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Benefits transfer of willingness to pay estimates and functions for health-risk reductions: a cross-country study

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Abstract

This paper provides a first application of the techniques of benefits transfer to the health economics literature. These techniques seek to transfer the value of some good from one 'survey' context to a new 'policy' context so avoiding the need for new valuation surveys each time a new policy question arises. Two approaches to benefits transfer are assessed: the simple transfer of mean values and the transferral of value functions. We develop a new methodology for the latter approach in which value functions are iteratively built up from theoretical principles with transfer errors being tested each time a new variable is added. Through a novel application of advanced statistical tests we show that this approach outperforms the transferral of statistically driven Best-fit functions. The case study presented focuses upon the transfer of contingent valuation (CV) willingness to pay (WTP) estimates and associated value functions for reducing the health risks associated with solar ultraviolet (UV) exposure. Common format studies are conducted in four countries with transfers between all of these being undertaken. By calculating errors in predicted versus actual values across countries we show that, when transferring between similar contexts, simple mean-value transfers outperform more complex value function transfers (with the magnitude of the former errors being encouragingly small). However, this result is reversed when transfers are undertaken across dissimilar contexts where

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value functions partially adjust for these differences. In summary these findings provide support and guidance for future applications.

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1. Introduction

The ongoing and increasing reliance upon benefit–cost analysis as the basis for economic inputs to the policy and decision making process has, in recent years, led to a growing interest in methods for the monetary valuation of preferences. This has translated into an explosion of valuation studies with applications across a broad range of risk, environmental and other issues. In particular stated preference methods for estimating willingness to pay (WTP) such as contingent valuation (CV) and choice experiments (CE) have been prolifically applied and subject to intensive critical appraisal (Hausman, 1993; Bjornstad and Kahn, 1996; Bateman and Willis, 1999; Hanemann, 2000; Louviere et al., 2000; Bennett and Blamey, 2001; Carson et al., 2001; Bateman et al., 2002, 2004).

Although many of the early applications of valuation methods focussed upon changes in the provision of environmental public goods, the 1990s saw a broadening of this focus into other areas. In particular the decade witnessed a rapid growth in studies examining the economic value of risk reduction and health care interventions (Johannesson et al., 1991; Donaldson et al., 1996; Kartman et al., 1996; Ryan, 1996, 1999; Diener et al., 1998; Ryan et al., 1998; Donaldson, 1999; Farrar and Ryan, 1999). This literature has continued to grow in recent years and now embraces both the public and private provision of a plethora of health care issues ranging from hip replacements and cardiovascular interventions to in vitro fertilization and the provision of helicopter ambulances (Johnson et al., 2000; Olsen and Donaldson, 2000; Blumenschein et al., 2001; O'Shea et al., 2001; Ryan et al., 2001; Clark, 2002; Ryan and San Miguel, 2002; Stewart et al., 2002).

While such valuation studies have opened up a new dimension within health care resource allocation and decision making, the studies themselves incur both direct and time related costs. Consequently, the proliferation of these studies has recently coincided with interest in the potential for transferring results from one context to another thereby obviating the need to undertake new analyses on each occasion. This of course is the major advantage claimed by the QALY methodology (Drummond et al., 1997; Loomes and McKenzie, 1989; Phillips and Thompson, 2003). However, the increasing drive towards a cost–benefit approach to health care resource allocation has raised interest in the possibility of transferring WTP estimates for health risk reduction, although as Hanley et al. (2003) point out, to date such an exercise has not been undertaken within the health economics field, a failing which Ryan and Gerard (2003) feel should now be addressed.

Benefit transfer techniques involve taking information concerning the value of a good gathered in one context and applying this with appropriate adjustment to permit estimation of the value of a good in a second context. For example, benefit transfer techniques have been widely applied to estimate values for the non-market benefits of open-access recreational resources. Here values and other information gathered from 'survey' sites are applied to estimate values for non-surveyed 'policy' sites (for a recent example see Rosenberger and Loomis, 2000). We retain this 'survey' and 'policy' nomenclature in this paper[1].

A number of approaches to undertaking benefits transfers are available[2]. However, by far the most common approaches are the simple transfer of unadjusted mean WTP estimates ('mean value transfers') and the transfer of WTP value functions ('value function transfers'), the latter approach providing some adjustment to WTP estimates by applying coefficient estimates from survey sites to the levels of explanatory variables found at policy sites[3]. The objective is of course to obviate the need for conducting new surveys each time a new policy has to be evaluated. However, in order to initially assess the viability of the benefit transfer approach to the health area, the present study needs to assess the accuracy of such transfers. For this purpose we conduct surveys at a series of sites. This allows us to treat each as both a 'survey' site (from which we transfer values to other sites) and as a 'policy' site (to which we transfer values from other sites). By comparing these values we obtain an estimate of the 'transfer error'; i.e. the difference between the value obtained by surveying a given site and the value obtained by transferral from another site. Assessment of this error allows us to judge if the transfer process is reliable and hence whether in the future we might transfer values from survey sites to policy sites without having to conduct new research or surveys at the latter.

While the simplicity of the point value transfer approach is attractive, intuition might suggest that the function transfer technique might provide a more reliable approach for effecting transfers. This latter method tests the assumption that value function determinants and coefficients are stable between the study and policy site. Notice that this does not assume that the *level* of any (or all) determinants is constant across sites, but rather that only their *relationship* with WTP values is similar. So, for example, if WTP is found to be a function of income levels then if these vary across sites so will predicted WTP. This advantage over simple mean value transfer has made the function approach a feature of many recent benefit transfer exercises (Loomis, 1992; Bergland et al., 1995; Loomis et al., 1995; Downing and Ozuna, 1996; Kirchhoff et al., 1997; Brouwer and Spaninks, 1999).

The optimal strategy for estimating WTP functions for transferral purposes may be different from that followed when we simply wish to describe the determinants of WTP in a specific case study. In particular, efforts to identify the statistically Best-fitting function in specific case studies may be counter productive if we then wish to transfer that function

[1] While we consider transfers across sites these can also be undertaken across scenarios or (as we discuss in Brouwer and Bateman, 2000a) across time.

[2] For reviews of the issues raised by benefit transfer applications see Brookshire and Neill (1992), OECD (1994), Bergland et al. (1995), Desvousges et al. (1998) and Brouwer (2000).

[3] This highlights a limitation of the function transfer approach as explanatory variables describing policy sites are restricted to those available from existing secondary sources (e.g. from the census or other generally available databases). An example of such an application is given in Brainard et al. (1999) who utilise the data interrogation powers of a geographical information system to conduct function transfers.

to a different site. If we suspect that WTP determinants at a survey site include highly site-specific factors then Best-fit functions may transfer poorly as they would then include variables which are of little relevance to a different policy site. Adopting such an approach may result in large transfer errors and poor estimates of WTP at policy sites. Instead it might be better to start with relatively simple models of WTP in which values are a function of some generic variable which theory suggests should be a strong predictor of WTP (e.g. household income level). This model can then be transferred between survey and policy sites and transfer errors calculated. The model can then be expanded to include a further predictor and the analysis repeated. Further expansions can be tested until the optimal transfer function is identified. Errors can then be compared to those arising from simple mean-value transfers.

Our a priori expectation is that where survey and policy site populations are similar so the errors associated with function transfer should be relatively small. However, it is in just such circumstances where simple mean-value transfers should also work best as similar populations are likely to have similar WTP. Therefore it remains an open empirical question as to which approach will work best in such circumstances. Conversely, where the preferences of survey populations differ substantially from those at the policy site both function transfers and mean-value transfers may well produce relatively large errors. We argue that this complexity of interrelationships explains why some case studies report successful value function transfers (Desvousges et al., 1998) while others do not (Barton, 1999; Bergland et al., 1995), and why either function or mean-value transfers may yield smaller errors (Brouwer, 2000).

Given the above, the present study applies both simple mean-value transfers and more sophisticated function transfer tests to a novel application of the CV method to a health improvement issue (the reduction of risks associated with solar ultraviolet (UV) exposure) discussed in more detail below. These tests are applied to transfers between both similar and dissimilar populations (as assessed from both a health risk and economic characteristic perspective). Furthermore, a superior approach to the testing of function transferability is implemented. Most applications of benefit transfer techniques within the environmental economics literature adopt likelihood ratio (LR) or Chow tests of transferability which pool all observations from all studies and then test whether functions obtained solely from any given survey site are significantly different from that of the pooled model. However, in this paper we contrast such LR results with those obtained from a novel application to benefit transfer data of the more theoretically consistent Wald test. Instead of pooling data, here we take a given function estimated using data from one site (here designated as a survey site) and then apply this model to data from a second site (the designated policy site). This in effect gives us two estimates of the coefficients in this model, one set based upon the survey site, the other based upon the policy site. The Wald test examines the stability of these coefficients seeing whether they change significantly between the two sites. By repeating this test for all possible transfers (i.e. transferring from a given survey site to each policy site in turn, then redesignating another site as the survey site and repeating the operation until all possible transfer pairing have been considered) we build up a richer picture of where transferability is feasible and where it is not. Contrasting Wald with LR results suggests that the latter is more liable to confirm transferability than the former, i.e. the Wald test provides a more rigorous transfer criterion.

The remainder of the paper is structured as follows. In the following section, we set out the case study design relating this to the expectations set out above. Section 3 provides further details regarding our benefits transfer testing procedure. In Section 4, we present results, starting with estimates of mean WTP and tests of the transferability of these values. These are followed by findings from LR and Wald tests which show some interesting differences across these tests. Presentation of results is concluded in Section 5 were we estimate WTP sums based upon function transfers and calculate consequent errors. Findings show that LR and Wald tests do not always coincide although general patterns of transferability are reflected in consequent transfer errors. Section 6 discusses these findings and draws conclusions.

2. Case study design

Given the issues raised above, careful selection of a case study issue was important if our analysis was to provide a fair test of the benefits transfer approach. In the event we chose to focus upon WTP for a private good (a newly developed sunscreen which allows complete protection from the harmful effects of the sun) for reducing the risks associated with exposure to solar UV light. This good was chosen for three principle reasons. First by using a private good we avoided many of the strategic behaviour incentives which bedevil many CV studies of public goods. Second, relative to many of the risk sources considered in the risk and health economics literature (e.g. nuclear power, medical interventions, etc.) it was felt that the general population would have at least some innate understanding of their current risk level, thereby avoiding reliance upon complex and often poorly understood information concerning risk probabilities. This simple scenario was enhanced by specifying that the good reduced risks to zero for the period during which the sunscreen was applied. Thirdly, by selecting survey samples from some countries across which risks are relatively similar and contrasting these with countries which have markedly different risk levels we can formulate expectations regarding transferability.

Considering the latter issue of case study site selection, it was decided to conduct surveys in New Zealand, Scotland, England and Portugal. These countries were specifically chosen to generate the mix of similar and dissimilar sample populations vital to our analysis. Specifically, while the sample populations in New Zealand, Scotland and England are of similar skin type and ethnic origin, the population of Portugal is generally darker skinned. The issue of skin type is a vital one in the determination of sun related skin cancer risk, with populations with darker skin types generally being at considerably lower risk levels than those with paler skin (Slaper et al., 1992). Indeed melanoma mortality rates in Portugal are less than half those in the UK and an even lower proportion of rates in New Zealand (Langford et al., 1998a; Globocan, 2001). As we demonstrate subsequently in our discussion of survey results, our sample populations reflect these skin type differences and respondents in our Portuguese sample are aware of their lower risk levels and reflect this both in greater sun exposure behaviour and a lower WTP for the risk reduction good.

We therefore have the mix of similar and dissimilar samples which are needed to test where benefits transfer may or may not work effectively. Data were collected through common format CV questionnaire surveys conducted in all four study countries during the southern hemisphere and succeeding northern hemisphere summer of 1997–1998 (season being held constant to allow for possible fluctuation in values across seasons[4]). All responses were obtained by on-site, in-person interviewing conducted at beach or nearby locations. Aside from WTP responses, data was collected regarding a variety of socio-economic, demographic, attitudinal and behavioural factors which might influence those responses (for further details see Brouwer et al., 2001). Respondents were shown the good in question (a 150 ml bottle of sunscreen providing complete protection from all the harmful effects of the sun whilst still allowing users to develop a sun-tan) and provided with information regarding its recent development after which they were asked to state, via an open-ended elicitation format, their maximum WTP to acquire this product. While the open-ended format is open to the charge that it may induce free-riding and other understatement strategies when applied to the valuation of public goods (Mitchell and Carson, 1989; Bateman et al., 2002), this criticism is effectively irrelevant in the valuation of private goods such as that considered in this study[5]. In subsequent analysis these responses were made comparable across countries by converting local currencies into 1998 Pound Sterling (£) and accounting for differences in purchasing power parity using adjustments given in World Bank (1999).

3. Statistical testing procedure

As noted above, the validity of a benefits transfer can be statistically tested in a number of ways. Comprehensive statistical procedures were originally proposed by Bergland et al. (1995). They identified a number of hypotheses, which we test in this study. The first of these concerns the validity of mean-value transfers as formalised in hypothesis H_0^1 in Eq. (1):

$$H_0^1 : \overline{WTP}_{\text{ps}} = \overline{WTP}_{\text{ss}} \tag{1}$$

where $\overline{WTP}$ denotes mean WTP estimated from responses at the designated site, with the subscripts ps and ss identifying policy sites and survey sites, respectively.

As a complement to the above, we also test the validity of transferring functions across sites. Following Bergland et al., this procedure can be broken down into various hypotheses. First, we can examine the equality of coefficient estimates from different WTP functions

[4] Work by Horton (2003) suggests that values for averting risks which vary across the seasons may indeed vary according to when in the year those values are elicited.

[5] There have been a number of studies comparing open-ended with other elicitation formats both in the environmental and health economics literatures (Johannesson et al. (1991); Bateman et al., 1995; Donaldson et al., 1997; Frew et al., 2003) and the open-ended approach has been subject to criticism when applied to the elicitation of values for public goods (Mitchell and Carson (1989); Carson et al., 2001). These criticisms are mainly focussed upon the issue of incentive compatibility. However, such concerns become less pressing (if not irrelevant) in the present application where we focus upon purchases of a private good. Furthermore, given that all samples adopt the same elicitation method any residual bias is in effect held constant across samples. Finally, the open-ended approach provides a much more statistically efficient alternative to close ended, dichotomous choice questions which are themselves the subject of considerable criticism (Cummings et al., 1997; Green et al., 1998; Taylor Laura et al., 2001).

(H_0^{2a}) as shown in Eq. (2):

$$H_0^{2a} : \hat{\beta}_{\mathrm{ps}} = \hat{\beta}_{\mathrm{ss}} \tag{2}$$

where $\hat{\beta}$ is a vector of coefficients estimated at the designated site. Second, we can test the equality of variances (H_0^{2b}) of these functions as formalised as Eq. (3):

$$H_0^{2b} : \hat{\sigma}^2_{\mathrm{ps}} = \hat{\sigma}^2_{\mathrm{ss}} \tag{3}$$

where $\hat{\sigma}^2$is the estimated variance-covariance matrix.

Any given WTP function has estimated coefficients $\hat{\alpha}$ (the intercept) and vector$\hat{\beta}$. Function transfer the proceeds as shown in Eq. (4).

$$W\tilde{T}P_{\mathrm{ps}} = \hat{\alpha}_{\mathrm{ss}} + \hat{\beta}_{\mathrm{ss}} X_{\mathrm{ps}} \tag{4}$$

Here, we assume that the coefficients estimated at the survey site ($\hat{\alpha}_{\mathrm{ss}}and\hat{\beta}_{\mathrm{ss}}$) are also valid for the policy site, i.e. relationships between explanatory variables and WTP are the same at both sites (for example, while incomes may differ between a survey and policy site, we assume the same positive relationship between income and WTP at both sites). By multiplying these constant coefficients ($\hat{\beta}_{\mathrm{ss}}$) by the values of the explanatory variables at the policy site (X_{ps}) and assuming the same intercept value ($\hat{\alpha}_{\mathrm{ss}}$) we obtain a function transfer estimate of WTP at the policy site (which we denote $W\tilde{T}P_{\mathrm{ps}}$ in Eq. (4)). We can then test a hypothesis (H_0^3) that values estimated through function transfer from survey sites will be equal to those derived directly at policy sites as per Eq. (5):

$$H_0^3 : \overline{WTP}_{\mathrm{ps}} = W\tilde{T}P_{\mathrm{ps}} \tag{5}$$

The performance of both mean value transfers and value function transfers can be assessed in terms of their corresponding transfer errors. In the case of mean value transfers these errors are calculated as per Eq. (6):

$$\text{Mean value transfer error} = \left(\frac{\overline{WTP}_{\mathrm{ss}} - \overline{WTP}_{\mathrm{ps}}}{\overline{WTP}_{\mathrm{ps}}}\right) 100\% \tag{6}$$

For function transfers errors are calculated as per Eq. (7):

$$\text{Function transfer error} = \left(\frac{W\tilde{T}P_{\mathrm{ss}} - \overline{WTP}_{\mathrm{ps}}}{\overline{WTP}_{\mathrm{ps}}}\right) 100\% \tag{7}$$

In order to be able to assess how meaningful the calculated errors are from a statistical point of view, their significance has to be tested. Such testing has often been omitted from previous benefits transfer studies, but is a vital part of the procedure. The hypotheses defined in H_0^1 and H_0^3 can be examined using either the *t*- or *Z*-test (for large samples, the test statistic for these two tests is the same; Bhattacharyya and Johnson, 1977). A number of tests may be applied for assessing various aspects of hypotheses H_0^{2a} and H_0^{2b}.

The likelihood ratio (LR) or Chow tests are most frequently used in the benefits transfer literature for examining hypothesis H_0^{2b} concerning the equality of variance (e.g. Parsons and Kealy, 1994; Loomis et al., 1995; Kirchhoff et al., 1997; McConnell et al., 1998). As noted, these tests pool observations from all studies and then test whether functions obtained from any given survey are significantly different from that pooled model. However, an important limitation of these tests is that they are only able to indicate whether a function based upon observations from a given site was significantly dissimilar from the pooled model (i.e. the likelihood that observations from that site originate from the same underlying distribution) and not whether value functions for individual sites are significantly dissimilar from each other (Bergland et al., 1995). However, the Wald or the Lagrange multiplier (LM) test can also be used to examine equality of variance (H_0^{2b}) by including the estimate of the standard error of the regression in the vector of coefficients and the estimate's own standard error in the information matrix at the expense of one degree of freedom (Greene, 1993). Furthermore, both tests are also able to directly examine the equality of coefficient estimates of functions derived from two different samples (H_0^{2a}). The Wald test has not been used previously within a benefits transfer context and is somewhat more tractable to implement than the LM test and is accordingly adopted here, constituting a further novel feature of the present application.

4. Results

4.1. Sample characteristics

Full details regarding the characteristics of our various samples are presented in Brouwer et al. (2001). However, in summary these confirm the similarities and differences in characteristics, behaviour and attitudes catered for in our study design. While only 1% of the Portuguese sample described their skin tone as 'very pale' this rate was far higher in other samples reaching 77% in the English sample. Similarly, 27% of the Portuguese sample stated that they never suffered from sunburn compared to less than 8% of respondents in the other countries surveyed. Again, in comparison to respondents in other countries, Portuguese respondents were more than three times more likely to sunbathe frequently, were considerably more likely to agree with statements regarding the attractiveness of tanned skin and were much less likely to know someone who had been affected by some form of sun exposure related skin disorder (just 15% of the Portuguese sample knew of someone with such an affliction compared to a maximum of 69% of the New Zealand sample). We therefore have three similar samples (New Zealand, Scotland and England) and one dissimilar sample (Portugal). We can therefore hypothesise that transfers are more likely to succeed within the former than to and from the latter.

4.2. Mean-value transfers

The upper part of Table 1 presents summary statistics regarding respondents mean WTP for the sunscreen good (i.e. these are values of $\overline{WTP}$ for the respective survey sites). Even though these raw results fail to adjust for difference in respondent characteristics across

Table 1
Summary WTP statistics and tests of equality of means across countries

	New Zealand	Scotland	England	Portugal
Mean WTP[a]	10.1	10.1	9.1	4.5
Standard error	1.2	0.5	0.6	0.3
95% Confidence interval	7.6–12.6	9.2–11.1	7.9–10.2	4.0–5.1
t-Test (and *p*-values) for equality of mean WTP[b]				
New Zealand	–	**0.04**	**−0.83**	−6.55
		(0.97)	**(0.41)**	(0.01)
Scotland	–	–	**−1.34**	7.85
			(0.19)	(0.01)
England	–	–	–	10.36
				(0.01)

[a] WTP in 1998 Pounds Sterling.
[b] Bold values indicate that we cannot reject the hypothesis of no significant difference between mean WTP sums between the countries shown (New Zealand, Scotland and England). The *p*-values indicate the two-tailed probability of type I error.

populations the general pattern of findings conforms to expectations, with the Portuguese sample yielding a substantially lower mean WTP than other samples, arguably reflecting relative risk levels[6].

Non-parametric tests rejected null hypotheses of equal mean and median WTP across the full set of countries ($p < 0.01$)[7]. Differences between individual countries, formalised in hypothesis H_0^1 were also assessed using a *t*-test (assuming that the central limit theorem applies). Results are reported in the lower portion of Table 1 and show that (prior to adjusting for any difference in sample characteristics across countries) WTP values in England, Scotland and New Zealand are not significantly different but all three were significantly higher than the values recorded in our Portuguese survey, a result which accords with prior expectations based upon relative risk differences.

4.3. *Value function transfers*

The WTP elicitation format adopted in our studies permits respondents to state any non-negative value, including zero, for the good on offer. Therefore, WTP responses are truncated from below at zero[8] and are consequently modelled using Tobit regression techniques estimated using maximum likelihood techniques (Maddala, 1983)[9]. Testing indicated that specifying the dependent variable as a natural logarithm improved the explanatory power of models and this transformation was employed throughout our regression analyses.

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[6] Indeed some 41% of the Portuguese sample stated that they had a WTP value of zero for the good, compared to 6–13% of respondents in the other countries surveyed.

[7] The resultant Kruskal–Wallis test statistic (which has a Chi-squared distribution) was 129.5 (4 degrees of freedom), while the median test statistic (also Chi-squared distributed) was 76.7 (also 4 degrees of freedom).

[8] Kolmogorov–Smirnov tests confirm that WTP responses are not normally distributed ($p < 0.01$ for each of the four samples).

[9] Note that Tobit regression coefficients must be adjusted before they can be interpreted (Halstead et al., 1991). However, this is not a central issue for our analysis.

As outlined previously, we propose an approach to model building for function transfer purposes which is fundamentally different to that of the approach adopted by the statistician who seeks purely to optimise the explanatory power of estimated models. We expect that the transferability of functions between some pair of samples to be highest when those functions focus upon variables which are of relevance to both samples, and lower where those functions contain variables which are only of relevance to one sample. Therefore, our first approach to the estimation of transferable functions is to derive models from basic economic-theoretic principles. Here, we use theory to indicate fundamental drivers of preferences (such as respondents income, the price respondents currently pay for substitute sunscreens, etc.) and estimate models containing these determinants. We start with simple one variable models, estimate these and transfer them between samples. Transferability of coefficients is tested using the LR and Wald tests discussed previously, and transfer errors calculated as outlined above. Models are then extended to include a second, theoretically determined explanatory variable and testing repeated to determine whether this extension improves or degrades model transferability. Our expectation is that the introduction of additional control variables may, up to a point, improve the reliability of function transfers. However, once the stock of theoretically determined variables is exhausted (and economic theory does not prescribe many such variables) then further variables may prove to be of uneven importance across samples. Indeed, some of these variables may be highly relevant to one sample while being totally irrelevant to another. Adding such variables may increase the explanatory power of a model describing WTP at a given site, but actually decrease its transferability to another site.

In order to further investigate the hypothesis that Best-fit models may actually perform relatively poorly in function transfer tests, we supplement our iteratively built models with a purely statistically driven model for each sample site, estimated so as to optimise explanatory power for that site. Our expectation is that such models may transfer poorly to other sites if they include site specific factors. Nevertheless, such models are in themselves interesting as they provide an insight into the diversity of factors which may significantly influence WTP for risk reduction in different countries. We therefore report and briefly discuss these Best-fit models in Appendix A to this paper.

Table 2 summarises the findings of one full pass through the above function transfer testing procedure providing simultaneous tests of hypotheses H_0^{2a} and H_0^{2b}[10]. Here, in column (1) we give results for the transferral of our simplest model of WTP[11] consisting of the single theoretically derived explanatory variable, household income[12]. In columns (2)–(12) this model is progressively augmented with further explanatory variables. These are initially derived from economic theory (e.g. the price of substitute goods) but are subsequently supplemented by more ad-hoc variables derived from empirical regularities observed in

[10] Full numerical results for this set of tests are reported in Brouwer and Bateman (2000b). Note that for every single LR test between a pair of countries there are two Wald tests as transferring the estimated function in country A to country B is not the same as transferring the estimated function in country B to country A.

[11] Here the dependent variable, WTP, is transformed into natural logarithms to improve fit (see details in Appendix A).

[12] Also transformed into natural logarithms.

Table 2
Outcome of the stepwise procedure testing the validity of function transfer based on the Wald and LR test

Transfer from		Transfer to	Income (1)	Income price (2)	Income HRP (3)	Income age (4)	Income houses (5)	Income price HRP (6)	Income price holiday (7)	(7) and Age (8)	(8) and HouseS (9)	(9) and ScrUse (10)	(10) and Know (11)	(11) and Tanatt (12)	Best-fit models (13)
New Zealand	→	England	■	■	■	■	■	■	■	■	■	■	■	■	–
New Zealand	→	Scotland	–	–	–	–	–	–	–	–	–	–	–	–	–
New Zealand	→	Portugal	–	–	–	–	–	–	–	–	–	–	–	–	–
England	→	New Zealand	☺	☺	☺	☺	☺	■	☺	☺	☺	☺	☺	☺	–
England	→	Scotland	–	–	–	–	–	–	–	–	–	–	–	–	–
England	→	Portugal	–	–	–	–	–	–	–	–	–	–	–	–	–
Scotland	→	New Zealand	–	–	–	–	–	–	–	–	–	–	–	–	–
Scotland	→	England	–	–	–	–	–	–	–	–	–	–	–	–	–
Scotland	→	Portugal	–	–	–	–	–	–	–	–	–	–	–	–	–
Portugal	→	New Zealand	–	–	–	–	–	–	–	–	–	–	–	–	–
Portugal	→	England	–	–	–	–	–	–	–	–	–	–	–	–	–
Portugal	→	Scotland	–	–	–	–	–	–	–	–	–	–	–	–	–

Income: annual income; holiday: whether on holiday or not; HouseS: household size; know: Knowledge about melanoma; HRP: health risk perception of sunbathing; price: current sunscreen price; age: age group; ScrUse: frequency of applying sunscreen; tanatt: attitude towards having a tan.

☺: H_0 of equal WTP functions cannot be rejected at the 5% significance level by both the Wald and likelihood ratio (LR) test.

■: H_0 of equal WTP functions cannot be rejected at the 5% significance level by the likelihood ratio test only.

–: H_0 of equal WTP functions is rejected at the 5% significance level by both the Wald and likelihood ratio test.

the valuation literature (e.g. respondents age). The final column (13) gives details of the transferability of the statistically derived Best-fit models detailed in Appendix A.

The rows of Table 2 give summary transferability results for each of these models when transferred from and to the countries shown. Here the happy face symbol (☺) is used to show cases in which the null hypothesis of equal WTP functions cannot be rejected at the 5% significance level based on both the Wald and the LR test (i.e. we cannot reject function transfer in such cases). The black square symbol (■) shows cases in which the null hypothesis of equal WTP functions is rejected by the Wald test, but not the more commonly used LR test statistic. Note that there are no cases in which the Wald test is passed but the LR test rejected. This of itself is interesting given the statistical superiority of the Wald test, suggesting that apparently valid transfers reported in previous LR based studies may require reconsideration using the more rigorous Wald test.

Considering the results presented in Table 2, we see that the null hypothesis of equal WTP functions is rejected at the 5% level in most cases.

Overall findings are broadly in line with prior expectations. Six of the twelve transfer pairs involve the Portuguese sample which, as we have already seen (and confirm further in Appendix A) has significantly different characteristics and attitudes to those expressed by the other samples collected and therefore might not be expected to yield transferable WTP functions. However, by the same argument we might expect to see evidence of transferability between the non-Portuguese samples. Here the results are more mixed. Only the estimated WTP functions for England and New Zealand seem to be derived from the same underlying distributions. Indeed, based on the Wald test alone, a valid transfer can only be established from England to New Zealand.

Considering the methodological contribution of this analysis, as expected, irrespective of whether or not the theoretically derived models transfer, we reject the transferability of all of the statistically driven Best-fit models (as shown column (13) of the table). This result suggests that the incremental, theoretically driven approach to function transfer developed in this paper is well founded (with theory based models outperforming purely statistically driven functions) and that whether or not valid transfer can be undertaken between given sites remains an open empirical question, with most findings conforming to prior expectations in this particular case study.

5. Predicted WTP values and transfer errors

Finally, we test hypothesis H_0^3 by using the various transfer models detailed in Table 2 to calculate the WTP predicted for each policy site as transferred from each study site (i.e.$W\tilde{T}P_{\mathrm{ps}}$) and comparing this to the actual WTP observed at that site (i.e. $\overline{WTP}_{\mathrm{ps}}$). Transfer errors are calculated as per Eq. (7) and their statistical significance examined (Appendix B to this paper presents the specific transformations and calculations necessary for transfer and error calculations using the Tobit models applied in this research). The resultant transfer errors are presented in Table 3[13]. Cases where transfer errors are *not*

[13] Predicted mean and 95% confidence intervals around the difference between predicted and original mean are presented in Brouwer and Bateman (2000).

Table 3
Transfer errors[a] (in %) based on comparison of $W\tilde{T}P_{\mathrm{ps}}$ and $\overline{WTP}_{\mathrm{ps}}$

Transfer from		Transfer to	Income (1)	Income price (2)	Income HRP (3)	Income age (4)	Income HouseS (5)	Income price HRP (6)	Income price holiday (7)	(7) and Age (8)	(8) and HouseS (9)	(9) and Scruse (10)	(10) and Know (11)	(11) and Tanatt (12)	Best-fit models (13)	Point estimates (14)
New Zealand	→	England	−23.5	−11.7	−18.1	−23.3	−27.5	**−11.9**	**−11.9**	**−11.3**	**−14.4**	**−17.3**	**−16.3**	**−14.2**	**−6.5**	**11.1**
New Zealand	→	Scotland	−32.9	−6.3	−26.6	−33.2	−34.1	**0.9**	**−7.5**	**−7.8**	**−7.8**	**−8.7**	**0.5**	**2.8**	**−2.7**	**−0.4**
New Zealand	→	Portugal	39.6	45.1	60.0	39.8	30.3	47.5	37.8	38.7	33.2	35.2	49.2	58.0	25.3	121.8
England	→	New Zealand	**−33.0**	**−31.3**	**−33.6**	**−33.0**	−35.9	**−33.5**	**−32.3**	**−32.4**	**−35.2**	**−35.9**	**−35.8**	**−33.5**	**−35.7**	**−10.0**
England	→	Scotland	−39.3	−18.6	−38.5	−38.0	−41.4	−18.1	−18.4	−14.7	−23.2	−23.6	−26.3	−25.4	**−5.2**	**−10.4**
England	→	Portugal	**3.1**	**36.0**	**9.0**	**5.1**	**2.2**	41.3	49.2	58.7	42.6	41.5	38.2	36.3	60.4	99.6
Scotland	→	New Zealand	**−7.9**	**−25.2**	**−15.3**	**−6.1**	**−7.6**	**−25.2**	**−23.8**	**−23.7**	**−24.2**	**−24.2**	**−14.3**	**−15.7**	**−7.9**	**0.4**
Scotland	→	England	**2.0**	**−14.8**	**−1.1**	**4.0**	**0.6**	**−13.8**	**−13.7**	**−13.4**	**−15.3**	**−15.4**	**−4.6**	**−4.3**	**−4.0**	**11.6**
Scotland	→	Portugal	77.6	60.4	91.2	85.7	69.2	66.2	57.8	58.9	53.2	53.2	61.5	63.7	49.5	122.6
Portugal	→	New Zealand	−79.1	−62.2	−79.4	−78.1	−77.9	−58.4	−68.5	−65.4	−57.8	−55.5	−52.9	−58.6	−72.2	−54.9
Portugal	→	England	−76.9	−57.4	−76.5	−76.0	−76.5	−54.0	−63.8	−60.6	−57.2	−54.2	−52.0	−55.4	−67.6	−49.9
Portugal	→	Scotland	−80.7	−57.7	−80.4	−76.1	−80.0	−54.0	−62.6	−56.2	−49.7	−45.6	−48.5	−52.3	−73.0	−55.1

[a] Bold values indicate cases where the null hypothesis of equal calculated and observed mean WTP values cannot be rejected at 5% level. Positive values indicate cases where $W\tilde{T}P_{\mathrm{ps}} > \overline{WTP}_{\mathrm{ps}}$ (and vice versa for negative values).

statistically significant (i.e. transfers are successful) are shown in bold type[14]. Positive values indicate that $W\tilde{T}P_{\mathrm{ps}}$ is higher than the observed value $\overline{WTP}_{\mathrm{ps}}$ and vice versa for negative values.

Columns (1)–(13) of Table 3 present the transfer errors associated with the corresponding transfer functions given in Table 2. So, for example, considering the first cell of column (1), this shows the transfer error arising from the transfer from New Zealand (the designated survey site; ss) to England (the designated policy site; ps) of a model containing only the single predictor household income. Here, $W\tilde{T}P_{\mathrm{ps}}$ is calculated as per Eq. (8):

$$W\tilde{T}P_{\mathrm{Eng}} = \hat{\alpha}_{\mathrm{NZ}} + \hat{\beta}_{\mathrm{NZ}}\overline{Y}_{\mathrm{Eng}} \tag{8}$$

where: $W\tilde{T}P_{\mathrm{Eng}}$ is the mean WTP for England as predicted by transferring this function from New Zealand; $\hat{\alpha}_{\mathrm{NZ}}$ and $\hat{\beta}_{\mathrm{NZ}}$ are respectively the estimated intercept and coefficient from this function as estimated from data collected in New Zealand; and $\overline{Y}_{\mathrm{Eng}}$ is the mean income of our English sample. The sample standard deviation of $W\tilde{T}P_{\mathrm{Eng}}$ is calculated in the standard manner (Greene, 1993), and the significance of transfer errors assessed using a standard Z-test. As can be seen, Table 3 reports a transfer error value for this example of −23.5, indicating that $W\tilde{T}P_{\mathrm{ps}}$ is some 23.5% lower than the observed $\overline{WTP}_{\mathrm{ps}}$ value. In the table this result is given in normal type, indicating that the transfer error is significant (i.e. values in bold type indicate cases in which we cannot reject transferability). However, when, in column (7), we add the variables Price (the current price paid for substitute sunscreens) and HRP (Health risk perception of sunbathing) to the transfer model, the resultant two variable function does yield statistically insignificant transfer errors[15].

The overall pattern of transfer errors provides some interesting similarities (and some contrasts) with the tests of function transferability given in Table 2. The latter results indicated that all transfers to and from the Portuguese findings failed both the LR and Wald tests. It is therefore unsurprising that of the 78 transfer errors involving Portugal reported in Table 3, some 74 (95%) prove to be statistically significant, a result which reflects the unanimity between the LR and Wald test results regarding this sample. Again, echoing our function transfer results, we find significant errors in predicted WTP involving transfers to and from Portugal. Also, as before, transfer errors between New Zealand and England are typically not significant. However, one difference is that whereas in Table 2 we rejected function transferability for Scotland, Table 3 shows that resultant transfer errors (predicted versus observed WTP) are in most cases not significant. This is also generally the case for transfers based upon statistical Best-fit models. While these fail formal tests of function transferability (H_0^{2a} and H_0^{2b}) the magnitude of corresponding WTP errors is not statistically significant (i.e. H_0^3 is not formally rejected here).

Table 4 summarises the magnitude of these transfer errors dividing these into those arising from function transfer (from columns (1) to (13) of Table 3) and those generated

[14] Specifically the values given in bold type denote cases where the null hypothesis of equal predicted and original mean WTP values cannot be rejected at the 5% significance level using a standard Z-test. The predicted mean WTP values, their standard deviation and the confidence intervals around the transfer errors are presented in Brouwer and Bateman (2000).

[15] Note that the addition of the Price variable outperforms all other two variable models in terms of consequent transfer error. This echoes the result of Table 2 where income and price proved the strongest predictors of WTP.

Table 4
Summary of transfer errors (%)

Cases	Variable	*N*	Mean	Std. Dev.	Min.	Max.
Excluding those transfers involving Portugal (similar study and policy sites)	Function transfer error	78	−18.7	12.2	−41.4	4.0
	Mean value transfer error	6	0.4	9.7	−10.4	11.6
Only those transfers involving Portugal (dissimilar study and policy sites)	Function transfer error	78	−9.0	58.1	−80.7	11.6
	Mean value transfer error	6	30.7	92.4	−55.1	122.6

by transferring mean values (from column (14) of Table 3). These summary statistics are further subdivided into those associated with transfers to and from Portugal (where errors are anticipated) and those concerning other countries (where we expect greater transferability). Concerning the latter cases, we see that in general errors are relatively modest and such transfers are likely to be of use for decision making purposes. Furthermore, between these somewhat similar countries we find that function transfer performs worse than simply transferring mean WTP values. Conversely, for transfers to and from Portugal the function transfer approach allows some adjustment for local characteristics and therefore performs substantially better than the simple transfer of mean values which yields some very substantial errors.

6. Discussion and conclusions

This paper provides a first application of benefits transfer techniques to the arena of health economics. We assess two basic approaches for transferring values from one site to another: First, the simple transfer of unadjusted mean WTP values; and second the transfer of valuation functions. Within the second approach we propose a novel methodology of building up transfer functions from theoretical principles, focussing upon factors which are likely to be determinants of WTP at all sites. Testing is conducted using both conventional approaches and a novel application of a statistically superior method.

A case study was designed so as to include transfers between both similar and dissimilar samples, the contrast intended to allow inspection of the limits of our two transfer methodologies. Results revealed that our approach of building theoretically guided models designed expressly for transfer purposes, is more likely to yield functions which pass formal tests of transferability than an approach which derives models solely upon statistical Best-fit principles and therefore may include non-generalisable, site-specific factors in such models. Comparison of observed WTP with that predicted by either function transfer or the transfer of mean values indicates that, for similar study sites, errors derived by both approaches are tolerably small with the simple transfer of mean values outperforming function transfer. However, across dissimilar cases, errors generated by the transfer of mean values are considerably larger than those arising from function transfer. This finding seems to accord with intuition. For similar cases simple approaches work best. However, in dissimilar cases some degree of adjustment, here via the variables in a transfer function, helps reduce errors. Overall, examination of resultant transfer errors showed, as expected, that errors were generally substantial for cases where statistical transferability was rejected, but significantly smaller where transferability tests were satisfied.

In summary, we have used this paper to set out a methodology for applied benefit transfer work and shown that in principle this can readily be applied within the field of health risk reduction.

Our empirical results suggest that, not surprisingly, transfers are more viable and the magnitude of errors smaller when we transfer between more similar contexts. This is an encouraging result given that many health-care scenarios are indeed similar. In terms of the practical applicability of these techniques, future work might concentrate on less diverse cases studies such as within-country applications. Once a given area has been shown to yield successful transfers we see no fundamental reason why researchers should not then focus upon the estimation of stable values for applied transfer purposes.

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Appendix A. Best-fit models of WTP

Table A1 reports statistical Best-fit models of WTP for each of our sample surveys. As per all our regression models the dependent variable (WTP) was transformed into its natural logarithmic form, as this produced a better model fit[16]. The models were all statistically significant, the outcome of the likelihood ratio (LR) test convincingly rejecting the null hypothesis of zero slopes.

Inspection of explanatory variables show that, as expected, WTP is positively related to both the current price paid for substitutes[17] and to household income[18] (although the latter

[16] In order to not lose any zero bidders in the transformation process, one is added to the WTP amounts.

[17] In order to avoid any anchoring of WTP responses (Mitchell and Carson, 1989), survey respondents were asked to state the price they pay for their current sunscreen *after* they were asked the WTP question for the private good. A significant positive correlation was found between sunscreen price and the sunscreen's SPF. Hence, sunscreen price can also be interpreted as an indicator of the extent to which respondents already seek to protect themselves against the harmful effects of the sun.

[18] Household income was also transformed into natural logarithms. The double-log function has the convenient property that estimated coefficients are elasticities (Johnston, 1984). Corresponding to previous research (Kristrom

Table A1
Tobit regression results: statistical Best-fit models

Explanatory variables	New Zealand ln(WTP)	Scotland ln(WTP)	England ln(WTP)	Portugal ln(WTP)
ln Annual household income (1998 £)	0.35 (0.11)***	0.14 (0.04)***	0.14 (0.06)**	–
ln Current sunscreen price (1998 £)	1.02 (0.18)***	0.47 (0.04)***	0.56 (0.07)***	0.41 (0.17)***
Sunbathing health risk perception (0–6)	0.13 (0.04)***	0.11 (0.05)**	–	–
Skin cancer check-up (yes = 1)	0.48 (0.12)***	–	–	–
Knowledge of melanoma (yes = 1)	–	0.13 (0.05)**	–	–
Attitude to having a tan (−2 to +2)	–	0.07 (0.03)**	–	0.19 (0.09)**
Sunbathing main activity (yes = 1)	–	–	0.21 (0.10)**	–
Smoker (0 = no, 4 = >20 cigarettes/day)	0.13 (0.06)**	–	–	–
Sun exposure (0–6)	–	−0.05 (0.01)***	–	–
Sunburnt past year (0–4)	−0.20 (0.06)***	–	–	–
Frequency of applying sunscreen (0–4)	−0.16 (0.05)***	–	–	–
Household size (1–8)	–	−0.05 (0.02)***	–	–
Age group (1 = 16–19, 7 = +70)	–	0.04 (0.02)*	–	−0.18 (0.07)***
Whether or not on holiday (on holiday = 1)	−0.25 (0.12)**	–	0.24 (0.09)***	0.31 (0.18)*
Constant	−2.82 (1.16)**	−0.08 (0.34)	−0.31 (0.58)	1.59 (0.58)***
Standard error regression	0.36 (0.04)***	0.24 (0.01)***	0.59 (0.03)***	1.19 (0.07)***
log Likelihood	−18.2	−3.4	−166.0	−305.2
Likelihood ratio test (χ^2)	125.2 ($p < 0.01$)	175.8 ($p < 0.01$)	137.2 ($p < 0.01$)	408.2 ($p < 0.01$)
Number of observations	46	124	182	207
Percentage of positive observations	100	100	96	76

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

and Riera, 1996), all estimated income elasticities are lower than one, even though Tobit estimates are larger in magnitude than OLS estimates (Halstead et al., 1991). Income elasticities of the positive WTP bids are the same in England and Scotland. New Zealand has a two and a half times higher income elasticity than England and Scotland, a result which seems to echo the higher risk awareness in New Zealand observed elsewhere (Langford et al., 1998b).

just fails to be statistically significant in the Portuguese model). However, once we step beyond these variables (both of which are derived from economic-theoretic expectations), we see that other predictors fail to be significant across all countries, being instead somewhat case specific and therefore unlikely to transfer well. That said, some interesting and plausible relationships are observed with WTP being positively related to sunbathing health risk perception and check-ups and negatively related to sun exposure and frequency of sunburn.

Appendix B. Function transfer and error calculation using Tobit models

The Tobit function is a commonly adopted approach for modelling data which is censored to contain only zero or positive values (such as the WTP responses considered in this analysis). Here log transformation of the WTP response variable was found to provide a superior fit to the data[19]. Following Halstead et al. (1991), the expected value (E(WTP)) of such data is as per Eq. (B1):

$$E(\mathrm{WTP}) = X'\hat{\beta}F(z) + \hat{\sigma} f(z) \tag{B1}$$

where E(WTP) is the expected value of WTP at the policy site; X a matrix of explanatory variable values at the policy site; $\hat{\beta}$ the vector of estimated Tobit coefficients obtained by estimating a function from data collected at the study site; z the standardised normal variable; $F(z)$ the value of the cumulative normal distribution at z; $\hat{\sigma}$ the standard error of the Tobit regression; and $f(z)$ the value of the standard normal distribution at z.

Subsequently, WTP has to be adjusted for the log transformation as per Eq. (B2):

$$E(\mathrm{WTP}) = \mathrm{e}^{(X'\hat{\beta})}\mathrm{e}^{(\hat{\sigma}/2)} - 1 \tag{B2}$$

The function transfer derived mean value of WTP at the policy site ($W\tilde{T}P_{\mathrm{ps}}$) is then calculated by substituting the relevant mean values for the explanatory factors (X) at the policy site into the function.

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19 A value of one was added to WTP responses to permit this log transformation.

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