Chapter 2
Introduction to Benefit Transfer Methods

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Abstract This chapter provides an introductory overview of benefit transfer methods. It begins with a discussion of the different types of benefit transfer (such as unit value transfer and benefit function transfer), including a review of these different approaches and the relative advantages and disadvantages of each. This is followed by a summary of foundations in welfare economics and valuation. Included in this methodological introduction are a discussion of stated and revealed preference valuation and how the results from each may be used for benefit transfer. Following this introductory material are discussions of the theoretical and informational requirements for benefit transfer, the steps required to implement a benefit transfer, the challenges of scaling, and sources of data. The chapter concludes with brief discussions of transfer validity and reliability, advanced techniques for benefit transfer, and common problems and challenges.

Keywords Unit value transfer · Benefit function transfer · Meta-analysis · Preference calibration · Reliability · Validity · Non-market valuation · Methodology · Value transfer

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2.1 Introduction

As described in the first chapter, benefit transfer is defined as the use of research results from pre-existing primary studies at one or more sites or policy contexts (often called study sites) to predict welfare estimates such as willingness to pay (WTP) or related information for other, typically unstudied sites or policy contexts (often called policy sites). It has also been described as the "application of values and other information from a 'study' site where data are collected to a 'policy' site with little or no data" (Rosenberger and Loomis 2000, p. 1097), or the "practice of … adapting value estimates from past research … to assess the value of a similar, but separate, change in a different resource" (Smith et al. 2002, p. 134). That is, research results generated at one site or context are extrapolated or transferred to another site or context; or conversely, information needed at a policy site is inferred from an existing body of research.

Although benefit transfer is often discussed in the context of welfare estimates, other model outputs may be transferred. These can include predicted quantities such as site visits, commodity demand, elasticities, or the size of affected populations. Similarly, while transfers often occur across different geographical locations, this is not a requirement. For example, transfers may occur across different affected populations or types/scales of policy outcomes at the same site (Morrison and Bergland 2006; Chap. 9 in this book).

Benefit transfers are most often used when time, funding, data availability or other constraints preclude original research, so that preexisting estimates must be used instead. Although the use of high-quality primary research to estimate values is preferred in most cases (Allen and Loomis 2008), the realities of the policy process, particularly time and budget constraints, often dictate that benefit transfer is the only feasible option (Griffiths and Wheeler 2005; Iovanna and Griffiths 2006; Johnston and Rosenberger 2010). Given these realities, benefit transfer has become a central component of virtually all large-scale benefit-cost analyses (Smith et al. 2002). Hence, while benefit transfers are subject to a variety of potential errors, the literature increasingly recognizes the need for the resulting information (Bergstrom and De Civita 1999; Desvousges et al. 1998; Johnston and Rosenberger 2010; Rosenberger and Johnston 2009; Rosenberger and Loomis 2003; Smith et al. 2002).

The use of benefit transfer was common as early as the 1980s. Although authors as early as Freeman (1984) began work on methods, it was not until the early 1990s that benefit transfer was broadly recognized as a distinct area of research, with formal attention to methods, procedures and protocols (Johnston and Rosenberger 2010; Rosenberger and Loomis 2003). The 1992 Association of Environmental and Resource Economics (AERE) and U.S. EPA workshop, and subsequent special section of *Water Resources Research*, 28(3), are often credited as the first broad discussions of benefit transfer methodology in the literature. Early criteria for ideal benefit transfers were provided by Boyle and Bergstrom (1992), and the first generation of more comprehensive methodological guides included that of

Desvousges et al. (1998). Later compilations of benefit transfer research included Florax et al. (2002) and Navrud and Ready (2007c). The published benefit transfer literature now includes hundreds of published articles on numerous topics.

Despite the large and increasing scholarly literature in this area and the ubiquity of benefit transfer in policy analysis, the method remains subject to misuse and misunderstanding. Consensus protocols remain elusive, leading to recurring questions regarding reliability and validity. There is a divergence between transfer practices recommended by the scholarly literature and those commonly applied within policy analysis (Johnston and Rosenberger 2010; Chaps. 3, 4, 5 and 6). In addition, some areas of scholarly inquiry routinely apply substandard or unreliable benefit transfer methods.[1] As noted in Chap. 1, these common shortcomings in benefit transfer applications are among the primary motivations for this book.

This chapter provides an introductory overview of benefit transfer methods. It begins with a discussion of the different types of benefit transfer (such as unit value transfer and benefit function transfer), including a review of these different approaches and the relative advantages and disadvantages of each. This is followed by a brief summary of foundations in welfare economics and valuation. Included in this methodological introduction is a discussion of stated and revealed preference valuation and how the results from each may be used for benefit transfer. Following this introductory material are in-depth discussions of the theoretical and informational requirements for benefit transfer, the steps required to implement a benefit transfer, the challenges of benefit scaling, and sources of data for benefit transfers. The chapter concludes with brief discussions of transfer validity and reliability, advanced techniques for benefit transfer, and common problems and challenges. These final discussions introduce material covered in greater depth in other chapters of this book. We emphasize that this chapter is not meant to review the benefit transfer literature; those interested in a more comprehensive literature review are directed to Johnston and Rosenberger (2010) and later chapters in this book.

2.2 Types of Benefit Transfer

Although there have been varying classifications of benefit transfer methods, most recent works distinguish two primary approaches: unit value transfers and benefit function transfers (Johnston and Rosenberger 2010; Rosenberger and Loomis 2003). Unit value transfers involve the transfer of a single number or set of numbers from preexisting primary studies. Unit values can be transferred "as is" or adjusted using a variety of different approaches (e.g., for differences in income or purchasing power, or according to expert opinion). Function transfers, in contrast, derive information using an estimated, typically parametric function derived from original

[1]For example, a significant proportion of the ecosystem services valuation literature is subject to this critique.

research, a meta-analysis that synthesizes results from multiple prior studies, or preference calibration that constructs a structural utility model using results from two or more prior studies. Function transfers typically outperform unit value transfers in terms of accuracy (Kaul et al. 2013; Rosenberger and Stanley 2006), although this is not always the case (Brouwer 2000; Brouwer and Bateman 2005; Ready et al. 2004). For example, unit value transfers can perform satisfactorily if the study and policy contexts are very similar (Bateman et al. 2011). The following sections summarize methods used for each of the primary types of benefit transfer.

2.2.1 Unit Value Transfer

As a foundation for subsequent discussion, we begin with a simple conceptual model for unit value transfer. Although we focus on the transfer of welfare estimates, parallel approaches apply for other estimated outcomes such as elasticities. Welfare measures for environmental resources, such as WTP estimates, are estimated primarily using information derived from individuals expressing their level of welfare based on tradeoffs observed through choices they either make (revealed preferences) or would make under hypothetical situations (stated preferences) (Freeman et al. 2014). Empirical studies generally report an aggregate or central tendency measure (e.g., mean or median) of welfare for a representative individual in the study sample, for a particular change in a good or service (henceforth, "good"). For example, studies in the valuation literature frequently report mean WTP for a given (marginal) change in the good (e.g., per unit WTP) for a particular sample of individuals. We denote this marginal welfare measure $\bar{y}_{js}$ with the subscript j identifying the site at which the study was conducted and s denoting the population sampled by the primary study, or to which the welfare estimate applies.

For illustration, we consider a common context for benefit transfer in which the analyst requires information on a parallel, but unknown, welfare estimate for a similar change and good at a different but similar site $i \neq j$ and population $r \neq s$, which we denote $\hat{y}_{ir}$. While we illustrate transfers across both sites and populations, parallel approaches apply for transfers only across sites (predicting an unknown value $\hat{y}_{is}$) or only across populations (predicting $\hat{y}_{jr}$). We assume that no primary study has been conducted for site $i \neq j$ and population $r \neq s$, so that benefit transfer must be used to generate needed welfare information. From this underlying model, transferred unit quantities can include: (1) a single unadjusted value, (2) a value somehow adjusted according to attributes of the policy context or using expert opinion, (3) a measure of central tendency such as a mean or median value from a set of prior studies, or (4) a range of estimates from a set of prior studies.

The simplest, and often least accurate form of transfer uses a single unadjusted value. In this case, one simply assumes that per person (or household) WTP at the study site is equal to that at the policy site, $\hat{y}_{ir}^{BT} = \bar{y}_{js}$, where WTP is relative to the same marginal quantity at both sites (e.g., per unit), and the superscript BT identifies $\hat{y}_{ir}^{BT}$ as a benefit transfer estimate. Assuming a population of size W that realizes these benefits, an aggregate transferred welfare estimate is given by $W * \hat{y}_{ir}^{BT}$.[2] Note that this represents a transfer of WTP for the *same or similar quantity of the good* at both sites. Any significant "scaling up" or "scaling down" of benefits to account for quantity differences between the study and policy site requires strong assumptions, including that per unit WTP is invariant to the total quantity of the good consumed (i.e., utility is linear with respect to quantity). Issues related to scaling and aggregation are discussed in greater detail below.

The second form of unit values transfer adjusts the transfer estimates according to attributes of the policy context or using expert opinion. For example, one might wish to adjust a unit value to account for differences in currency value, income or other factors. Adjusted unit value transfer is distinguished from benefit function transfer in that the adjustments in question do not rely on functions provided by the original primary studies, but are conducted ex post using an adjustment function determined by the benefit transfer analyst. In this case, $\hat{y}_{ir}^{BT} = f(\bar{y}_{js})$, where the function $f(\bar{y}_{js})$ is the ex post adjustment function. This function may be determined using objective (e.g., differences in currency value) or subjective (e.g., expert opinion) factors. For example, one might use an appropriate price index, P, to account for differences in real currency value between the time period during which the primary study was conducted and the period for which benefit estimates are required. In this case, $\hat{y}_{ir}^{BT} = f(\bar{y}_{js}) = P * \bar{y}_{js}$. Scaling for the relevant population of beneficiaries, W, occurs as described above.

As above, these types of scaling adjustments often involve strong assumptions, the consequences of which analysts should be aware. For example, the simple (e.g., linear) scaling of WTP estimates according to aggregate measures of income or purchasing power parity implies strong assumptions about the structure of preferences. As a result, this type of ex post scaling or adjustment will not always increase transfer accuracy. In some cases, it may be the source of additional transfer error.

A variant of adjusted unit value transfer is the use of administratively approved values (Rosenberger and Loomis 2003). In this case, transferred estimates are not provided through a formal, quantitative adjustment of a prior benefit estimate, but are rather values derived using a subjective and sometimes arbitrary process within a government agency, typically based on some combination of "empirical evidence from the literature, expert judgment, and political screening" (Rosenberger and Loomis 2003, p. 456). Although this is among the least formal, systematic or theoretically defensible approaches to benefit transfer, it may be required when conducting work to meet certain agency needs.

[2]Determining the relevant extent of the market, or size of the affected population is not always straightforward. Moreover, the size or location of the affected population can also be correlated with the size of $\bar{y}_{js}$. For example, WTP for a given change in a non-market good often declines with distance from the affected area (Bateman et al. 2006). Hence, projecting unit values to a larger population or spatial area than that in the original primary study can lead to substantial errors.

Unit value transfer methods (3) and (4) are straightforward extensions of the approaches described above. The primary difference is that the analyst uses information from multiple prior studies rather than a single study. To illustrate this case, assume that the analyst has access to $k = 1 \ldots K$ primary studies that each provide comparable estimates of $\bar{y}_{js}$. We denote the resulting WTP estimates $\bar{y}_{js}^{k}$. From these estimates one can either conduct an adjusted or unadjusted unit value transfer using a measure of central tendency, for example mean $\bar{y}_{js}^{k}$ over available primary studies. Rosenberger and Loomis (2003) demonstrate a simple example of this type of transfer. One can also conduct sensitivity analyses using the range of values from $\min(\bar{y}_{js}^{k})$ to $\max(\bar{y}_{js}^{k})$.

The primary advantages of unit value transfers are ease of implementation and minimal data requirements. Moreover, if the study and policy sites (and relevant changes in the good) are very similar, unit value transfers can perform acceptably (Bateman et al. 2011). However, in general, the assumptions implied by unit value transfers lead to larger errors than are observed with otherwise similar benefit function transfers (Kaul et al. 2013; Rosenberger and Stanley 2006). For additional discussion of transfer accuracy as related to unit value versus benefit function transfer, see Chap. 14.

2.2.2 Benefit Function Transfer

Benefit function transfers use a benefit function derived from a primary study or set of prior studies to calculate a welfare estimate calibrated to selected characteristics of a policy site (Loomis 1992; Rosenberger and Loomis 2003). There are two primary requirements for a benefit function transfer. The first requirement is a parameterized function that enables one to calculate the empirical outcome of interest, as a function of variables that include conditions observable at the policy site. Second, information on at least a subset of these variables is required for the policy site, in order to adjust the transferred function from the study site context to the policy site context. In principle, the ability to adjust benefit estimates according to observable differences between the study and policy contexts can lead to more accurate transfer estimates (i.e., lower transfer errors), and can perhaps relax the requirement for close similarity between the study site and a policy site across all relevant dimensions (Loomis 1992; Rosenberger and Loomis 2003; Rosenberger and Stanley 2006). However, there is a fair degree of consensus that site similarity remains an important determinant of transfer accuracy, even for benefit function transfer (Johnston and Rosenberger 2010).

The primary difference between alternative forms of benefit function transfer is the source of the benefit function. The simplest form of benefit function transfer uses an estimated function from a single primary study to calculate a calibrated welfare estimate for the policy site. This is often denoted single-site benefit function transfer. Functions used for benefit function transfer can be drawn from many different types of studies; common sources include recreation demand models, contingent valuation studies and choice experiments (Johnston and Rosenberger 2010; Rolfe and Bennett 2006). Functions are frequently drawn from within a single country, but may also be estimated from data that span multiple countries (Brander et al. 2007; Johnston and Thomassin 2010; Lindhjem and Navrud 2008; Ready and Navrud 2006).

Continuing the notation above, we can illustrate a benefit function in general form as

$$\hat{y}_{js} = g\left(\mathbf{x}_{js}, \hat{\boldsymbol{\beta}}_{js}\right), \tag{2.1}$$

where $\hat{y}_{js}$ is a predicted welfare estimate, $\mathbf{x}_{js}$ is a vector of variables representing the determinants of welfare estimate $\hat{y}_{js}$ at site j for population s, and $\hat{\boldsymbol{\beta}}_{js}$ is a conforming vector of estimated parameters. For example, a very simple linear benefit function would be

$$\hat{y}_{js} = \hat{\beta}_{js0} + \sum_{k=1}^{K} \hat{\beta}_{jsk} x_{jsk} + \hat{\varepsilon}_{js}, \tag{2.2}$$

where K is the number of non-intercept variables in the model and $\hat{\varepsilon}_{js}$ is a residual or error assumed to have a normal distribution with zero mean. If this function is parameterized so that one estimated parameter vector applies to all sites and populations (i.e., no systematically varying slopes or intercepts across sites or population groups), then (2.2) simplifies to

$$\hat{y}_{js} = \hat{\beta}_0 + \sum_{k=1}^{K} \hat{\beta}_k x_{jsk} + \hat{\varepsilon}_{js}, \tag{2.2a}$$

More sophisticated benefit functions may allow for non-linear effects of independent variables on the welfare estimate of interest.

For single-study benefit function transfer, all information in (2.1) would be gathered from a single primary study. Elements in $\mathbf{x}_{js}$ might include observable characteristics of the site, individual (or population), and good, including the quantity and/or quality of the good for which welfare effects are estimated. In general, the analyst will have policy site information for only some elements of $\mathbf{x}_{js}$. To accommodate this, we partition vector $\mathbf{x}_{js}$ into $\mathbf{x}_{js} = [\mathbf{x}_{js}^1\ \mathbf{x}_{js}^2]$, where $\mathbf{x}_{js}^1$ are variables for which the analyst has policy site data, and $\mathbf{x}_{js}^2$ are variables for which no policy site data are available. Parallel values for $\mathbf{x}_{js}^1$ at the policy site are given by $\mathbf{x}_{ir}^1$. As before, we assume that the analyst uses benefit transfer to predict a parallel but unknown welfare estimate for a similar change and good at a different but similar site $i \neq j$ and population $r \neq s$, which we denote $\hat{y}_{ir}$, with the associated benefit transfer estimate given by $\hat{y}_{ir}^{BT}$.

Given the simple model above, a benefit function transfer estimate of $\hat{y}_{ir}^{BT}$ may be calculated as

$$\hat{y}_{ir}^{BT} = g\left(\left[\mathbf{x}_{ir}^{1}\mathbf{x}_{js}^{2}\right], \hat{\boldsymbol{\beta}}_{js}\right). \tag{2.3}$$

That is, the analyst uses the parameterized function $g(\cdot)$ to calculate a benefit transfer estimate of value, substituting updated values of those variables for which policy site information is available ($\mathbf{x}_{ir}^{1}$). For variables with no updated policy site information, $\mathbf{x}_{js}^{2}$, original values from the study site are typically used. The result is a benefit transfer estimate, $\hat{y}_{ir}^{BT}$, that is adjusted for observable differences between the two valuation contexts (the study and policy site). The appendix to this chapter provides a simple textbook illustration of the difference between an applied unit value and benefit function transfer, for a hypothetical transfer of recreational value. Rosenberger and Loomis (2003) illustrate a benefit function transfer for a simple, real-world example.

In principal, benefit function transfers can be used to adjust or calibrate benefit transfer estimates for differences in such factors as the quantity or quality of the good being valued, the characteristics of individuals or populations (e.g., income, education), or other site characteristics such as the price, quality or availability of substitutes. However, Bateman et al. (2011, p. 384) argue that these functions should be "constructed from general economic theoretic principles to contain only those variables about which we have clear, prior expectations." An additional limitation is that function-based adjustments, for example adjusting for differences in socioeconomic characteristics of affected populations, will not always improve transfer accuracy (Brouwer 2000; Johnston and Duke 2010; Spash and Vatn 2006).

Single-site function transfers also require the strong assumption that the underlying parameterized valuation function, $g(\cdot)$, is identical at the study and policy sites. To account for potential differences in benefit functions across sites, one may also conduct *multiple-site benefit function transfer*, in which functions from different studies and/or sites are each used independently to derive distinct benefit function transfer estimates, with the results combined to provide a range of feasible values for the policy site. This approach differs from meta-analysis (described below), in which data from different studies and/or sites are combined statistically to generate a single "umbrella" benefit function that is used subsequently to generate a transfer estimate of value (Rosenberger and Phipps 2007). In contrast, multiple-site benefit function transfer generally involves the use of multiple, independent single-site transfers, the results of which are then somehow condensed into a single estimate (e.g., a mean value) or range of estimates.

2.2.2.1 Meta-analysis

Meta-analysis may be defined as the quantitative synthesis of evidence on a particular empirical outcome, with evidence gathered from prior primary studies. Meta-analysis in environmental economics is most often accomplished using statistical analysis, called meta-regression models (MRMs). Within these models, the dependent variable in a classical or Bayesian MRM is a comparable empirical outcome drawn from existing primary studies, with independent moderator variables representing observable factors that are hypothesized to explain variation in the outcome across observations. Observations used within meta-analysis (or the metadata) may be drawn from both the published and unpublished literature. Nelson and Kennedy (2009) provide a summary of meta-analysis in environmental and resource economics. Broad discussions of its use for benefit transfer are provided by numerous sources including Bergstrom and Taylor (2006), Florax et al. (2002), Johnston and Besedin (2009), Johnston and Rosenberger (2010), Rosenberger and Johnston (2009), Rosenberger and Loomis (2003) and Smith and Pattanayak (2002), among others.

When used for benefit transfer, MRMs are most often applied to identify and test systematic influences of study, economic, and resource attributes on WTP, characterize results of the literature addressing certain types of nonmarket values, and generate reduced-form benefit functions for direct transfer applications. All of these are grounded in the ability of meta-analysis to characterize a parameterized value surface reflecting multi-dimensional patterns in estimated WTP variation across multiple empirical studies (Johnston and Rosenberger 2010; Rosenberger and Phipps 2007). As described by Rosenberger and Johnston (2009, p. 411), if "empirical studies contribute to a body of WTP estimates (i.e., metadata), and if empirical value estimates are systematically related to variations in resource, study and site characteristics, then meta-regression analysis may provide a viable tool for estimating a more universal transfer function with distinct advantages over unit value or other function-based transfer methods." Many authors have noted the potential of MRMs to provide more robust, accurate benefit transfers compared to alternative methods (Johnston and Rosenberger 2010). Empirical evidence suggests that this may be true in many instances (Kaul et al. 2013; Rosenberger and Stanley 2006). Other works, however, have advised caution in the use of MRMs for benefit transfer (e.g., Bergstrom and Taylor 2006; Poe et al. 2001; Smith and Pattanayak 2002).

An empirical meta-analysis benefit function may be illustrated using similar notation to that introduced above. We now assume a case in which the analyst has access to a large number ($n = 1 \ldots N$) of studies, allowing her to estimate aggregate or central tendency measures (e.g., mean or median) of welfare for a particular good, from prior analyses conducted at different sites j and over different populations s.[3] Following the notation introduced above, we denote these welfare or WTP estimates as $\hat{y}_{js}$. These N welfare estimates then serve as the measured effect size or dependent variable in a statistical MRM represented in general form by,

$$\hat{y}_{js} = h(\mathbf{x}_{js}, \hat{\boldsymbol{\mu}}_{js}), \tag{2.4a}$$

[3]It is also possible for a single primary study to report multiple estimates for a single site and population, for example when multiple model specifications are estimated.

where $j = 1 \ldots J$ and $s = 1 \ldots S$. Here, $\mathbf{x}_{js}$ is a $1 \times K$ vector of variables representing resource, study and site characteristics (or moderator variables) hypothesized to explain the variation in welfare estimates $\hat{y}_{js}$ across sites j and populations s. $\hat{\boldsymbol{\mu}}_{js}$ is a conforming vector of parameters reflecting the estimated effect of each moderator variable on $\hat{y}_{js}$. In the simplest case a single parameter estimate will apply to each moderator variable in the dataset (across all j and s), so that the vector $\hat{\boldsymbol{\mu}}_{js} = \hat{\boldsymbol{\mu}}$.

The general form of (2.4a) allows for estimation using a variety of common linear-in-the-parameters functional forms, including linear, semi-log, log-linear and translog functional forms; all are common in the meta-analysis literature. For example, replacing the subscripts j and k with a single subscript n that identifies individual observations in the metadata, a simple linear econometric form for Eq. (2.4a) would be

$$\hat{y}_n = \mu_0 + \sum_{k=1}^{K} \hat{\mu}_k x_{nk} + \hat{\varepsilon}_n, \tag{2.4b}$$

where $\hat{\varepsilon}_n$ is the equation error or residual.

When estimating models such as (2.4b), analysts must account for a variety of potential statistical complications including sample selection effects, primary data heterogeneity, heteroskedasticity and nonindependence of multiple observations from individual studies (Nelson and Kennedy 2009; Rosenberger and Johnston 2009). Development of metadata also involves empirical challenges, including the reconciliation of variables across different primary studies (Bergstrom and Taylor 2006; Johnston and Rosenberger 2010; Nelson and Kennedy 2009). As noted by Nelson and Kennedy (2009) and others, many MRMs in the literature violate good practice guidelines for econometric estimation, although some of these guidelines are subject to debate (Johnston and Rosenberger 2010).[4] For conciseness these issues are not discussed further here, but are discussed and illustrated in later chapters.

Mirroring the methods for benefit function transfer presented above, prediction of an aggregate welfare measure for the policy site, $\hat{y}_{ir}^{MRM}$, using meta-regression model (2.4a) replaces moderator effects, $\mathbf{x}_{js}$, with analogous measures at the policy site $\mathbf{x}_{ir}$, such that

$$\hat{y}_{ir}^{MRM} = h(\mathbf{x}_{ir}, \hat{\boldsymbol{\mu}}_{js}). \tag{2.5}$$

The result is a predicted welfare estimate, $\hat{y}_{ir}^{MRM}$, calibrated to specific conditions at the policy site. When a variable in $\mathbf{x}_{ir}$ is unobservable at the policy site, it is often replaced by an associated mean value of that variable from the metadata. A step-by-step illustration of this process for a case study addressing water quality improvements is

[4]An example is the appropriateness of pooling otherwise commensurable Marshallian and Hicksian welfare measures within a single MRM (Johnston and Moeltner 2014; Londoño and Johnston 2012).

shown by Johnston and Besedin (2009). Other simple examples are provided by Rosenberger and Loomis (2003) and Chap. 12.

Variables that identify methodological aspects of primary studies included in the metadata (i.e., the methods used by each study to estimate values) are generally not observable for the policy site, because no research has been conducted there. Methodological factors shown to influence WTP in past MRMs include study type, survey implementation method, response rate, question format, treatment of outliers/protests, econometric methods, and other factors (Johnston et al. 2006a; Rolfe and Brouwer 2013; Stapler and Johnston 2009). In such cases, analysts either select values for these methodological variables based on levels they consider to be appropriate,[5] or use mean values for these variables from the metadata (Moeltner et al. 2007; Stapler and Johnston 2009).

The validity of any meta-analysis and the resulting benefit transfers depends on the quality, extent and unbiasedness of the underlying primary data (Nelson and Kennedy 2009; Rosenberger and Johnston 2009). Hence, it is critical that analysts use appropriate approaches to collect, evaluate and screen information gathered from the literature, and that methods used for this process are transparent. Section 2.5 discusses broader issues related to data sources and selectivity. Stanley et al. (2013) provide a concise review of recommended steps in meta-analysis data collection and reporting. We note that while these steps often complicate the selection of source studies for a meta-analysis, they have key advantages in that input studies of lower quality or relevance can be identified prior to use.

2.2.2.2 Preference Calibration or Structural Benefit Transfer

Benefit transfers, in general, lack a micro-level utility-theoretic foundation (Smith et al. 2002). Although all benefit transfers should draw on prior primary studies with a strong grounding in welfare theory, transfers themselves are almost always a purely empirical exercise; no additional constraints are placed on the transfer to ensure compliance with theory. As such, most benefit transfers and meta-analyses are considered to have a "weak" structural basis in utility theory (Bergstrom and Taylor 2006). Such critiques apply to traditional unit and benefit function transfers, as well as to MRM functions. In contrast to these other approaches, structural benefit transfer (or preference calibration) is distinguished by a strong and formal basis in an explicit, structural utility function. This assumed utility structure is used to combine and transfer information drawn from multiple prior studies or information sources (e.g., Pattanayak et al. 2007; Smith and Pattanayak 2002; Smith et al. 2002, 2006).

Structural benefit transfer requires the analyst to specify a specific, structural preference or utility function able to describe an individual's choices over a set of

[5] Johnston et al. (2006a) illustrate the potential risks of this approach related to the sensitivity of resulting transfer estimates.

market and nonmarket goods, presuming standard budget-constrained utility maximization. One then derives analytical expressions that determine a relationship between each available benefit measure from existing primary studies and the assumed utility function, inasmuch as possible guided by economic theory. Expressions also should "assure the variables assumed to enter the preference function are consistently measured across each study and linked to preference parameters" (Smith et al. 2002, p. 136). Finally, empirical methods are used to calibrate parameters to the specified utility-theoretic structure. That is, parameters of a benefit function (or system of functions) are solved so that the resulting preferences (and subsequent benefit transfers) are consistent with the empirical results of the available prior studies, given the assumed utility structure. In some cases preference or utility parameters may be solved algebraically based on the specified utility structure; in other cases some form of iterative optimization is required.

Unlike some other forms of benefit transfer, structural benefit transfer generally cannot be accomplished without significant expertise in welfare theory and mathematical economics. Because of the great variability in ways that structural benefit transfer may be accomplished and the complexity of the approach, it is not possible to provide a concise, general illustration of the method in this chapter. Readers are directed to Pattanayak et al. (2007), Smith and Pattanayak (2002), Smith et al. (2002, 2006) and Chap. 23 in this book for additional information and applications.

2.2.3 Choosing Among Different Types of Benefit Transfer

The choice among different types of benefit transfer is dictated by a number of different factors, including the type of information and number of studies that are available, the type of value that is required, the general similarity (or correspondence) between the study and policy contexts, the level of analyst expertise, the time and resources available to develop transfer methods, and the precision necessary for different types of policy decisions (Bergstrom and De Civita 1999; Navrud and Pruckner 1997). In general, benefit function transfers are preferred unless the study and policy contexts are very similar (Bateman et al. 2011; Kaul et al. 2013; Rosenberger and Stanley 2006), although the multiple dimensions over which sites may be similar or dissimilar can complicate such assessments (Colombo and Hanley 2008; Johnston 2007). Unadjusted unit value transfers, however, are generally treated with skepticism and considered one of the least appropriate forms of transfer (Johnston and Rosenberger 2010). An exception is the literature on the value of a statistical life (VSL), which emphasizes unit value transfers, noting that the appropriateness of function-based adjustments of VSLs is unclear (Brouwer and Bateman 2005; Mrozek and Taylor 2002; Viscusi and Aldy 2003).

The choice of single-site benefit function transfer versus meta-analysis depends on factors that include the availability of sufficient studies for MRM estimation and the availability of a single, closely matching study-site function (Stapler and Johnston 2009). The probability of finding a good fit between a single study site and a policy site is usually low (Boyle and Bergstrom 1992; Spash and Vatn 2006). In such cases the ability of MRMs to estimate a multidimensional value surface that combines information from many prior studies can lead to improved transfer accuracy (Rosenberger and Phipps 2007). However, the development of metadata and estimation of suitable MRMs requires greater time and expertise than is typically required for other forms of benefit transfer (structural benefit transfer is an exception). In general, MRMs are most appropriate when: (1) there is a large valuation literature addressing the nonmarket good in question, (2) there is no empirical study for a single, closely matching policy context, and/or (3) the analyst desires flexibility to estimate benefits for different policy contexts or outcomes (e.g., scales of improvement in the nonmarket good).

Structural benefit transfer methods have not yet been widely adopted for applied work. Advantages of structural transfer include the imposition of strong theoretical consistency on the use of prior information (Bergstrom and Taylor 2006) and greater transparency in assumptions. The method also has limitations, including potential sensitivity of model results to the assumed utility structure. The preference calibration method is also more complex than most alternative transfer methods, and the literature has yet to demonstrate clearly that this increased complexity leads to improvements in transfer accuracy (Johnston and Rosenberger 2010). Hence, the choice of strong structural versus weak structural transfer methods (Bergstrom and Taylor 2006) often depends on the analyst's level of expertise and predisposition regarding the relative importance of a strong structural utility foundation for benefit transfer.

Finally, while benefit transfer is often the only feasible option for estimating values required for policy analysis, analysts may sometimes have a choice between primary research and benefit transfer. This choice can be particularly relevant for smaller projects or policies, for which the cost of a high quality primary valuation study can be large compared to potential policy benefits. Allen and Loomis (2008, p. 9) model the choice of primary studies versus benefit transfer for a case study of recreational benefit estimation, and conclude that "only in the case of very small projects … would original research not yield positive returns in terms of better decisions." Hence, where primary research is feasible (at least of a certain minimum quality), it is almost always preferred.

2.3 Underlying Principles of Economic Valuation

Regardless of the transfer method used, a benefit transfer can only be as good as the underlying primary studies. Theoretically valid benefit transfers require a basis in theoretically valid primary valuations. There is a large and mature literature on valuation theory and methods (e.g., Bockstael and McConnell 2010; Champ et al. 2003; Freeman et al. 2014; Haab and McConnell 2002; Hanley and Barbier 2009;

Just et al. 2004). Here, we focus on the basic theoretical foundation for benefit or value estimation, although similar theoretical guidelines apply to the estimation of most empirical quantities used within benefit transfer.

Economic benefits and costs may be realized by individuals or firms (e.g., businesses). They are always quantified in comparative terms, relative to a well-defined baseline, and reflect the welfare (or well-being) of individuals or groups. For individuals, benefits are generally measured as the maximum amount of other goods that the individual is willing to forego in order to obtain another good that is desired. This reflects the individual's WTP. Although WTP is often denominated in money units, it can be expressed in any unit of exchange. Value may also be quantified in terms of willingness to accept (WTA), defined as the minimum amount that a person or group would be willing to accept in order to give up a specified quantity of a good that is already possessed. Economic values or benefits, therefore, are a simple reflection of tradeoffs: what individuals or groups are willing to give up in order to obtain something else, either in or out of organized markets. The resulting values are denoted *market* and *nonmarket values*, respectively. Economists' ability to monetize market or nonmarket benefits in this way relies on the concept of substitutability—that the welfare gained through increases in one commodity can be offset by decreases in other commodities.

Economic values are meaningful only for a particular quantity of a market or nonmarket commodity, relative to a specific baseline. If these changes are large (i.e., non-marginal), value estimation must account for the fact that per unit values for any commodity generally diminish as one obtains more of that commodity (this is called diminishing marginal utility). For example, a recreational angler is generally willing to pay more per fish to increase her catch from 0 to 1 fish than from 9 to 10 fish; the value of a marginal fish depends on how many fish have already been caught (Johnston et al. 2006b).

Different valid measures can be used to quantify economic values. Among the most common is *consumer surplus*, which may be interpreted as the difference between what an individual or group would be willing to pay for a commodity (measured off the estimated demand curve) and what is actually paid, summed over all units. A parallel measure for firms is *producer surplus*, which is similar to economic profits.[6] Theoretically exact welfare measures of surplus for individuals are called *Hicksian welfare measures*; these include compensating and equivalent surplus (Bockstael and McConnell 2010; Freeman et al. 2014; Just et al. 2004). For example, an individual's WTP for a fixed change in a public good such as air quality is a compensating surplus measure. Hicksian welfare measures, however, are difficult or sometimes impossible to measure using data on observed behavior. For this reason, economists will frequently use alternative estimates that can provide close approximations to exact Hicksian welfare measures. Among the most common of

[6]The difference between producer surplus and economic profits lies in the treatment of fixed costs of production.

these is Marshallian (consumer) surplus, which measures consumer surplus as the area below the estimated demand function but above the market price for a good (or zero if an amenity is not provided through markets or is otherwise unpriced).

Economists have developed different methods for quantifying market and non-market values such as these (Champ et al. 2003; Freeman et al. 2014; Hanley and Barbier 2009; Holland et al. 2010). Although the methods for measuring these values differ, these valuation techniques are all based on an internally consistent model of human welfare that allows benefit and cost measures to be aggregated and compared. The model assumes that, after considering the pros and cons of all options, people will make choices that they expect to provide the greatest long-term satisfaction or utility. The theoretical basis of this model allows one to link estimated monetary values (e.g., benefits, costs, and WTP) with the well-being of individuals, households, or groups.

The choice of valuation method(s) is determined by the type of values that are likely to be present. *Revealed preference methods* are based on the analyses of observed human behavior. Examples include recreation demand models and hedonic property value models (Bockstael and McConnell 2010; Champ et al. 2003; Freeman et al. 2014). Such methods can only measure *use values*—or values related to the consumptive or nonconsumptive use of a commodity. *Stated preference methods* are based on the analysis of responses to carefully designed survey questions; examples include *contingent valuation* and *choice experiment* (*or choice modeling*) *methods* (Bateman et al. 2002; Rolfe and Bennett 2006). Stated preference methods, while sometimes more controversial because of their reliance on survey responses, are able to measure both use and *nonuse values*. Nonuse values (also called passive use values) may be defined as values that do not require use of a commodity or related behavior. An example would be the value that individuals often hold for the continued existence of threatened wildlife species, apart from any direct or indirect use of that species.

All valuation methods have advantages and disadvantages (see discussions in, for example, Champ et al. 2003; Freeman et al. 2014). Both revealed and stated preference methods have been used extensively over the past three decades, have been extensively tested and validated by researchers, and are grounded in extensive published literatures. Both are widely accepted by government agencies as reliable for estimating economic values.

Just as there are a large number of valid techniques for estimating economic values, there are also a large number of techniques that—while producing results in monetary units—do not quantify economic benefits in ways that are consistent with well-defined surplus (or welfare) measures for consumers or producers (Holland et al. 2010). These methods generally have little or no grounding in economic theory or structural relationship to human welfare. Benefit transfers of such results will lead to similarly invalid and misleading estimates. Common examples of these techniques include *replacement cost methods*, which quantify the "value" of a nonmarket good or service based on the cost of "replacing" that good or service using technological or other means; *damage cost methods*, which seek to quantify the protective value of natural resources (such as wetlands that protect homes from flooding) based on the monetary damages they prevent; and *embodied energy methods*, which seek to estimate values based on the total energy required to produce goods and services (Holland et al. 2010). Except in rare circumstances, neither replacement nor damage cost approaches are suitable for quantifying economic value. Embodied energy approaches never generate valid economic value estimates.

When one conducts a benefit transfer, any errors in the original value estimates are also transferred. Hence, the transfer of an invalid measure of economic value will lead to an invalid transfer estimate. Regardless of the type of benefit transfer applied, it is crucial that the original primary study estimates represent valid measures of economic value.

2.4 Scaling Benefit Estimates

One of the most misunderstood and misused aspects of benefit transfer involves the scaling of benefits over populations, affected areas or quantities of change (Rolfe et al. 2011). A good general discussion of the role of scope and scale in valuation is provided by Rolfe and Wang (2011). Scaling, or multiplication of per unit values by a different quantity, population or area than was evaluated by the original source study (or studies), requires strong and often unrealistic assumptions. These include the invariance of per unit values to scale, an assumption that holds only in rare circumstances or for small changes in scale. For example, due to geographical proximity effects such as distance decay (that values tend to decline as one moves further from an affected area; Bateman et al. 2006) and diminishing marginal utility, per unit values tend to be higher in small local case studies than regional or national ones (Rolfe et al. 2011; Rolfe and Windle 2008). Hence, unit values should not be scaled to significantly larger or smaller geographic areas (or scales) without adjustments (Johnston and Duke 2009).

Common violations of accepted practice in benefit transfer involve the scaling of benefit measures in attempts to quantify the total benefits of an environmental asset at a planetary, nation/statewide, or ecosystem scale (Bockstael et al. 2000; Toman 1998). These attempts ignore diminishing marginal utility and the fact that economic values are meaningful only for clearly specified changes in a good or service, rather than an entire environmental asset (Bockstael et al. 2000). That is, they ignore the errors that can occur when benefit transfers scale benefit estimates. Perhaps the most commonly cited of these analyses is Costanza et al. (1997), which attempts to use benefit transfer to quantify the value of planetary ecosystem services (Bockstael et al. 2000). Many subsequent analyses have used similarly flawed benefit transfers in an attempt to value large ecological assets.

This section uses very simple graphical tools to demonstrate the importance of scale in benefit transfer and the errors that result when scale differences are ignored.

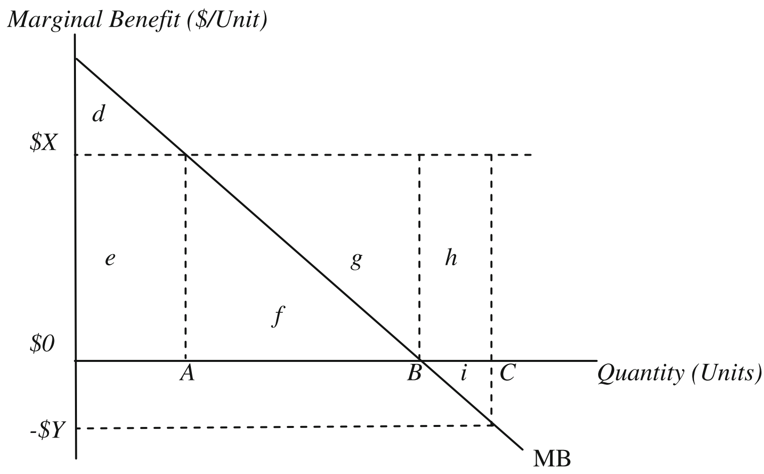

Fig. 2.1 Marginal benefits and scale over quantities

For illustration, we focus on three types of scaling that are often abused in benefit transfers—scaling over quantities, populations and geographic areas. Although the illustrations are stylized and simple, they are grounded in established theoretical expectations with strong support in empirical research.

We begin with Fig. 2.1, which illustrates a standard downward sloping marginal benefit curve (MB) for a market or nonmarket good. For a market good, this marginal benefit curve would be equivalent to a market demand curve. For any given quantity of the good, the MB curve shows a representative individual's marginal benefit (or WTP) for the last, or marginal unit consumed. For example, if an individual consumes *A* units of this good, the marginal benefit of the last unit is *$X*. The total benefit of consumption for all units consumed (not only the marginal unit) is the area underneath the MB curve from zero to the total quantity consumed. So, for example, the total benefit of consuming *A* units (assuming they were obtained at zero cost) would be area $d + e$. In contrast, the total benefit of consuming *A* units, assuming that the individual pays a price of *$X* per unit, would be area *d*. Assuming that Fig. 2.1 is a market (or Marshallian) demand curve, these are interpreted as measures of consumer surplus.

Drawing from this standard model, assume that a primary valuation study estimates a value of *$X* per unit, based on a consumption quantity of *A* units. Assuming perfectly matching study and policy sites, this unit value would reflect an accurate benefit transfer (zero error) of marginal value, as long as the quantity is the same at both sites (that is, no scaling). Now assume, however, that a benefit transfer attempts to scale this unit value to a larger quantity of the good, for example *B* units. At *B* units, the true marginal value of the good is zero, but the scaled benefit transfer would continue to predict *$X* per unit. The true total benefit of consuming *B* units (assuming zero cost) is $d + e + f$; the area under the MB curve up to *B* units.

The scaled unit value transfer, however, would predict a value of *$X* multiplied by *B*, or a total area of $e + f + g$. Hence, both the transferred marginal and total values are biased.

The bias becomes more severe for larger scaling, for example to *C* units. At this quantity, marginal net benefit drops below zero to *negative $Y*.[7] However, the scaled unit value transfer continues to predict a constant value of *$X*. In terms of consumer surplus for all units consumed, the true value at *C* units of consumption (assuming the good is obtained at zero cost) is area $d + e + f - i$. The scaled, transferred value, however, is $e + f + g + h$. As the scaling of unit values increases in magnitude, the error (the difference between the true and transferred value) also increases. From this diagram, it is easy to see the fallacy in the claim that scaled unit values provide a "reasonable" approximation of actual values. In fact, scaled unit values may not even have the same algebraic sign as true values. Scaling by a small amount, however, can sometimes generate reasonable approximations of value, depending on the slope of the marginal benefit curve.

Similar errors to those shown in Fig. 2.1 occur when one seeks to scale up values calculated per unit area (e.g., ecosystem service values per acre) to much larger areas than the original primary study. In this case, the total quantity of the good is correlated with the landscape area. For example, as shown by Johnston and Duke (2009), the marginal per acre WTP for farmland preservation is much greater when one considers smaller total acreages of preservation.[8] Among the few exceptions to this rule—at least in some cases—are market goods such as agricultural products sold on world markets. In such cases, production on additional acres in any local area (assuming equal productivity) is unlikely to influence world price to a large degree, and hence per acre agricultural production values can be scaled to a certain extent. One can make similar arguments for other goods or services that are valued primarily based on their global consequences. An example is the per ton value of carbon sequestration, which is likely approximately constant (albeit difficult to estimate) for a wide range of potential quantities.

Related difficulties with geographical scaling are shown by Fig. 2.2, which illustrates a similar per unit, marginal benefit curve. Here, however, we envision a case in which there is a fixed quantity increase in a nonmarket good at a particular location. The graph shows how the benefit of this change diminishes as the distance to the affected location increases. This is similar to the function derived empirically by Hanley et al. (2003). For example, it is well established that individuals are often willing to pay less for environmental improvements that are at a greater distance from their homes (Bateman et al. 2006; Jørgensen et al. 2013; Schaafsma et al. 2012).

[7]A good example of this pattern would be water levels in a river, which often have positive marginal values up to a point where flooding occurs, at which point marginal values for additional water become negative.

[8]In addition, non-linearities and thresholds in ecological systems can lead to nonconvexities when one considers ecosystem conservation at different geographical scales. This further complicates any scaling up or down of certain types of environmental values.

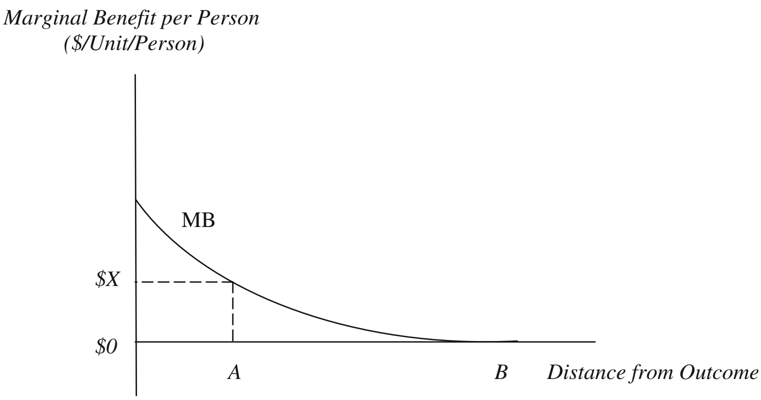

Fig. 2.2 Marginal benefits and scale over distance (or populations over greater areas)

Given this MB curve, we assume that a primary study has estimated a marginal unit value of *$X* per person, for a study over a population at distance *A* from the affected location. Based on such studies, benefit transfers will sometimes scale unit values over larger populations or areas, extending greater distances from the affected location—for example distance *B*. The graph shows the errors that result from such scaling. Continuing to scale the fixed unit value *$X* to a population at distance *B* overlooks the fact that marginal value drops to nearly zero at this distance. If one were to aggregate these transferred unit values over greater and greater distances, the error in aggregated values would increase with the distance of the aggregation (or the size of the total area).

These simple diagrams show the risks involved in scaling unit value estimates over different quantities, areas or populations than those considered by the original primary study. It is rarely the case that values—whether per person, per unit, or per unit area—are invariant to different types of scale. Simple linear scaling up of values—except in rare circumstances—will typically lead to significant errors. Among the advantages of benefit function transfer in such cases is the potential ability to model or predict the entire MB function, thereby providing a function-based mechanism to adapt value estimates to the resulting scale differences. Meta-analysis can also provide a possible means to adjust across scales, if the underlying studies in the metadata reflect studies conducted at different scales.[9] However, even in such cases, it is important that scaling not occur beyond the range of the data in the original primary studies; doing so risks the same types of scaling errors that occur with unit value transfers.

[9]For an example, see Johnston et al. (2005).

2.5 Site, Context and Commodity Similarity

Among the primary requirements for accurate benefit transfer is correspondence, or similarity between the site, valuation context and populations at the study site and those at the policy site (Loomis and Rosenberger 2006). This includes similarity in factors such as the availability of substitutes and complements to the good in question. The degree and dimensions of similarity that are required, however, can vary across different types of transfers (Colombo and Hanley 2008; Johnston 2007). Challenges of site similarity are even greater for international benefit transfers, given potential differences in such factors as currency conversion, user attributes, wealth/income measures, cultural differences and extent of the market (Johnston and Thomassin 2010; Ready and Navrud 2006). Commodity consistency is another critical prerequisite for valid transfer (Boyle and Bergstrom 1992; Johnston et al. 2005; Loomis and Rosenberger 2006; Smith et al. 2002). That is, accurate transfers require an understanding of the welfare-influencing quantities or qualities of goods at affected sites, both in primary studies from which values are estimated and in policy sites for which estimates are needed.

Even studies of seemingly similar nonmarket goods may estimate values for differing underlying quantities or qualities. For example, improvements in water quality within reservoirs used as a source of drinking water are, for welfare estimation purposes, a different type of commodity than improvements in water quality within streams used solely for recreation. Even though the chemical change in the water itself might be similar, the mechanism through which these changes influence utility differs. As a result, there is no theoretical or empirical expectation that WTP for these two changes should be related. Given such possibilities, benefit transfer requires analysts to consider similarity not only in the biophysical dimensions of affected goods, but also the welfare dimensions.

It is sometimes possible to reconcile (or match ex post) commodity definitions across studies. For example, this is almost always required to develop metadata for valuation MRMs (Johnston et al. 2005; Smith and Pattanayak 2002). However, reconciliation that promotes sufficient uniformity is not always feasible (Smith et al. 2002; Van Houtven et al. 2007), and analysts are often delinquent in such areas (Nelson and Kennedy 2009). Appropriately specified MRMs may also be able to account for some systematic patterns that differentiate welfare measures for similar, but not identical, commodities by including appropriate variables on the right-hand side of regression models. For example, the MRM of Johnston et al. (2006b) includes variables that allow marginal WTP per fish among recreational anglers to vary depending on the type of fish species, the fishing mode, and the catch rate, among other factors. The extent to which such adjustments can be accomplished in a defensible manner, however, is limited (Bergstrom and Taylor 2006). The task is made more difficult "as [the] complexity of changes in environmental quality and natural resources increase[s]" (Navrud and Ready 2007a, p. 3).

Given the many dimensions over which valuation commodities and contexts can be similar and dissimilar, benefit transfers typically require the analyst to make (hopefully informed) judgments regarding whether commodities at the study and policy site are "close enough" to support valid and accurate benefit transfer. These judgments should also be influenced by the degree of accuracy required of different types of transfer (Bergstrom and De Civita 1999; Navrud and Pruckner 1997). Theory can provide only limited assistance for these choices. Conservative decisions in such cases can be important to reducing generalization errors.

2.6 Data Sources and Selectivity

The accuracy of benefit transfer depends on the type and quality of primary studies used to generate transfer estimates. When one selects primary studies for benefit transfer, there are implicit assumptions that the underlying body of valuation literature provides an unbiased sample of the population of empirical estimates and that these estimates provide an unbiased representation of true resource values. If these assumptions do not hold, the result will be systematic transfer biases. These are often called selection biases. Such concerns are most often noted for the case of meta-analysis but apply to all types of transfer (Rosenberger and Johnston 2009). Benefit transfers can only be as good or as unbiased as the sample of data from which they are derived, or to the extent that any biases can be corrected during the transfer process. Among the first steps in any high quality benefit transfer is a comprehensive review of the literature to find suitable high quality studies.

The methods used to select and screen studies for benefit transfer are important. Rosenberger and Johnston (2009) identify four potential sources of selection bias that can influence benefit transfers, including research priority selection, methodology selection, publication selection, and [metadata] sample selection. For each, there are a variety of steps that can be taken to minimize the potential for these biases to carry over into empirical benefit transfers. For example, there are a variety of methods that can be used to identify, measure and correct for publication selection bias, including approaches that weight empirical estimates by their standard errors to give greater importance to estimates that have been estimated with greater accuracy (Florax et al. 2002; Stanley 2005, 2008). These and other approaches to address potential selection biases are discussed in Chap. 14.

At the same time, avoidance of measurement error in benefit transfers requires that primary studies are of a certain minimum quality. As noted above, for example, studies that do not generate theoretically valid estimates of value cannot serve as the basis for a valid benefit transfer. Hence, studies should be screened to ensure the fundamental validity of the estimated welfare measures according to economic theory. The quality of empirical research methods is also important, but is more difficult to quantify. Although publication in peer-reviewed journals can be a potential signal of study quality, presence in a peer-reviewed journal does not guarantee suitability for benefit transfer. For example, some studies may be published on the strength or novelty of their methodological or theoretical contributions, despite a weak empirical application. Such studies may not be suitable for benefit transfer. Other studies may have inadequate reporting of data or methods (Loomis and Rosenberger 2006). In still other cases, there may be biases inherent in the types of paper accepted for publication, leading to systematic biases in the published literature (Stanley 2005, 2008; Chaps. 14 and 15). Signals of quality also vary across types of valuation. For example, the use of extensive focus groups and survey pretesting is an important signal of quality in stated preference research, but is largely irrelevant for many revealed preference methods. Overall, the benefit transfer literature has reached consensus that primary study quality is necessary to avoid measurement errors in benefit transfer, but has not reached consensus on clear protocols to evaluate quality. Those with expertise in economic valuation can help identify studies suitable for benefit transfer, but even among experts there may not be total agreement.

Increasingly, valuation databases such as the Environmental Valuation Reference Inventory (EVRI, http://www.evri.ca) can help practitioners identify research studies suitable for transfer (Johnston and Thomassin 2009; McComb et al. 2006; Morrison 2001). EVRI is a specialized internet database that contains summaries of empirical studies of the economic value of environmental costs and benefits and human health effects. The database is now the largest international nonmarket valuation database in existence, including data from thousands of nonmarket valuation studies. Although EVRI has many potential uses, the primary goal of the database is to assist policy analysts with benefit transfer. Similar but smaller databases include ENVALUE (http://www.environment.nsw.gov.au/envalue/), developed by the New South Wales Environment Protection Authority. Academics tend to view these and other databases as a useful starting point for research or policy analysis and as an important source of information regarding the valuation literature, but treat with skepticism transfers that rely solely on database information (Johnston and Thomassin 2009; Morrison 2001). Accurate benefit transfers require careful and systematic attention to relationships between primary study attributes and those of the intended policy target. As noted by Morrison (2001, p. 54), "analysts should not expect to be able to simply download value estimates for a cost-benefit analysis from these [valuation] databases, unless the cost-benefit analysis is particularly rudimentary and of little policy significance." Hence, valuation databases cannot substitute for practitioner expertise and detailed analysis of original primary studies.

Yet even with the increasing size of the valuation literature and existence of expanding valuation databases, many of the primary challenges to benefit transfer relate to a lack of accessible, unbiased information (Johnston and Rosenberger 2010). Despite a large research literature in environmental valuation, there is a lack of studies providing high-quality, policy-relevant, replicable, empirical estimates of nonmarket values for many environmental commodities. Instead, the published literature is dominated by studies illustrating methodological advances, often at the expense of useful empirical estimates. Similarly, the literature often fails to provide sufficient information on study attributes and data to promote defensible transfer. Recognizing these challenges, a number of authors have called for additional emphasis into the provision of high-quality, well-annotated empirical estimates of nonmarket values (Loomis and Rosenberger 2006).

Given the difficulty in finding suitable data, practitioners may be tempted to use one of the increasing array of prepackaged software tools or databases to conduct or support benefit transfers. This should be considered only with extreme caution. These ready-made tools are often grounded in large-scale, data-intensive models built around spatial (GIS) modeling of ecosystem functions.[10] Although these tools have many useful purposes, among their shortcomings for welfare analysis is that the embedded benefit transfer methods and assumptions are often obscured; the typical lay user sees only the final transferred estimate of value. Also, the ecological components of these models are typically better developed than the economic components. Many of these tools rely on simple unit value transfers of the type often treated with skepticism by benefit transfer experts. Only through a dedicated, expert exploration of the model code or documentation are these underlying transfer methods and assumptions visible. The ability of such tools to support accurate benefit transfers depends on the validity of the underlying ecological and economic models and the coherence with which these models are combined. Before using such tools for benefit transfer, users should verify that the embedded methods, assumptions and data conform to recommended practices. Users should universally avoid any benefit transfer tool for which the underlying methods and functions are proprietary or otherwise unavailable for such a critical evaluation. Additional discussion of these issues is provided in Chap. 12.

2.7 Measuring Transfer Accuracy

Benefit transfers are subject to a variety of potential errors, many of which are related to the issues discussed throughout this chapter. These errors are often grouped into two general categories. Transferred errors from the original primary studies are denoted *measurement errors*. These are differences between the true underlying value and a primary study estimate (Brouwer and Spaninks 1999; Rosenberger and Stanley 2006). These are distinct from *generalization errors*, which are the errors related to the transfer process itself. Generalization errors are related to such factors as commodity inconsistency, benefit scaling and a lack of site similarity, among others (Rosenberger and Phipps 2007). Most evaluations of transfer accuracy focus on generalization error, since it is assumed that original research provides unbiased estimates, or that biased studies have been eliminated by quality control during the selection of studies for transfer.

[10]One of the best known and well-developed of these tools is InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs), although many others have been developed over recent years. Among the advantages of InVEST is documentation that clarifies the transfer methods that are used. Many other tools lack such clarity, and are effectively “black boxes” in terms of transfer methods and data.

Benefit transfers are generally evaluated in terms of predictive accuracy (sometimes called reliability) and transfer validity. A transfer accurately predicts a value estimate, or is reliable, when generalization error is small. Benefit transfer validity, in contrast, requires that value estimates or other transferred quantities are statistically identical across study and policy contexts (i.e., there is no statistically significant transfer error).[11] In actual transfer applications the true value of the topic of interest is obviously unknown (otherwise benefit transfer would not be required). For this reason, out-of-sample predictive performance, or convergent validity testing, is most often used to test accuracy and validity. That is, benefit transfer is tested in circumstances where a policy site study has been conducted. Benefit transfer estimates are then compared to the estimate provided by original research at the policy site. Because the need for accuracy and validity varies across applications, there is no universal test or maximum error that dictates the acceptability of benefit transfer.

Evaluations of benefit transfer errors across the literature include Brouwer and Spaninks (1999), Kaul et al. (2013), and Rosenberger and Stanley (2006). The findings of these analyses are broadly similar and mostly intuitive. Results of Kaul et al. (2013), for example, suggest that (1) benefit function transfers tend to outperform unit value transfers, (2) transfers of values for quantities are more accurate than those for qualities, (3) geographic site similarity influences transfer error, (4) contingent valuation estimates are associated with systematically lower transfer errors than other nonmarket valuation techniques, and (5) the combination of data from multiple studies can reduce transfer errors. Chapter 14 in this book provides extensive discussion of the measurement and interpretation of transfer accuracy and validity.

2.8 Steps in a Benefit Transfer

There are various ways in which one may categorize the steps in a benefit transfer, and the steps will depend somewhat on the transfer method and policy context. These caveats aside, the following section attempts to briefly summarize the main steps involved. Readers are also directed to Desvousges et al. (1998) and Rosenberger and Loomis (2003), who provide alternative discussions of benefit transfer steps.

2.8.1 Define the Benefit Transfer Context

The first step in any benefit transfer is to define the valuation and policy context in which benefit transfer will potentially occur, and to determine the type of economic

[11]Transfer validity may also be viewed in terms of the underlying validity of the primary study estimates (i.e., lack of measurement error), although this is a less common use of the term.

information required. Answers to a variety of questions are typically sought at this stage. What is the circumstance for which values are required? What general type of information (e.g., value estimates) is required? What types of policy changes, commodities and populations will be affected, and what types of information are likely to be available on these effects? What will be the primary use of economic information, and what does this use imply for required accuracy? What time and resources are available for analysis? This step typically involves discussions with decision makers and reviews of background documents to establish the general context under which benefit transfer might occur, and the broad parameters of the analysis.

2.8.2 Establish the Need for Benefit Transfer

As noted above, high-quality primary studies are generally preferred to benefit transfer if feasible. Hence, the next stage in a potential benefit transfer is to assess whether benefit transfer is indeed necessary, or whether a primary study of sufficient quality is feasible. Factors influencing this decision include but are not necessarily limited to: (1) time and resources available for analysis relative to that required for a primary study, (2) availability of information for a primary study, (3) approvals or policy process constraints which restrict the collection of primary data or use of primary analysis, (4) the accuracy and other needs of the policy context and users of the information, (5) the size of policy impacts relative to the cost of a primary study (Allen and Loomis 2008), and (6) the availability of a suitable body of evidence from which one can conduct a defensible benefit transfer (Rosenberger and Johnston 2009).

2.8.3 Define the Policy, Good and Population

Assuming that benefit transfer is required, the next step is to define relevant aspects of the policy in question, the good(s) to be valued, and the affected population whose values are desired. In some cases these are clear ex ante, but not always. For example, while potential policy actions are often known, the effects on valued goods may not always be clear. Hence, even before the considerations of economic values begins, it is often necessary to clarify the specific types of market or non-market goods that will be affected (i.e., what are the aspects of policy effects that will directly influence people's welfare, or for which they would likely be willing to pay). This may involve consultations with biophysical scientists, policy makers and stakeholders, an examination of available biophysical data to predict policy effects and a review of the economic literature to assess how similar policy outcomes were valued in other settings.

Once the policy outcomes and goods have been identified, the relevant population for benefit assessment must also be identified. Three issues are particularly relevant for defining the population for benefit transfer. The first question is whether there are any policy, institutional or legal constraints for the policy analysis that dictate the population to be considered (i.e., the political jurisdiction; whose benefits count?). For example, benefit-cost analysis for state government programs is often limited to state residents, regardless of whether residents in other states are affected. The second question is the extent of the relevant economic jurisdiction or market, or where values are nonzero regardless of the political jurisdiction. Unlike the political jurisdiction, determining the extent of the economic market in a benefit transfer study is often difficult, because this information may not be provided by primary valuation studies (Desvousges et al. 1998; Loomis and Rosenberger 2006). Loomis (2000) provides a detailed contrast between economic markets and political jurisdictions, and when each is likely to be relevant for analysis. Desvousges et al. (1998) also provide a useful discussion of the extent of the market for benefit transfer studies.

A third question is whether values are likely heterogeneous in any systematic way over the population that is relevant for policy analysis and benefit transfer. A common example would be spatial heterogeneity or distance decay in WTP (Bateman et al. 2006; Hanley et al. 2003; Johnston and Ramachandran 2014; Loomis and Rosenberger 2006; Chap. 18). Policy makers may also require welfare estimates for different subgroups within the overall population.

Note that these steps are similar to those within any benefit cost analysis or primary valuation exercise (Boardman et al. 2006; Champ et al. 2003). However, an additional consideration for benefit transfer is that the answers to these questions may help define the type of benefit transfer that is most appropriate. For example, spatial heterogeneity in WTP may require adjustments possible only through a benefit function transfer in which spatial variables are incorporated; unit value transfers are unlikely to provide accurate transfers in this case.

2.8.4 Define and Quantify Policy Options and Changes in Goods

Benefit transfer validity depends on a clear quantification of the marginal changes to be valued. Based on the characterization of the general policy and affected goods in the prior step, the next step in benefit transfer is to specify the specific policy options that will be evaluated and the exact quantities of goods (including baselines and marginal changes) for which values will be estimated. This may include changes in quantities, qualities or sometimes both. Often these quantities or qualities are not determined by the analyst but are provided by the policymaker ex ante. However, in other cases economic models from the literature may be used to help quantify the change in valued goods that might occur under various policy options.

Care must be taken to ensure that these quantities and qualities are associated with non-overlapping and final effects on utility, so that double counting is avoided (Boyd and Banzhaf 2007; Johnston and Russell 2011).

Some valuation contexts will require welfare estimates for only a single policy option and set of changes in relevant goods. Others will require evaluation of multiple policies and changes. A related aspect of benefit transfer is whether there is *uncertainty* in the policy outcomes which must be accounted for; for example using expected values or sensitivity analysis (Desvousges et al. 1998; Holland et al. 2010). In such cases, benefit transfer may require information both on the possible policy outcomes and the probability of these outcomes (i.e., a probability distribution). All of these factors must be determined before gathering data and implementing transfers.

2.8.5 Gather and Evaluate Valuation Data and Evidence

This is typically among the most time-consuming components of a benefit transfer; it includes a comprehensive review of available data and evidence on the outcome to be evaluated from the published and unpublished literature. Typically this includes a comprehensive literature review to first identify prior empirical studies that address the general type of policy effects and goods under study. The resulting set of studies is then screened carefully for quality, relevance and correspondence to the specific policies and changes to be predicted by the transfer. Correspondence is evaluated in terms of numerous factors, including the general policy context, exact goods or services being valued, scope and scale of the analysis, policy site attributes (e.g., physical site characteristics, location, population attributes, availability of substitutes and complements), and the time period of the analysis. Table 2.1 lists a set of general criteria that can be used to help evaluate the methodological quality of primary studies. Desvousges et al. (1998) provide additional discussion of this topic. Stanley et al. (2013) provide guidelines for the systematic reporting of such literature reviews; although designed for meta-analysis, similar guidelines can apply to any gathering of data for benefit transfer.

The analyst must also identify the type of values or other quantities that are estimated by each study. As noted above, total economic values (or WTP) for any type of outcome may be comprised of multiple components (e.g., market versus nonmarket values; use versus nonuse values; different types of nonmarket use values). Given these different types of benefits, no single valuation methodology can generally measure and distinguish all possible aspects of the value for most types of environmental changes.[12] Different methodologies may be used to evaluate values for similar outcomes, each designed to measure a different aspect of value (Champ et al. 2003; Freeman et al. 2014; Holland et al. 2010). Analysts must

[12]For a practical example, see Johnston et al. (2002).

Table 2.1 General criteria for evaluating the quality of primary studies for benefit transfer

1.	Detailed and transparent reporting of data and methods
2.	Detailed reporting of site and population characteristics
3.	Foundation in economic theory
4.	Quality of underlying biophysical data or modeling
5.	Restrictiveness and realism of assumptions
6.	Clear specification of goods and quantities/qualities
7.	Empirical methods and development (e.g., use of accepted valuation methods)
8.	Modeling detail (i.e., model includes all elements suggested by theory)
9.	Data collection methods
10.	Sample sizes and representativeness
11.	Statistical techniques and model specifications
12.	Evidence of selectivity bias
13.	Robustness of results
14.	Evidence of peer review or other recognized quality indicators

exercise caution when comparing or aggregating benefits generated by different valuation methods, because these values may not be theoretically equivalent, and may sometimes overlap. Those unfamiliar with the nuances of different types of values and valuation methods should consult an expert in economic valuation to assist in the collection and interpretation of valuation data and evidence. Additional discussion of benefit transfer data, including approaches to avoid selection biases, is provided in Sect. 2.6.

2.8.6 Determine Benefit Transfer Method(s)

Based on the information provided by the prior research stages, the analyst must then determine the benefit transfer methods that are most appropriate to policy needs and available data. The choice of transfer method is covered in Sect. 2.2.3.

2.8.7 Design and Implement Transfer(s)

Methods to design and implement the transfer will depend almost entirely on the transfer method(s) applied. General methods for unit value, benefit function, meta-analysis and structural benefit transfer are described in Sect. 2.2. Johnston and Rosenberger (2010) provide an extensive literature review of prior benefit transfer analyses that apply different types of approaches. Desvousges et al. (1998) and Rosenberger and Loomis (2003) give contrasting examples of different types of benefit transfer. Many examples are provided by later chapters in this book.

2.8.8 Aggregate Values over Populations, Areas, and Time

Once per unit values are estimated, they must often be aggregated over relevant populations, geographical areas and time periods. Although aggregation can be straightforward in some cases, it is also an area in which large and often overlooked errors can be introduced. In the simplest possible case in which marginal values are homogeneous (i.e., approximately identical across the population), or in which the benefit transfer provides an accurate estimate of mean value across the population, aggregation across populations can be as simple as multiplying a representative mean value per person by the size of the population. However, there are a large number of complications which can occur (e.g., the treatment of households versus adults versus children when aggregating benefits; whether the sample of the primary study is indeed representative), so that simple multiplication by population size is no longer appropriate. In general, these aggregation issues are similar to those encountered in any benefit-cost analysis, as described by Boardman et al. (2006). The discussion in Sect. 2.4, is also relevant to these aggregations.

Similar considerations and caveats apply to aggregation across geographical areas. However, here there is an important distinction between the aggregation of benefits over populations living in different areas versus scaling of benefits provided by environmental changes in different (or different-size) areas. For the former, similar rules for aggregation over any population apply, although the analyst should also correct for any systematic differences in values across populations living in different areas or distances from affected sites (Bateman et al. 2006; Johnston and Duke 2009; Johnston and Ramachandran 2014; Jørgensen et al. 2013; Martin-Ortega et al. 2012; Schaafsma et al. 2012). For the latter (scaling of benefits provided by changes in different areas), see the discussion in Sect. 2.4.

The aggregation or comparison of benefits over time requires *discounting*.[13] People will not typically pay one dollar today for the opportunity to obtain one dollar in the future; future benefits are worth less than an otherwise identical benefit received in the present. As a result, future benefits must be discounted in order to make them comparable to benefits today. Assuming that time is counted in discrete units and that discounting is calculated accordingly, a simple formula for the present value (PV) of a future payment of $\$X$—what that future payment is worth today—is given by:

$$PV = \frac{\$X}{(1+r)^t},$$

where r is the discount rate per time period in decimal notation (i.e., 5 % = 0.05) and t is the number of periods into the future when the payment will be received. Aggregating all discounted future benefits associated with a project over all time periods generates the *net present value* of benefits. An alternative method based on

[13]It can also require adjustments for systematic differences in values over time (cf. Brouwer 2006).

continuous (non-discrete) discounting calculates present value as $\$X(e^{-rt})$, where *e* is the exponential operator; results will be similar, but not identical, to the discrete discounting method above.

Although discounting is the standard means of aggregating benefits over time, it can lead to unintended consequences when assessing projects with very long time horizons. For example, if one uses common discount rates between 4 and 10 %, then benefits in the distant future (e.g., 50 to 100+ years) often have little impact on present value. For this reason, researchers have proposed a number of alternative discounting approaches for projects with long-duration effects. However, for most projects and policies where benefits are evaluated over a limited time horizon (e.g., 40 years or less), standard discounting procedures will likely generate the most accurate reflection of true social benefits and costs. Additional discussion of methods and complications associated with the aggregation of benefits over time is provided by Boardman et al. (2006) and Portney and Weyant (1999).

2.8.9 Conduct Sensitivity Analysis and Test Reliability (Where Possible)

The penultimate step in benefit transfer is sensitivity and reliability analysis. As is the case with any model, sensitivity analysis quantifies the sensitivity of results to changes in the modeling approach and uncertainty about key parameters or data, including different potentially influential assumptions and model specifications (Boardman et al. 2006; Desvousges et al. 1998; Holland et al. 2010). For example, one might aggregate benefits under a variety of different discount rates to evaluate the impact on present values. One might also estimate MRMs using different functional forms, using different subsets of the data, or using a different treatment of outliers (see Chap. 19 for a technical discussion of these steps applied to meta-analysis). Benefit transfer can also be conducted using a variety of fundamental approaches, for example, unit value versus single-site benefit function transfer, to evaluate effects on transfer estimates. Monte Carlo simulation analysis can provide a systematic way to evaluate the sensitivity of model results to uncertainty regarding key model parameters or data (Desvousges et al. 1998; Holland et al. 2010); an application to the impacts of methodological variables on benefit transfer is illustrated by Johnston et al. (2006a). Among other goals, sensitivity analysis can help the users of benefit transfer outputs to understand the confidence they can and should have in transfer results, based on the relative robustness of those results to methodological choices made by the analyst.

Where possible, it is also useful to provide information characterizing the potential reliability of benefit transfer results (or the accuracy). Because the true value is unknown, a variety of indirect methods must be used. As described in Sect. 2.7, convergent validity tests may be used to evaluate the performance of similar types of transfer in cases for which a primary study has been conducted, and hence transfer errors can be calculated. When an MRM is used, one can use leave-one-out, cross-validation convergent validity tests to characterize predictive performance (e.g., Brander et al. 2007; Stapler and Johnston 2009).[14] For additional discussion of this topic, see Sect. 2.7 and Chap. 14.

2.8.10 Report Results

The final step in a benefit transfer is the reporting of benefit transfer results. In general, this reporting follows the same guidelines applicable to any analysis of economic benefits. Given that the accuracy of benefit transfer depends critically on the procedures and data that are applied, transparent description of these factors is crucial to good reporting. Minimum features that should be reported in a benefit transfer include, but are not limited to: (1) a full description of the steps of the transfer; (2) the policy site, populations and goods; (3) reasons for assumed correspondence among the site, populations and goods within the study and policy contexts; (4) quantities or qualities for which values are estimated, including the specific units in which these are measured; (5) data sources used; (6) the specific type of value that is transferred, e.g., WTP, consumer surplus, etc.; (7) methods used to collect and screen data; (8) transfer methods; (9) statistical methods and assumptions; (10) any scaling that is conducted and implied assumptions; (11) final transferred unit and aggregated estimates of value or other outcomes; (12) results of any sensitivity analyses, robustness tests and accuracy evaluations. Additional reporting requirements may apply for particular types of analyses (for example meta-analysis, as described by Stanley et al. 2013).

2.9 Advanced Techniques

In addition to fundamental approaches, there are a number of advanced techniques that are used for benefit transfer. Most of these extend or supplement the approaches outlined above. Although this section does not provide a comprehensive list of advanced benefit transfer techniques that have been proposed, it highlights a few

[14] Assume that one has metadata with $n = 1 \ldots N$ unique observations. The first step is the omission of the nth observation from the metadata. The MRM is then estimated (using the original model specification) for the remaining $N - 1$ observations. This is iterated for each $n = 1 \ldots N$ observation, resulting in a vector of N unique parameter estimates, each corresponding to the omission of the nth observation. For each $n = 1 \ldots N$ model runs, the nth observation is an out-of-sample observation corresponding to the vector of parameter estimates resulting from that iteration. Parameter estimates for the nth model iteration are then combined with independent variable values for the nth observation to generate a WTP forecast for the omitted observation. The result is N out-of-sample WTP forecasts, each drawn from a unique MRM estimation. Transfer error is assessed through comparisons of the predicted and actual WTP value for each of the N observations.

principal areas in which substantial work has been conducted. Examples include Bayesian model search, updating and averaging that may be used for such purposes as addressing the possible sensitivity of transfer results to model specification, incorporating prior information and expectations, enabling estimation of MRMs with small samples, and evaluating the commensurability of different types of data (Johnston and Moeltner 2014; León et al. 2002; Leon-Gonzalez and Scarpa 2008; Moeltner and Rosenberger 2008, 2012; Moeltner et al. 2007). There has been significant work on the use of advanced choice modeling techniques for benefit transfer (Johnston and Rosenberger 2010; Morrison and Bergland 2006; Rolfe and Bennett 2006); this is discussed in detail in Chaps. 10 and 11. Researchers have proposed a variety of approaches to extend, improve and advance classical statistical methods for meta-analysis (Nelson and Kennedy 2009; see also see Chaps. 15, 16 and 17), including approaches to avoid selection biases (Rosenberger and Johnston 2009). Methods have also been proposed to improve validity and reliability testing in benefit transfer (Johnston and Duke 2008; Kristofersson and Navrud 2005; Muthke and Holm-Mueller 2004), and particularly for meta-analysis (Kaul et al. 2013); such methods are discussed in Chap. 14. Finally, there has been work to extend the spatial and geographical aspects of benefit transfer (Bateman et al. 2006; Johnston and Duke 2009; Martin-Ortega et al. 2012); these are discussed in Chap. 18.

Although these and other advanced methods can often improve benefit transfer accuracy and robustness, users are cautioned that greater complexity or flexibility does not always imply improved performance (cf. Bateman et al. 2011; Johnston and Duke 2010; Rosenberger and Stanley 2006). As noted by Navrud and Ready (2007b, p. 288), "[s]imple approaches should not be cast aside until we are confident that more complex approaches do perform better."

2.10 Conclusion

Benefit transfer is one of the most commonly used, but also easily misused components of benefit-cost analysis. Despite the common presumption that benefit transfer is a simple and easy approach to valuation, accurate benefit transfer requires significant attention to methods and data. Fortunately, many determining factors of transfer accuracy are within direct control of the analyst, and the benefit transfer literature now provides guidance on these factors. This chapter is an attempt to describe some of the most important of these, and provide at least basic guidance on methods recommended by the benefit transfer literature. Given the dependence of transfer accuracy on the many choices made by the analyst, perhaps the most important aspect of any benefit transfer is transparency, including the provision of detailed information on the data used, methods applied, and assumptions made. Clear reporting can help ensure that users are aware of both the strengths and limitations of the underlying methods and data, as well as interpretations of the resulting benefit estimates. Conversely, benefit transfers for which the methods and data are not clearly stated should be treated with caution.

Although benefit transfers generally require less time and resources than comparable primary studies, they do not necessarily require less expertise—methods such as meta-analysis and structural benefit transfer, for example, can require a level of expertise that parallels or even exceeds that required to conduct primary valuation research. Even simpler methods such as single-site benefit function transfer and unit value transfers require considerable expertise to evaluate such influential factors as the choice of transfer method, site and commodity correspondence, the suitability of functions or values for transfer, the quality and interpretation of primary studies, the aggregation of benefit estimates, and many others. Although the chapters in this book provide considerable information on theory, methods and data, new producers or consumers of benefit transfer are urged to seek the assistance of those with relevant expertise.[15] Doing so can help ensure that transfer errors are minimized and that the resulting estimates reflect the best possible use of existing information.

As noted by Loomis and Rosenberger (2006, p. 349), "the pace and widespread activity in non-market valuation makes the future of benefit transfer promising. There will continue to be more and better empirical studies to base our benefit transfers on in the future." The availability of an increasing body of high-quality primary studies, however, does not guarantee the accuracy of benefit transfer. At the same time that the body of valuation literature is increasing, the body of benefit transfers—of both high and low quality—is also increasing. Only through careful attention to (improved) benefit transfer methods will researchers be able to optimally leverage this body of work to provide the most accurate and useful policy guidance.

Appendix

Illustration of Unit Value and Benefit Function Transfer

To illustrate the mechanics of a very simple benefit transfer, consider the following stylized example. Assume that a published study reports the results of a simple, linear travel cost model predicting the number of visits to a local wildlife refuge

[15]There is also an increasing array of national and international agency publications in the U.S., EU and elsewhere that provides guidance for benefit transfer (e.g., Commonwealth of Australia 2002; Pearce et al. 2006; UK Environment Agency 2004; U.S. Environmental Protection Agency 2007, 2009).

Table 2.2 Stylized travel cost recreation demand model results

Ordinary least squares parameter estimates (dependent variable: TRIPS)		
Variable	Parameter estimate	Prob > T
INTERCEPT	5.5000	0.0256
TRAVCOST	−0.5000	0.0001
INCOME	0.0001	0.0996
VIEWINGS	0.5000	0.0021
SUBCOST	0.0500	0.0852
N (number of observations)	116	
R^2	0.67	

Variable definitions	
TRIPS	Number of trips per season, to the refuge, by each individual in the sample
TRAVCOST	Cost of travel to the site, including the opportunity cost of time, for each visitor
INCOME	Annual income of each individual
VIEWINGS	Expected viewings of rare bird species, per average visit
SUBCOST	Cost of traveling to the nearest substitute wildlife refuge

Mean values for model variables	
Variable	Average value
TRIPS	4.5 trips per season
TRAVCOST	$10 per visit
INCOME	$20,000 per person
VIEWINGS	3.0 per trip
SUBCOST	$10 per visit

(Site A), with statistical model results reported in Table 2.2 (assume a simple ordinary least squares model).[16]

Assume that there is a *nearby wildlife refuge* (Site B) that is similar to Site A. However, the average number of rare bird viewings at Site B is higher than those at Site A. Assume that average viewings at Site B are 6.0 per visit. Assume also that the analyst wishes to use benefit transfer to estimate consumer surplus at Site B (the policy site), based on the study published from data at Site A (the study site).

[16]Note that this is a very simple model used for basic illustration purposes only. Linear OLS models such as this are rarely suitable for applied recreation demand modeling. Most recreation demand research applies more sophisticated approaches such as count data or random utility models (Bockstael and McConnell 2010; Haab and McConnell 2002). For an applied example see Rosenberger and Loomis (2003).

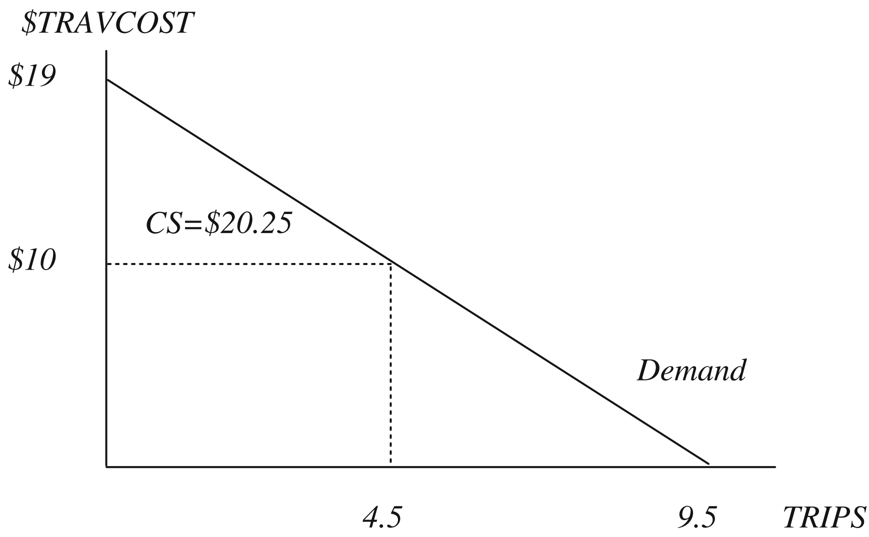

Fig. 2.3 Illustrative travel cost demand function and consumer surplus (CS)

To conduct our benefit transfer, we first use data at Site A to calculate the original study site demand curve and mean per visitor consumer surplus (CS).

$$\begin{aligned} TRIPS &= 5.5 - 0.5(TRAVCOST) + 0.0001(INCOME) \\ &\quad + 0.5(VIEWINGS) + 0.05(SUBCOST) \\ TRIPS &= 5.5 - 0.5(TRAVCOST) + 0.0001(20{,}000) \\ &\quad + 0.5(3) + 0.05(10) \\ TRIPS &= 9.5 - 0.5(TRAVCOST) \end{aligned}$$

The result is shown in Fig. 2.3, which illustrates the travel cost demand curve and associated consumer surplus. Here, the consumer surplus estimate of $20.25 reflects the access value of Site A, or the total value that each visitor receives from all visits to Site A, each year. Following standard practice, this is estimated as the area above the average travel cost ($10 per trip) and below the estimated travel cost demand curve.

To conduct a unit value transfer of this estimate to Site B, one would simply assume that the same consumer surplus estimate applies to both sites, so that the annual per visitor consumer surplus at Site B would be approximated as $20.25. This unit value estimate does not account for the difference in rare bird *VIEWINGS* between Site A and B.

To conduct a simple benefit function transfer of this estimate to Site B, one would estimate a new demand function using the updated information on *VIEWINGS* from Site B.

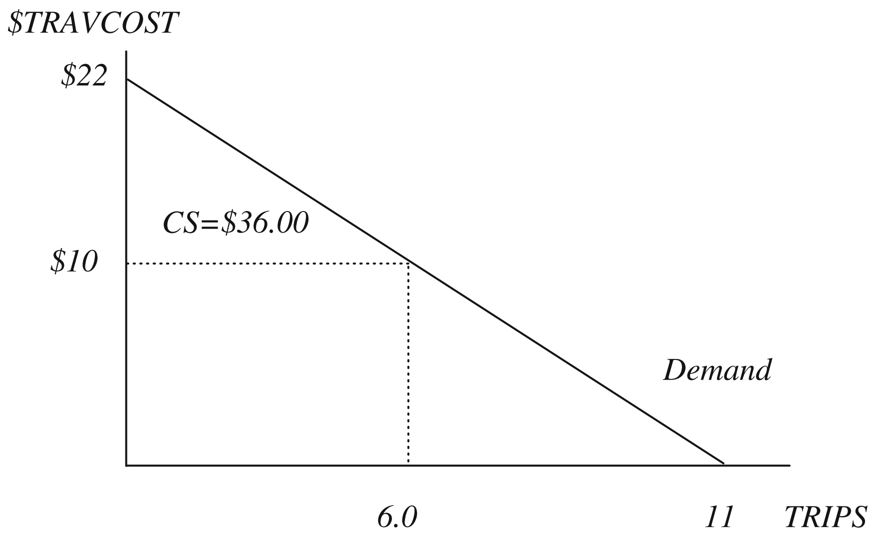

Fig. 2.4 Benefit function transfer of travel cost model results

$$\begin{aligned} TRIPS &= 5.5 - 0.5(TRAVCOST) + 0.0001(INCOME) \\ &\quad + 0.5(VIEWINGS) + 0.05(SUBCOST) \\ TRIPS &= 5.5 - 0.5(TRAVCOST) + 0.0001(20{,}000) \\ &\quad + 0.5(6) + 0.05(10) \\ TRIPS &= 11.0 - 0.5(TRAVCOST) \end{aligned}$$

Given this updated demand curve (Fig. 2.4), the benefit function transfer estimate of consumer surplus for Site B visitors is $36.00 per year. The consumer surplus difference ($36.00 vs. $20.25) reflects ability of benefit function transfer to calibrate for the difference between *VIEWINGS* at the two sites, and hence predict a higher access value for Site B, all else equal. Although more sophisticated models (cf. Haab and McConnell 2002) may require more complex calculations to implement unit value or benefit function transfers, the general process is similar.

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