (Table 4) are largely similar to those from Model 1, but are generally more conservative in value. It should also be noted that the standard errors in Model 7 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.

DISCUSSION AND SUMMARY

This study utilised the choice experiments method to elicit local resident's values for a range of amenity benefits / dis-benefits associated with various coastal defence options currently being considered for the village of Borth. In this discussion, the study results are first discussed in the context of recommendations for coastal defence at Borth. The scope of the discussion is then widened to comment on the implications of this research for future appraisal of coastal defence options in both the UK and elsewhere.

Implications for Borth

Ceredigion County Council and WAG have a duty to follow the MAFF (2000) guidelines during their appraisal of the alternative coastal defence options at Borth. However, as mentioned earlier, these guidelines do not specify a requirement to consider the non-market (amenity) benefits associated with the alternative options. This study provides evidence on the amenity benefits that local residents would gain from the options being proposed.

In the results section, implicit prices associated with various coastal defence amenity attributes were presented. The data from the valuation study may also be used to assess the overall utility impacts of the alternative policy options currently being considered for Borth. These compensating surplus values are reported in Table 5. The first option, replacing the existing timber groynes, has a compensating surplus value of zero since simply replacing the groynes would not affect the amenity value of the beach. The second option involves replacing the existing groynes with rock groynes. The overall impact of this is a small reduction in utility (-£8.84). Thus in terms of amenity impact, Borth residents appear to be largely indifferent to the type of groyne used. However, the option of replacing the existing groynes with a multi-purpose reef significantly increases utility (£98 excluding improved surf conditions and £171 including improved surf conditions). Thus, not only does the reef option provide significant amenity benefits for surfers (as would be expected), but it also generates significant amenity benefits for the non-surfing community. The fact that the non-surfing amenity benefits associated with the reef are high is an important finding since these benefits have largely been ignored in the current deliberations on the Borth reef option. The final policy option relates to raising the height of the seawall. As already mentioned there is split opinions relating to this attribute and that these differences are largely related to whether the respondent lives in upper or lower Borth. It is however important to point out that the option to raise the seawall is in fact independent of whether groynes or a reef are used to stop longshore drift. The above evidence clearly indicates that the reef option is far more superior that the other, more traditional forms of coastal protection in terms of generating amenity benefits.

It should also be noted that this study only attempted to estimate the amenity values affecting local residents. Borth is a tourist destination and it is likely that tourists will also attain utilities from the alternative coastal defence options being considered at Borth. If it was found that tourists have similar preferences as the local residents, then the construction of a multi-purpose reef at Borth would generate much wider amenity benefits, and potentially could also attract additional tourists to the village. In addition to the non-market benefits, additional tourists would also generate economic benefits to the local economy in terms of income and job creation (see BLACK *et al.* (2003) for a summary of the predicted economic impacts of the proposed Borth reef). Borth is located in EU Objective 1 region; that is it has been designated as one of the most deprived areas in Europe. Furthermore, tourism is the main industry in the village. The reef option would therefore appear to provide a significant opportunity for the village in terms of both improving the standard of living for local residents as well as boosting the local economy. We therefore argue that policy makers should take account of the non-market amenity benefits in its deliberations over the coastal defence options for Borth.

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 and BLACK, 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 the UK. We therefore recommend that DEFRA modify its 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 not only follow the HM TREASURY'S (2003) 'Green Book' guidelines, but will also 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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