Guidance to Enhance the Validity and Credibility of Environmental Benefit Transfers

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Abstract

Benefit transfer is the use of pre-existing empirical estimates from one or more settings where research has been conducted previously to predict measures of economic value or related information for other settings. These transfers offer a feasible means to provide information on economic values when time, funding and other constraints impede the use of original valuation studies. The methods used for applied benefit transfers vary widely, however, and it is not always clear why certain procedures were applied or whether alternatives might have led to more credible estimates. Motivated by the importance of benefit transfers for decision-making and the lack of consensus guidance for applied practice, this article provides recommendations for the conduct of valid and reliable transfers, based on the insight from the combined body of benefit transfer research. The primary objectives are to: (a) advance and inform benefit-transfer applications that inform decision making, (b) encourage consensus over key dimensions of best practice for these applications, and (c) focus future research on areas requiring further advances. In doing so, we acknowledge the healthy tension that can exist between best practice as led by the academic literature and practical constraints of real-world applications.

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1 Introduction

To make quantitative statements about the likely effects of public policies, economists must extrapolate findings from previous empirical studies to new policy scenarios (US EPA).[1]

Benefit transfer is the use of pre-existing empirical estimates from one or more settings where research has been conducted previously to predict measures of economic value or related information for other settings. The primary feature that distinguishes benefit transfer from other types of economic valuation is that values are quantified by using "existing data or information in settings other than for what it was originally collected" (Rosenberger and Loomis 2003, p. 445). Benefit transfers offer a feasible means to provide information on economic values to support decision-making when time, funding and other practical constraints impede the use of original valuation studies. Due to considerations such as these, benefit transfers have become a ubiquitous component of benefit–cost analyses in the United States, European Union and elsewhere (Griffiths and Wheeler 2005; Iovanna and Griffiths 2006; Johnston and Rosenberger 2010; Brouwer and Navrud 2015; Loomis 2015; Rolfe et al. 2015a; Johnston et al. 2015b, 2018; Wheeler 2015; Newbold et al. 2018a).

Among the primary goals of benefit transfers is the provision of credible value estimates to inform decisions. The methods used for applied transfers vary widely, however, and it is not always clear why certain transfer procedures were applied or whether alternatives might have led to more credible estimates.[2] More than ten years ago, Boyle et al. (2010, p. 162) argued that "even a cursory review of the benefit transfer literature displays a wide variety of implementation procedures, with no consensus on which procedure actually results in the lowest transfer error […]." This comment reflects similar observations found elsewhere in the benefit-transfer literature (Wilson and Hoehn 2006; Johnston and Rosenberger 2010; Johnston et al. 2018).

Recognizing the importance of benefit transfers as an input to decision making worldwide, there have been longstanding efforts to address this ambiguity over best practices. Research since the late 1980s has provided insights into applicable theory and methods.[3] The first widely recognized, collaborative effort to inform benefit-transfer methods was a 1992 US EPA sponsored workshop.[4] These and other efforts have contributed to multiple areas of implicit methodological consensus, summarized in works such as Brouwer (2000), Boyle et al. (2010), Johnston and Rosenberger (2010), Richardson et al. (2015), and Johnston et al. (2018). Yet despite a growing literature, there are still no established expectations for most benefit transfer procedures in applied use. The peer-reviewed literature emphasizes novel contributions to theory, methodology, and empirical results, while remaining agnostic on many practical questions facing benefit-transfer practitioners. This

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[1] https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=340067, accessed April 8, 2020. Also see discussion by Newbold et al. (2018a).

[2] For example, recent benefit transfers applied by the U.S. EPA to support regulatory impact analyses have used procedures ranging from scaled unit-value transfers (e.g., U.S. EPA 2011) to benefit-function transfers from meta-analysis (e.g., U.S. EPA 2010, 2012, 2015), with "surprisingly little discussion of the academic literature on benefit transfer" (Wheeler 2015, p. 111). Review of benefit transfer applications by other governmental and intergovernmental organizations reveals similar heterogeneity and opacity on why certain methods were applied.

[3] The term "benefit(s) transfer" did not become common until the 1990s.

[4] See Water Resources Research, Vol. 28, No. 3, 1992.

divide between the academic literature and practitioner needs has impeded the development of consensus protocols.[5]

The resulting lack of guidance and consistency in applied practice threatens to undermine the scientific credibility of benefit transfers used to support decision-making. It can also prevent transfers from being used in situations where they might otherwise provide useful information. For example, the absence of consensus best-practice guidance can lead to situations wherein decision makers choose to ignore or suppress potential information from benefit transfers or, conversely, those seeking to discredit value estimates impose ad hoc or unattainable methodological requirements in the name of "validity" without a strong scientific basis (Boyle et al. 2017). In such cases, guidance can both support the use of benefit transfers and establish minimum standards to frame validity and applicability debates.

Motivated by the importance of benefit transfers for decision-making and the lack of consensus guidance for applied practice, this article provides recommendations for the conduct of valid and reliable transfers, based on insights from the combined body of research. The primary objectives are to: (a) advance and inform benefit-transfer applications that support decision making, (b) encourage consensus over key dimensions of best practice for these applications, and (c) focus future research on areas requiring further advances. In doing so, we acknowledge the healthy tension that can exist between best practice as led by the academic literature and practical constraints of real-world applications.

We also recognize that benefit transfer is an evolving method. Although there are some areas in which the literature supports unequivocal guidance for best practices, there are others in which methodological questions remain. For example, there is consensus over the need for unambiguous definitions of the commodity change and theoretical welfare measure that characterize the value to be estimated at the policy site. However, there is less consensus over the degree of similarity that should be required between these clearly defined policy-site concepts and information available from study-sites. How similar is "similar enough"? Further, variation across multiple study sites may enable the sites to collectively characterize policy-site conditions, potentially reducing the need for individual site-to-site similarity across all dimensions. Recognizing that questions of this type persist in the literature and that important tradeoffs exist, we identify areas where the literature does not yet support clear guidance and for which additional research is needed. In areas such as these, it is particularly important for practitioners to document their assumptions and consider the robustness of presented results.

We organize the proposed guidance around ten core recommendations. These recommendations are summarized here and expanded upon in the sections that follow.

1. *Value Definition and Valuation Context*: The economic value to be estimated should be defined clearly in the context of the policy-site decision context and information needs.
2. *Theoretical Foundation*: The welfare-theoretic foundations for the benefit transfer should be described, focusing on the definition and properties of the change to be valued.

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[5] For additional discussion of the divergences between academic research and practitioner needs, see McComb et al. (2006), Loomis and Rosenberger (2006), Boyle et al. (2010), Johnston and Rosenberger (2010), Johnston et al. (2015c), Richardson et al. (2015), Rosenberger and Loomis (2017), and Johnston et al. (2018).

3. *Selection of Study Sites and Study-site Value Information*: The search for information to support the benefit transfer, including study sites and value information, should be conducted in a comprehensive and systematic manner that reflects that underlying value definition and valuation context, along with the information available from each study and site.

4. *Selection of a Transfer Method*: The transfer method should be selected based on: (a) data availability, (b) steps required to harmonize study-site estimates with policy-site conditions, (c) insight from the literature regarding the accuracy of transfer methods under different circumstances, and (d) the intended uses of the resulting information.

5. *Data Adjustments*: Study-site data adjustments should be completed to harmonize information across studies and enable well-defined value estimates for policy sites. These adjustments should be consistent with the value definition, valuation context, theoretical foundation for the transfer, and available study- and policy-site information.

6. *Auxiliary Data*: Auxiliary data that are not provided in study-site documentation and that can enhance transfer accuracy should be used when available.

7. *Data Analyses*: Transfer methods should adhere to recommended practices for the underlying analytical methods that are applied. These include the use of established theoretical and empirical methods for all types of transfers and best practices for the estimation and use of meta-analysis.

8. *Aggregation and Scaling*: The extrapolation and aggregation of transfer-value estimates to the policy-site population should follow best practices established for welfare and benefit–cost analyses. Any benefit scaling should be justified with respect to the type of commodity and change in question, within the context of policy-site conditions.

9. *Robustness Analyses*: Robustness analyses should explore the sensitivity of policy-site value estimates to decisions such as those associated with the selection of studies and value estimates, the transfer procedures that are applied, and assumptions about the extent of the market.

10. *Reporting*: Reporting should document all key components of the transfer exercise. This should include reporting on key study- and policy-site characteristics, data used in the transfer, transfer procedures, analyst assumptions and resulting value predictions.

The paper proceeds with an initial overview of the benefit-transfer literature as a foundation for the discussion of each recommendation. We also briefly review benefit-transfer validity and reliability as core concepts motivating the presented guidance. Although we present the subsequent recommendations in a linear fashion, we acknowledge that the steps in a benefit transfer are interrelated and that what is learned as one proceeds through the transfer process may require review and revision of what has been done on previous steps. Hence, the recommendations for different components in the transfer process are intertwined.

2 Setting the Context for Best Practices

Benefit-transfer methods have been recognized since the 1980s and refined since the 1992 US EPA workshop. Transfers may occur over time, space, populations, policies or other dimensions. The key feature that distinguishes benefit transfers from other types of valuation is that prior study results are used to develop a value estimate for a setting that is different from the setting originally considered. For conciseness in terminology, the source-data

settings are typically called "study sites" and the receiving estimates, "policy sites".[6] The primary goal of a benefit transfer is the provision of value estimates for changes in the quantity or quality of a good or service that is expected to arise from an action being evaluated. The credibility of transfer estimates, considered in terms of validity and reliability (Bishop and Boyle 2019), is determined by the procedures used to implement the transfer.[7]

The transfer of value information to estimate benefits and costs is common across governmental, intergovernmental, and non-governmental organizations.[8] These practices took place long before "benefit transfer" was recognized as a field of study. Inspired by seminal work such as Freeman (1984), benefit transfer became recognized as a distinct area of research and application in the early 1990s. The 1992 Association of Environmental and Resource Economics and US EPA workshop and a subsequent special section of *Water Resources Research* (1992, 28(3)) are credited with launching contemporary research in the area.

Evolution of the literature over the following two decades led to the formalization of benefit transfer as a tool for benefit–cost analyses within US EPA (2000)[9] and other US government agencies (Loomis 2015; Wheeler 2015), with similar acknowledgement in Canada (Treasury Board of Canada Secretariat 2007). The approval of the European Water Framework Directive in 2000 promoted greater use of benefit transfers in Europe (Hanley et al. 2006; Brouwer and Navrud 2015; Rosenberger and Loomis 2017).[10] The potential use of benefit transfers in Australia was motivated by the demand for value estimates within Regulatory Impact Statements and in New Zealand by the demand for similar information within Regulatory Impact Analyses (Rolfe et al. 2015a).

In 2005 the US EPA and Environment Canada sponsored a benefit-transfer workshop and special issue in *Ecological Economics* (2006, 60(2)). Subsequent reviews were provided by Boyle et al. (2010) and Johnston and Rosenberger (2010). Frequently cited books on benefit-transfer methods during this period included Desvousges et al. (1998), Florax et al. (2002), Rolfe and Bennett (2006), Navrud and Ready (2007), and later Johnston et al. (2015a). A recent collective contribution was the 2016 US EPA workshop, *Benefit Transfer: Evaluating How Close is Close Enough?* (Smith 2018), with an accompanying special issue of *Environmental and Resource Economics* (2018, 69 (3)). Among the topics emphasized within this special issue were challenges faced by practitioners seeking to apply benefit transfer within the context of applied policy analysis (Newbold et al. 2018a), the extent to which structural modeling could be used to improve transfer validity and reliability (Kling and Phaneuf 2018; Newbold et al. 2018b), and the econometrics of meta-analytic transfers (Boyle and Wooldridge 2018).[11]

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[6] This terminology is used as shorthand only; the target for a benefit transfer need not be a new, unstudied (geospatial) site; it may be a new policy question at a site where a study has already been conducted.

[7] Within the benefit transfer literature, a transfer is typically considered *valid* if it provides a statistically unbiased estimate of the true value at the policy site. *Reliable* transfers, in contrast, are associated with lower transfer errors or variances (Bishop and Boyle 2019; Rosenberger 2015). Both are elements of the accuracy of transfer estimates.

[8] See Boyle et al. (2010), Brouwer and Navrud (2015), Griffiths et al. (2012), Griffiths and Wheeler (2005), Iovanna and Griffiths (2006), Johnston et al. (2015a, 2018), Johnston and Rosenberger (2010), Loomis (2015), Rolfe et al. (2015a), Wheeler (2015) and Newbold et al. (2018a).

[9] Updated guidance in US EPA (2014) includes similar acknowledgement of benefit transfer.

[10] See https://ec.europa.eu/environment/water/water-framework/index_en.html, accessed April 12, 2020.

[11] Other papers in the issue included Blow and Blundell (2018), Kuminoff (2018), McConnell and Siikamaki (2018), Smith (2018), and Turner (2018).

These efforts reflect the expanding literature on benefit transfer. Insights from this work are diverse and scattered across hundreds of articles, chapters, and monographs. Although multiple publications going back to the 1980s have sought to present instructions for benefit transfer, these have been limited to such contributions as primers on basic methods, core theoretical conditions for validity, ideal criteria for benefit transfers, and general insights such as the relevance of site similarity.[12] Although this information is suitable for the introduction of theory, principles and techniques, it falls short of the practical, consensus recommendations required to guide analysts and inform decision makers on the elements of a credible transfer.

2.1 Methodological Overview

Although many different types of information can be transferred, benefit transfers are most often discussed in terms of welfare estimates such as measures of willingness to pay (WTP). As discussed by Boyle et al. (2010), the transfer of pre-existing information to new situations is common across multiple disciplines, and benefit transfer is not the only situation in which monetary quantities are transferred.[13] Yet there is a difference between benefit transfers and other types of data transfers in heath, engineering and some other areas of economics. Other data transfers are often grounded in observable phenomena, such as death rates in human populations, structural integrity of buildings, and housing sales prices. With such data, observations can be used to establish the accuracy of the transfers.[14] Transfers of welfare estimates, like many types of economic data (e.g., demand and supply elasticities), do not share this observability condition to establish accuracy (Bishop and Boyle 2019). Applications typically involve the transfer of measures for a well-defined theoretical concept, like WTP, that is *never* observed. Like many other concepts in the social sciences, they are estimated via statistical inference from associated observational data such as choices in a market or responses to a survey.

The provision of environmental goods and services outside of organized markets compounds the challenge for environmental benefit transfers (Boyle et al. 2010). Because market transactions are not observable for many environmental goods and services, the most

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[12] For example, see Freeman (1984), Boyle and Bergstrom (1992), Brouwer (2000), Boyle et al. (2009, 2010), Bateman et al. (2011a), Johnston et al. (2015b), Richardson et al. (2015), and Rosenberger and Loomis (2003, 2017).

[13] For example, Hines (1999) notes that "… to quantify the economic costs of (taxes, regulations, externalities, monopolistic practices, etc.) … it is standard practice … to use a small number of assumptions and selected elasticities to estimate areas of the relevant 'Harberger triangles'" (p. 167). Other economic data transfers include replacement cost (De Groot, Wilson and Boumans, 2002) and resource (habitat) equivalency (Flores and Thacher, 2002). Multiple types of economic information transfers are used within national accounting efforts such as the UK Office for National Statistics extended GDP Household Satellite Account, which accounts for the contribution of unpaid household production activity (https://www.ons.gov.uk/economy/nationalaccounts/satelliteaccounts, accessed March 31, 2021). Beyond economics, engineers use "steam tables" to predict pressure and flow in power facilities, "weight-load" tables to predict weight holding capacity of floors and roofs, and the U.S. government publishes an actuarial table of the "probability of death." Other examples include dose–response functions used by physical scientists to identify the health effects of changes in environmental quality (see Spash and Vatn 2006).

[14] For example, a real estate appraisal is a type of economic transfer that has two important differences from the transfer of a typical neoclassical welfare estimate (such as consumer surplus). First, the appraisal is grounded in actual observed sales, not estimated sales prices. Second, the appraisal estimate can be validated by a subsequent sale of the subject property.

appropriate ways to characterize and measure these goods and services for valuation are not always clear (Boyd et al. 2016). Moreover, the ways that environmental changes are measured at a study site may not be equally relevant for the policy site. The resulting diversity in measurement protocols can cause errors and ambiguities within benefit transfers (Johnston and Zawojska 2020).

Challenges such as these have led to the characterization of benefit transfer as one of the most difficult types of information transfer (Boyle et al. 2010). However, this does not imply a lack of mechanisms to evaluate validity and reliability (and hence credibility). Welfare estimates that are the foundational building blocks for any benefit transfer are based on the same economic theory that informs all welfare analysis. Theory informs the logic process through which study-site values are estimated and then transferred to a policy site (Smith 2018). This same logic process provides the foundation for benefit-transfer guidance and evaluations.

Regardless of approach, all benefit transfers construct a policy-site value estimate using information from one or more study-site value estimates. The initial steps in a transfer include identification of: (a) the change in the quantity or quality of the good or service to be valued, (b) the population or market for whom values are to be estimated, (c) the policy or decision the transfer estimate will support, and (d) the type of value information required to support decision making. These considerations, framed in the context of the desired theoretical welfare estimate for the policy site, inform the search for policy-site studies and the choice of value information from these studies, as well as the decision to seek and use related auxiliary data. Available study-site information plays a critical role in determining whether alternative transfer methods can provide credible policy-site value estimates. Another crucial factor is the similarity between study and policy sites, broadly defined, which influences the degree to which (and what type of) adjustments may be required to calibrate study-site information to policy-site conditions.

The key differences among alternative transfer methods are the information used from the study-site and the procedures used to develop and calibrate policy-site value estimates. Methods can be broadly classified into two groups: *value transfers* and *function transfers*.[15] Value transfers use a single value estimate or a set of value estimates from existing studies to compute a policy-site value estimate. These are also called "unit-value transfers." Values can be transferred as a single study-site value or a summary statistic (e.g., mean) of several study-site values. The resulting estimates can be transferred "as is" or can be adjusted in various ways to calibrate transfer estimates to policy-site conditions.

Function transfers produce calibrated policy-site value estimates using information provided by available studies at one or more study sites, where study information is used to develop a function that produces these estimates (Loomis 1992). The information drawn from each study is not limited to a single value or set of values but includes additional information needed to construct a benefit function. Multiple approaches may be used to produce these functions. For example, transfers may rely on benefit functions estimated directly for one or more study sites using recreation-demand models, hedonic-price (or wage) models, defensive-behavior methods, stated-preference models, various types of ecological production/productivity methods, or other techniques (Freeman et al. 2014; Champ et al. 2017). Transfers of

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[15] Another alternative is expert elicitation such as Delphi approaches. While these approaches have not been extensively investigated and are not directly based on affected peoples' preferences, some recent studies suggest potential for benefit transfers applied to global public goods (Strand et al. 2017, Navrud and Strand 2018, Dugstad and Navrud 2019, Siikamaki et al. 2019).

this type are often called single-site or single-study benefit function transfer, as they rely on functions estimated previously for individual sites or studies in the literature. Despite this nomenclature, these functions may be estimated using primary data taken from multiple sites, with the function specified to include spatially explicit explanatory variables that characterize conditions at each site (e.g., Parsons and Kealy 1994; Fezzi and Bateman 2011; Bateman et al. 2013).

In addition, benefit functions may be derived from meta-equations that statistically synthesize value information from multiple prior valuation studies, typically using meta-regression analysis (Bergstrom and Taylor 2006; Nelson and Kennedy 2009; Boyle and Wooldridge 2018). These are commonly referred to as meta-functions and are an increasing source of benefit functions in the literature (Johnston et al. 2018). As a final example, benefit functions may be developed via structural models that use data from multiple prior valuation studies to calibrate preference parameters (Smith et al. 2002, 2006; Smith and Pattanayak 2002; Van Houtven et al. 2011; Phaneuf and Van Houtven 2015).

Function transfers have an advantage over value transfers, in that they can allow systematic adjustment of study-site value information to calibrate transfer estimates to policy-site conditions (Loomis 1992). These adjustments may also have greater credibility because they rely on functions derived from information in the original studies. In contrast, adjustments within value transfers do not typically rely on information present in source studies, and frequently reflect post hoc calibrations (e.g., adjustments to account for income differences, grounded in assumed income elasticities of demand; Czajkowski and Ščasný 2010; Barbier et al. 2017).

A meta-function has a potential advantage over original-study functions in that the synthesis of information from multiple studies allows calibration for factors that are fixed for an individual study but vary across studies. For example, this can provide the capacity to identify and control for systematic influences of primary-study valuation methods on welfare, or characteristics such as baseline environmental conditions that may not vary within the context of an individual primary study. Preference calibration, in turn, ensures that value predictions are consistent with economic theory in the context of policy-site conditions. Both meta-functions and preference calibration allow information from multiple study sites to *collectively* reflect policy-site conditions, whereas it is typically assumed that value transfers require closer alignment between one or few study sites and the policy site.

All types of transfer enable information from primary studies to be supplemented with auxiliary information. Common examples include the use of information from consumer price indexes to convert monetary quantities to a common base year and the use of government census data to obtain data on household incomes. For example, Hammitt and Robinson (2011) discuss the use of exogenous information to account for differences in income or currency value across sites. Others have discussed or illustrated the use of GIS data to provide spatial information to support benefit transfers, such as data on land cover and land use, baseline environmental conditions, or geospatial information such as distances between households and environmental changes (e.g., Bateman and Lovett 1998; Bateman et al. 2006, 2011a, 2011b, 2013; Martin-Ortega et al. 2012; Perino et al. 2014; Schaafsma 2015; Johnston et al. 2017a, 2019). Data supplementation of this type is common for meta-function transfers but may be encountered across the spectrum of transfer approaches.

2.2 Validity and Reliability

The recommendations that follow are intended to promote accuracy within benefit transfer, framed in terms of validity and reliability. As introduced above, validity reflects the

unbiasedness of an estimate, whereas reliability reflects the variance (Bishop and Boyle 2019). Both measures are related to the errors in benefit-transfer value predictions. These errors are commonly discussed within two broad categories (Rosenberger and Stanley 2006). Errors in benefit transfers that arise due to underlying errors in the original study-site value information are often called measurement errors. Errors that arise due to the transfer of information between study- and policy-sites are often called generalization errors.

Measurement errors occur in original study-site value estimates and it may not be possible to control or offset such errors in the transfer process. All empirical values are estimated with at least random error and, by definition, are random variables. There may also be systematic errors if, for example, a biased econometric estimator was used to produce the original study-site value estimates. If we assume an unbiased estimator (i.e., a valid original estimate), then the primary concern is related to the associated variance (i.e., the reliability). If the original estimate is known or assumed to be biased, implications for the transfer prediction can be difficult to determine, because the direction and magnitude of the bias are almost always unknown.[16]

Generalization errors are artifacts of the transfer process. These errors can arise if study-site information is not well aligned with the policy-site value to be estimated and calibrations during the transfer are not sufficient to offset this lack of alignment. They can also be introduced by any step of the transfer process. For example, a generalization error might occur due to the selection of study sites or study-site information or extrapolation of value predictions to the affected population.[17] Potential errors arising from the transfer process, like errors discussed with respect to study-site values in the previous paragraph, may or may not be measurable.

Although a general point has been made that benefit transfers can only be as accurate as the original underlying benefit estimates (Brookshire and Neill 1992; Wilson and Hoehn 2006), the relationship between the original accuracy of study-site value estimates and the accuracy of benefit transfers is neither monotonic nor straightforward. Measurement and generalization errors can interact or offset in complex ways that depend in part on the transfer methods that are applied. For example, in a value transfer the study-site estimate might have upward bias that is partially or fully offset, or perhaps overcompensated due to adjustments or generalization errors that occur when transferring that value between sites.[18] These are complicated issues. Hence, the accuracy of any benefit-transfer must be considered within a holistic framework that addresses how well the transfer estimate approximates the theoretical study-site value.

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[16] Even if the direction of the bias is suspected the magnitude of bias can rarely be determined.

[17] For example, the study-site population may be from a high-income majority group and the policy-site population is a low-income minority group, and the analyst may not be able to control for these differences in the transfer process. Alternatively, a meta-function might be specified as a linear function while the true underlying value relationship is nonlinear. A preference calibration transfer might assume a utility function that does not match policy-site population preferences. As a final example, values may differ between study and policy sites due to factors that are unobservable to the analyst, and hence remain uncorrected within the transfer.

[18] As another example, some study sites used to estimate a meta-equation might provide estimates with upward biases while others provide estimates with downward biases. In such cases, the meta-equation coefficients could lead to a policy-site value estimate that is an overestimate or underestimate, with a bias that is likely not as large as the over- and under-estimation that occurs in some study-site estimates.

When considering issues such as these, a challenge is that one cannot establish the accuracy of welfare estimates via direct comparisons with observable data. Welfare measures cannot be observed directly. Hence, the guidance proposed below is grounded in the three-Cs framework (content, construct and criterion validity) for evaluating the accuracy of nonmarket values (Bishop and Boyle 2019). *Content validity* considers the procedures used to implement the transfer, evaluated based on theory, estimation procedures and findings from prior research such as we describe below.[19] *Construct validity* evaluations use insights from empirical tests to identify procedures and conditions that minimize bias and reduce variance in estimates. Most evaluations of this type for benefit transfers have taken the form of *convergent validity* tests that compare welfare estimates from benefit transfers and primary studies or those from two or more benefit-transfer procedures, when used to measure the same policy-site value. There have been numerous contributions to this area of the literature. *Criterion validity* involves tests that compare benefit-transfer value estimates to measures that have presumed truth. We are not aware of any criterion validity tests applied in the context of benefit transfers.[20]

It is important to keep in mind that no single paper or study can establish or refute the accuracy of an empirical method in general, and that the literature may contain conflicting opinions and outcomes. The empirical results of an economic study typically reflect "hundreds of decisions [on] data collection, preparation, and analysis", which may lead to variation in the reported conclusions (Huntington-Klein et al. 2021, p. 944). Moreover, all validity tests have limitations.[21] Thus, in preparing this guidance we take a weight of evidence approach to support recommendations that promote the content validity of practical benefit transfers, supported in part by evaluations of content and construct validity in the benefit transfer literature.

3 Guidance for Benefit-Transfer Practice

The guidance proposed below is designed to assist analysts in the design and conduct of benefit transfers that satisfy conditions of content validity. This guidance is motived by factors such as theoretical constructs of consumer demand theory that guide the estimation of welfare values, together with insights from the peer-reviewed literature that investigates benefit-transfer validity and reliability. These recommendations are meant for benefit

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[19] Although we frame the subsequent discussion primarily around the content validity of benefit-transfer procedures, it is also important to consider the content validity of the study-site value estimates that may be used to support the transfer. This consideration takes place as part of study-site information selection as discussed below.

[20] Related *behaviors* may be observable. Hence, some criterion validity tests can be conducted by evaluating the extent to which an economic procedure predicts observable behaviors that are related to welfare estimates (e.g., voting, Vossler and Kerkvliet 2003; Johnston 2006; Vossler and Watson 2013).

[21] Consider the example of convergent validity tests. When these tests are applied to benefit transfers, the study-site and policy-site studies are often designed simultaneously by the researchers and have identical features. This is not the case when an actual transfer is conducted, because no study is available at the policy site. This type of convergent-validity test therefore abstracts from reality. It is also possible to confirm convergent validity for two estimates that are equally biased. As a final example, the outcome of these tests can vary depending on whether a classical null hypothesis of equality is assumed or whether one begins instead with a presumption that prior value estimates are different (Muthke and Holm-Mueller 2004; Kristofersson and Navrud 2005). Thus, convergent-validity investigations are informative but additional evidence is needed to draw strong conclusions on validity.

transfers *used to inform decision making*. Nothing in this paper is meant to impose constraints on research to enhance benefit-transfer practice. It is our hope that this paper will be a guide for benefit-transfer analysts and a forum for decision makers to evaluate transfer estimates, as well as motivating innovative validity and reliability research.

We also emphasize that methodological decisions in any benefit transfer are joint and often iterative, with feedback loops allowing reconsideration of earlier decisions. While the recommendations are presented in a linear sequence below, decisions regarding elements of the transfer may be made jointly or recursively.[22] To help clarify implications for the guidance that follows, Fig. 1 shows the linkages between the key components and decisions in benefit transfer and the topics covered by each recommendation. While each recommendation speaks primarily to one component of the benefit-transfer process (i.e., theory, information, data, analysis), it indirectly relates to others via the joint and sometimes recursive nature of benefit-transfer procedural decisions. Thus, the recommendations presented below should be considered collectively rather than as a menu of parts to be considered and chosen independently, in isolation or within a fixed sequence.

As a final precursor to these guidelines, we stress that—like all economic valuation—benefit-transfer procedures often require input from disciplines beyond economics. Biophysical data and modeling are often required to predict changes in environmental goods and services or the locations where these changes will occur. Input from health sciences and engineering may also be needed for some applications. Geospatial data and analyses are frequently required to model spatial dimensions of affected systems. These and other areas of research have developed best practices to ensure credible science, which apply similarly when these methods contribute to benefit transfers. Hence, beyond the best practices presented below, guidance from other disciplines may be required to ensure valid and credible benefit transfers.

3.1 Value Definition and Valuation Context

The economic value to be estimated should be defined clearly in the context of the policy-site decision context and information needs.

In all benefit transfers, a defined valuation objective is required to guide transfer design, implementation, analysis, and interpretation. This includes definitions of relevant features such as (1) the policy change in question, (2) the identification and description of the good(s) or service(s) to be valued, (3) the increment or decrement of the change(s) to be valued, (4) baseline (or current/status quo) conditions, (5) the theoretical definition of the value to be estimated, (6) the affected population and extent of the market for the analysis, and (7) other factors that characterize the valuation context. Within the final category, relevant considerations may include, but are not limited to, the geographic location of the policy site, geospatial and biophysical features of the site, quantities/qualities of substitutes

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[22] As an illustration, discoveries made during the literature search may guide the selection of a transfer method—for example uncovering a large study-site literature that facilitates the estimation of a meta-equation to support computation of transfer estimates. Subsequent screening and coding may then lead the analyst to revisit and update the original methods used to search the literature or may encourage a rethinking of intended transfer method. For example, upon closer inspection and screening of the data, the analyst may determine that the previously discovered literature is too heterogeneous or poorly documented to support a meta-regression analysis. Such a determination can then prompt a return to earlier steps in the benefit transfer process.

and complements, and related market conditions such as prices and incomes. Together, these conditions and characteristics describe policy-site conditions.

These specifications set the foundation for implementing the transfer and for the interpretation of the transfer estimate in terms of policy-site conditions. For example, the valuation context directly informs:

- selection of relevant study sites,
- selection of value information (e.g., value estimates and functions) from study-site documentation,
- selection of auxiliary information from study-site documentation (e.g., increment of change valued, summary statistics on sample demographics),
- determination of whether information is needed beyond that provided in existing valuation studies (e.g., spatial information on substitutes), and
- selection of a transfer method and adjustments of study-site values to calibrate estimates to policy-site conditions.

When documenting these conditions, it is important to recognize that original valuation studies rarely match policy-site conditions across all dimensions. Benefit transfers must therefore define policy-site conditions both with respect to (a) characterizing policy-site conditions, and (b) identifying factors that will facilitate the use of study-site information to compute a transfer estimate that is calibrated to those policy-site conditions. Identification of policy-site conditions is necessary to identify relevant study sites and the value information therein, and to choose a transfer method to make appropriate adjustments in the calibrated value prediction.

Among the issues that should be considered is the definition of the policy-site value estimates that are desired. These values should be defined in specific units of measurement that encompass relevant temporal, demographic and/or spatial dimensions,[23] e.g., WTP per person/activity day for recreational use of a lake, WTP per person/symptom day for morbidity impacts, or Value of a Statistical Life (VSL) per person in a national population. These definitions provide the foundation for subsequent procedures in the benefit transfer and for interpreting the value predictions that emerge.

Not all potential sources of study-site value information will provide value estimates in the desired metrics of measurement for a particular application. Hence, attention should be given to the implications of policy-site information needs for the search for study sites and screening of information from these studies. Among the issues to be considered is whether study-site documentation contains information necessary to transform study-site value estimates into the desired unit of measurement for the policy site, assumptions that may be required to make these transformations, and potential implications for the accuracy of benefit transfer procedures (Rolfe and Windle 2008; Zhao et al. 2013; Johnston and Zawojska 2020).

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[23] Multiple spatial dimensions of the policy site and policy-site values can be important. For example, where will changes in the studied good or service occur relative to the individuals who might value those changes? How large is the geospatial area affected by environmental quality improvements? What is the relevant extent of the market for the analysis? What are the geospatial dimensions of relevant substitute and complements? Works such as Hanley et al. (2003), Bateman et al. (2006, 2011a, 2011b, 2013), Johnston and Duke (2009), Martin-Ortega et al. (2012), Perino et al. (2014), Schaafsma (2015), Kuminoff (2018), Artell et al. (2019), and Johnston et al. (2017a, 2019) discuss these and other issues related to spatial dimensions of benefit transfer.
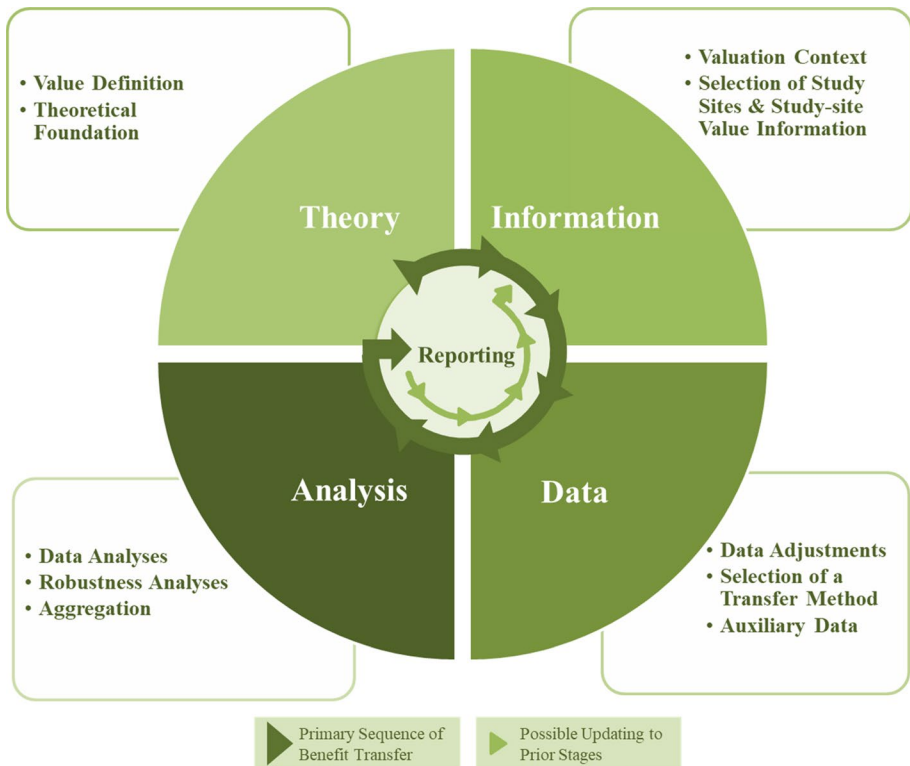
Fig. 1 Benefit-Transfer Components and Guidance Topics

Matching the units of measurement is a necessary step in the search and selection of study-site value information. However, it is not sufficient. Other dimensions of study- and policy-site contexts influence the values that are provided by a good or service, even for the same units of measurement. For example, two study sites might provide value estimates in the same units of measurement but for different decision-making contexts and decision criteria (Brouwer 2000), e.g., value per fish for commercial, recreational or subsistence harvest. In fact, it is unlikely there will be an exact match between study-site and policy-site contexts. Flexibility is needed in study-site choices and value-information selection such that information is available to calibrate a single value to policy-site conditions or so that multiple studies can collectively provide the information needed to calibrate the transfer estimate. Analysts must determine the allowable variation in the commodity and context when identifying studies to support the transfer. Value definitions should consider not only the ideal and often restrictive definitions that might apply for a primary valuation study (or the "perfect" transfer), but also the allowable flexibility in these definitions that is allowable when searching for relevant source studies. The criteria for these determinations should be transparent, to promote credibility and replicability.

Evaluating the tradeoffs between rigidity and flexibility in value definitions can involve complex and multidimensional considerations. For example, overly strict and narrow definitions can diminish the sample size of studies available to support transfer procedures. This can reduce the total amount of information available to inform the transfer and

potentially magnify the impact of individual (perhaps outlier) studies, e.g., limiting the ability of study-site values to collectively describe policy-site conditions. Thus, it is not always the case that more rigid and narrow value definitions engender more accurate transfers (Moeltner and Rosenberger 2014).

This guidance implies a balance between narrow definitions of policy-site conditions and the flexibility required to implement benefit transfers. Transfer procedures should maintain consistency between the value prediction and the policy-site context. However, economic theory provides limited guidance on the set of commodity and study-site characteristics that are most important when matching study- and policy-site conditions. Thus, the analyst must also rely on the collective knowledge from the literature to make key decisions. Because site similarity is not solely an economic consideration, insights from other disciplines may be relevant. The analyst can potentially match study sites and policy sites through approaches such as: a) value adjustments, b) the collective variation of value estimates across study sites, or c) calibrated predictions from transfer functions. For example, within the context of meta-analysis, U.S EPA guidance states "(i)t is unlikely that any single study will match perfectly with the policy case; however, each potential study case should inform at least some aspect of the policy decision."[24]

Despite the importance of policy-site definitions, the benefit transfer literature gives only modest attention to the topic. This, in part, is due to a divergence between benefit transfer as studied in the peer-reviewed literature and as applied in actual settings. Many studies in the academic literature are predesigned tests of convergent validity and not applied benefit transfers. As a result, valuation context conditions and applicable model specifications are often defined *ex ante* to be similar or identical across study and policy sites, which may not reflect the conditions present in actual benefit transfers (Carson et al. 2015; Johnston et al. 2018; Carolus et al. 2020). It also leads to a common situation in which "benefit-transfer" procedures implemented in academic literature obviate some of key steps required for actual benefit transfers. Hence, the peer-reviewed literature tends to overlook, or perhaps underappreciate, the importance of (a) careful definitions of policy-site conditions and (b) relationships between policy-site definitions and subsequent search and decision protocols for benefit transfers.

3.2 Theoretical Foundation

The welfare-theoretic foundations for the benefit transfer should be described, focusing on the definition and properties of the change to be valued.

Theoretical validity is a foundational element of content validity for all economic analyses, including benefit transfers. Among other things, this implies that validity hinges on (a) the theoretical definition of the policy-site value to be estimated and (b) consistency of procedures and outcomes with economic theory. This theoretical foundation informs the transfer process in multiple ways.

The first is guiding the identification of study-site value estimates to inform the transfer. Economic theory provides guidance for selection of study-site value estimates with respect to the type of welfare measure(s) desired for the policy site. For example, values for otherwise identical goods might be measured as increments or decrements in quantity (or

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[24] See: https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-07.pdf, p. 7–46, accessed April 13, 2020.

quality) and might have been estimated as utility-held-constant (Hicksian) surplus (e.g., a stated-preference study) or income-held-constant (Marshallian) surplus (e.g., a travel-cost study). Theoretical and empirical evidence can be used to infer how differences among alternative welfare measures may or may not be relevant within each benefit-transfer setting.[25] The resulting insights can be used to guide the selection and use of value information to ensure sufficient consistency across potentially distinct types of study-site value information used to support the transfer.

Another potentially important issue of welfare consistency is the difference between values measured in terms of willingness to pay (WTP) versus willingness to accept (WTA). These alternative approaches generate different (but related) estimates due to variations in the budget constraint, behavioral factors and assumed property rights, so that substituting or pooling these values can lead to inconsistencies that may influence the validity of the transfer (Horowitz and McConnell 2002; Rolfe et al. 2015b; Tunçel and Hammitt 2014; Zhao and Kling 2001). However, many study sites report WTP estimates only,[26] and this can lead to a challenge when the property-rights context of the policy site implies that WTA measures are more appropriate. This conundrum is not unique to benefit transfers (Lloyd-Smith and Adamowicz 2018).

Differences between theoretical definitions of the value measure can also be more fundamental, such that issues of validity become unequivocal. For example, the producer surplus realized by a fishing charter boat operator is an entirely distinct theoretical measure from Marshallian consumer surplus realized by charter boat clients, even though both are derived from the same recreational activity (charter fishing trips). Some existing meta-analyses have pooled estimates of consumer surplus (e.g., from recreation-demand or stated-preference models), producer surplus (e.g., from factor-input methods), and measures that are not typically grounded in welfare-theoretic foundations (e.g., damage or restoration cost estimates). Pooling such divergent welfare constructs within valuation metadata may be useful for analyzing an empirical literature on a topic, but for benefit transfer these existing meta-analyses are "not consistent with an analysis and prediction of a well-defined economic value" (Boyle and Wooldridge 2018, p. 612). A key difference is that these divergent measures apply to different populations and different welfare effects even if arising from the same policy action. Distinct measures of this type should not be aligned in the transfer process.[27]

To avoid these problems, unambiguous delineation of the theoretical value definition for the policy-site value is required. The theoretical justification for selected study-sites and value estimates should explain how these choices align with the policy-site value to be estimated. When variations between study-site value estimates and the policy-site welfare measure are permitted, the rationale and processes to adjust for these differences and to establish sufficient consistency of the included measures should be elucidated (Smith et al. 2002; Johnston and Moeltner 2014; Moeltner and Rosenberger 2014; Moeltner 2015).

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[25] For example, in some settings it might be defensible to use otherwise identical Hicksian and Marshallian estimates interchangeably within a benefit transfer (as they are for practical purposes in many applied studies), whereas in other cases the anticipated differences between these estimates might be large enough that such practices could jeopardize validity. See discussions in Londoño and Johnston (2012) and Johnston and Moeltner (2014).

[26] Some original valuation studies estimate WTP when property rights suggest that a WTA measure is more applicable, due to the complexities involved in estimating WTA (e.g., Bishop et al. 2017).

[27] Discussions of this topic are provided in sources such as Brouwer (2000), Bergstrom and Taylor (2006), Nelson and Kennedy (2009), Boyle and Wooldridge (2018), and Vedogbeton and Johnston (2020).

If transfer methods include tradeoffs between theoretical properties and empirical performance, these tradeoffs and their resolution should be transparent (e.g., Newbold 2018b; Moeltner 2019).[28]

Theory can also provide evidence on the validity of study-site values selected for the transfer; this speaks to the content validity of the original value estimates selected to inform the transfer. For example, in general and all else equal, study-site value estimates should be higher for more unique or quantity- or quality-constrained items, exhibit diminishing marginal utility, and be sensitive to the presence of substitutes and complements. Individual WTP would normally be positively related to incomes. Conditions such as these, when satisfied, can support the credibility and validity of study-site value estimates in transfer analyses.

However, these relationships are artifacts of posited economic models that may or may not hold (e.g., due to potential confounding, incorrect assumptions, the use of chosen functional forms for empirical analysis, etc.). Hence, it is rarely the case that any one theoretical construct can provide an absolute or sufficient "litmus" test for including or excluding study-site value estimates, or for the type of model structure that should be used for transfer procedures (Kling and Phaneuf 2018; Bishop and Boyle 2019). For example, what constitutes a substitute or a complement for a good may vary across settings. Similarly, the size of any economic effect, such as the relationship between quantity and marginal WTP, is an empirical question. It is also the case that information available from study sites may not permit certain tests to be conducted or effects of interest to be identified.

In summary, the role of theory within benefit transfers must be considered in context. This consideration is part of the "balancing act" of theory, available value information, empirical model performance, and policy relevance that is inherent in all benefit transfers (Smith 2018). Although theory is an important foundation for all welfare analysis, judgement is required when determining how it should inform transfer procedures.

3.3 Selection of Study Sites and Study-site Value Information

The search for information to support the benefit transfer, including study sites and value information, should be conducted in a comprehensive and systematic manner that reflects that underlying value definition and valuation context, along with the information available from each study and site.

Grounded in prior steps within the benefit-transfer process (Fig. 1), the goal of the data selection process is to assemble study-site value information to inform valid and reliable policy-site value estimation. This process should consider the full breadth of information available in the literature and whether the content of the literature includes patterns or biases that may affect benefit-transfer procedures or validity (Hoehn 2006; Rosenberger and Johnston 2009). The selection of information to support the transfer—including study sites and value information—requires candidate studies (sources of data for the transfer) to be identified based on factors that include the similarity of each study site to policy-site conditions, the extent to which the information provided by each study is consistent with the theoretical definition of value required for the policy-site application, and the quality of

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[28] For example, in some cases model specifications designed to ensure desirable theoretical properties may lead to inferior empirical performance (Newbold et al. 2018b; Moeltner 2019).

the data (e.g., biophysical, socioeconomic, geospatial, etc.) used to produce the study-site value information.

The data selection process includes four general steps, grounded in the prior recommendations and procedures outlined above:

- identification of potentially relevant studies,
- evaluation and screening of studies for transfer suitability,
- identification and coding of relevant study-site data, and
- supplementation of study-site data with information from external sources.

When executing each of these steps the analyst should develop systematic processes so that the data-selection and coding processes can be replicated to ensure transparency and credibility. The analyst should explain the procedures used to select and screen studies, along with the value information therein. This documentation should also outline data coding protocols. Systematic procedures are crucial for consistent selection of study sites and the coding of value information from study-site documents.[29]

The selection of study-site identification should reflect a transparent and comprehensive search of the literature based on predetermined key words and application-specific protocols. Valuation databases such as the Environmental Valuation Reference Inventory (EVRI, https://www.evri.ca/en) or the Economics of Ecosystems & Biodiversity Database (TEEB, https://www.teebweb.org) can be good starting points. Common internet search engines such as Google Scholar are also helpful. The use of on-line search engines should be supplemented with additional search procedures when there is evidence that relevant studies may be omitted, for example when there may be grey literature or recent research that may have limited online access, or when standard keyword searches may be insufficient to identify all relevant studies. These procedures can include direct contact with researchers and queries through social media or internet lists (e.g., RESECON listserv, https://www.aere.org/resecon).

Among the decisions to be made based on the literature search is whether sufficient data and study documentation are available to support policy-site value predictions, using different types of transfer procedures. This requires consideration of site characteristics and the characteristics of available studies at those sites. As noted above, similarity in benefit transfers should not be construed to imply that study sites and policy sites must be identical across all or even most dimensions. Instead, one should consider whether available study-sites *collectively* provide information that can be used to predict policy-site values, considering key dimensions that are expected to influence value estimates. The analyst should strive to select study sites, perhaps augmented with auxiliary information, that allow value predictions to be calibrated to policy-site conditions. This flexibility enables one to broaden the potential population of study sites for consideration. Not all study- and policy-site conditions are germane to prediction of policy-site values. Differences across irrelevant features should not be an impediment to the use of study-site data. At the same time, some consistency is required. Considerations related to the degree of similarity that is required between study- and policy-sites are often discussed under the general headings of

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[29] See Loomis and Rosenberger (2006), Nelson and Kennedy (2009), Rosenberger and Johnston (2009), Boyle et al. (2013, 2015), Stanley et al. (2013), Nelson (2015), Boyle and Wooldridge (2018), and Newbold et al. (2018a).

"commodity" and "welfare consistency"; these considerations flow directly from the discussion of theoretical properties above.[30]

The literature contains numerous informal references and discussions related to similarity between study sites and policy sites, but few benefit-transfer applications explicitly specify the dimensions of similarity that were considered when selecting data and adjusting study-site values to estimate policy-site values (Rolfe et al. 2015b, 2015c; Brouwer et al. 2016; Carolus et al. 2020). The literature contains differing insights on ways to define site similarity (e.g., Morrison and Bergland 2006; Johnston 2007; Colombo and Hanley 2008; Bateman et al. 2011a) and there are few areas of consensus regarding the dimensions of similarity that are most relevant for valid transfers (Boyle et al. 2010; Johnston and Rosenberger 2010; Johnston et al. 2018; Carolus et al. 2020). Except for a few core dimensions such as income, studies are not consistent with respect to the dimensions of similarity considered to be important.

Nonetheless, it is possible to draw some conclusions regarding the type of consistency that should be expected between study- and policy-sites. First, the level of required consistency varies depending on the type of transfer. For a value transfer the study-site value estimates should be more closely aligned with the policy-site value context, *ceteris paribus*, because fewer adjustments are possible and generalization errors may be more of a concern (Rolfe et al. 2015c). In contrast, for a meta-equation or preference-function transfers, study-site value estimates should collectively provide the data to calibrate the transfer estimate to policy-site conditions. Moeltner and Rosenberger (2014) further suggest that benefit transfers may sometimes be enhanced by pooling data from seemingly unlike types of study-site applications. An associated condition is that study-site documentation should provide sufficient information to allow the adjustment of transfer values estimates to policy-site conditions (Loomis and Rosenberger 2006). The ability of the analyst to make these selection decisions depend on the documentation of procedures and assumptions for potential study sites.

Second, it is possible to provide some guidance on the general types of consistency that should be considered. These recommendations are grounded in prior guidance on the valuation context and value definition discussed above. Specifically, we suggest that analysts consider similarity or consistency in terms of:

- the underlying definition of the good or service, and how it influences welfare (i.e., is it the same or similar commodity, and whether it produces welfare in a similar way across settings)[31];
- core economic factors such as substitutes, complements and income;
- consistency of welfare measures, whether adjustments are possible to convert to a common welfare measure, and whether differences between inconsistent measures are likely to be small or large;

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[30] For example, see discussions in Bergstrom and Taylor (2006), Nelson and Kennedy (2009), Johnston and Moeltner (2014), Moeltner and Rosenberger (2014), Moeltner (2015), Boyle and Wooldridge (2018) and Vedogbeton and Johnston (2020).

[31] Consider, for example, an otherwise identical increase in bowhead whale populations used for subsistence harvest by Native communities in the Arctic, compared to the same biophysical population change used for recreational whale watching. Even though the biophysical change might be identical (e.g., an increase in X whales within a population stock), these changes influence welfare through fundamentally different channels, and would therefore be unlikely to have sufficient consistency to support valid benefit transfer.

- the general magnitude of change to be valued at the policy site and whether it is an increment or decrement;
- potentially influential geopolitical or cultural differences (e.g., are values compared across different countries or regions wherein cultural differences might influence values);
- other important contextual similarities and differences between study sites and the policy site, considering relevant biophysical and socioeconomic dimensions.[32]

The literature provides considerable evidence on the validity and reliability of international transfers, including transfers involving more and less similar countries.[33] Results of this literature are mixed, but many studies suggest the possibility for heterogeneity in values (Ready et al. 2004), including differences across arguably similar countries such as the US and Canada (Johnston and Thomassin 2010) or high-income countries in Europe such as Germany and Sweden (Ahtiainen et al. 2014; Artell et al. 2019). Studies have also found that large and/or statistically significant differences in value estimates for otherwise identical changes can occur across intra-country regions such as states within the US and Australia (e.g., Loomis et al. 1995; Morrison et al. 2002; Johnston and Duke 2010; Johnston et al. 2005, 2017a, 2019; Moeltner and Rosenberger 2014; Rolfe and Windle 2012).[34] Hence, researchers should consider the possibility that differences such as these might influence transfer accuracy when selecting study site information. Similarity in core dimensions of demographic, institutional and cultural contexts may be particularly important, as the evidence is mixed when using function transfers to calibrate policy-site value estimates for differences in dimensions such as these (Ready et al. 2004; Lindhjem and Navrud 2008; Brouwer et al. 2015; Hynes et al. 2013). In fact, value transfers between "most similar" sites with income adjustments have often been shown to perform better than function transfers in international contexts (e.g., Bateman et al. 2011a; Czajkowski et al. 2017; Artell et al. 2019).

Beyond this general guidance, it is not yet possible to identify a consensus for specific variables that must be included in all benefit transfers, and hence for which study-site information is required. Instead, the analyst should ground these decisions on a weight of evidence consideration of theoretical/empirical insights and application-specific considerations. These considerations should justify study-site and value-estimate selections, and any calibrations (or lack thereof) that are conducted to predict policy-site value estimates. Analyst judgement is required when determining the suitability of study-site information for any benefit transfer (Newbold et al. 2018a).[35]

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[32] Relevant contextual considerations will vary across settings and the types of values considered. As an example, the value of otherwise similar environmental quality improvements may vary depending on whether public access is permitted to improved areas, so that legal access provisions can represent an important socioeconomic dimension of similarity in some cases (Olander et al. 2018). Another illustrative example is that the value of a riparian buffer for treatment of water pollution depends on the extent to which that buffer is located downstream of pollution sources—a purely biophysical characteristic that is central to the values provided by a given buffer area. Biophysical features such as these can also represent relevant contextual dimensions of site similarity for benefit transfers (Simpson 2016).

[33] Section 4.9 in Johnston et al. (2018) reviews past findings on international benefit transfers.

[34] Some papers conclude that "international benefit transfer is as valid as intra-country transfer" (Ready and Navrud 2006, p. 434), although there does not appear to be consensus on this issue.

[35] For example, study sites may be excluded because of insufficient correspondence to the policy site across one or more potentially important dimensions, because study documentation lacks information on key variables involved in the transfer (Moeltner et al. 2007), because the valuation approach is inconsistent with

A related consideration for study-site selection is the type and quality of valuation studies that have been conducted at each candidate study site (e.g., stated-preference studies, recreation-demand studies, hedonic property value studies, etc.). Study type directly influences the type of value estimates that are available to support the benefit transfer, as related to the theoretical value definition for the transfer and policy-site information needs. The original study type can also influence transfer accuracy in other ways. For example, prior work suggests that the use of data from some types of valuation methods within a transfer may affect transfer accuracy in a systematic manner (Londoño and Johnston 2012; Kaul et al. 2013; Ferrini et al. 2014).[36] Hence, one should consider the type of original study used to generate study-site value information when determining the suitability of this information to support the transfer.

Studies should also be screened for adherence to recommended methodological practices, considering the multiple caveats on validity assessments described above. For example, Johnston et al. (2017b), Bishop et al. (2020) and Lupi et al. (2020) present best-practice guidelines for stated-preference methods, hedonic studies and recreation-demand methods, respectively. Validity screening is similarly applicable to non-economic procedures applied by the study (e.g., biophysical or spatial analysis), as applicable to the study type, context and intended uses of study-site information.[37]

However, care must be taken with quality screening. As described above, overly rigid or narrow screening can lead to the elimination of imperfect-but-informative studies in ways that reduce transfer accuracy. A study does not have to be ideal across all dimensions to provide potentially useful information. Moreover, although study screening and value selection processes are necessary components of benefit transfer, they may contribute to selection biases (Florax 2002; Hoehn 2006; Nelson and Kennedy 2009; Rosenberger and Johnston 2009; Boyle and Wooldridge 2018). Analysts should be aware of these potential biases and take steps to identify and ameliorate them when possible. Nelson and Kennedy (2009, p. 347) describe "publication bias (aka "file-drawer problem") [as] a form of sample selection bias that arises if primary studies with statistically weak, insignificant, or unusual results tend not to be submitted for publication or are less likely to be published." It may also occur if objective criteria with a strong scientific basis are not applied to define selection. The peer-review process—while screening for quality—may exacerbate this problem by discouraging the publication of (otherwise valid) applied valuation studies that do not have methodological or theoretical novelty (McComb et al. 2006; Loomis and Rosenberger 2006; Johnston and Rosenberger 2010). Selection biases may also prevent studies from being conducted in the first place or from being fully documented.

If publication bias is present in a research literature, estimates of true effect sizes drawn from the literature (such as estimates of mean WTP) are distorted, leading to potentially biased inferences (Florax 2002; Stanley 2005, 2008). Study-site selection criteria through on-line search engines may be more likely to identify peer-reviewed journal articles with

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Footnote 35 (continued)

established practices (Newbold et al. 2018a), or due to other considerations that may render a study unsuitable for a benefit transfer application.

[36] For example, this work seems to suggest that transfers of contingent valuation estimates are more accurate than transfers of other types of value information.

[37] For example, accurate characterization and modeling of the biophysical dimensions of the environmental good(s) or service(s) to be valued are important dimensions of validity for many types of valuation studies, beyond economic methods that are applied (Mendelsohn and Olmstead 2009; Bateman et al. 2011b; Johnston et al. 2012; Schultz et al. 2012; Boyd et al. 2016; Simpson 2016).

an unintentional systematic exclusion of grey literature (Stanley and Doucouliagos 2012). Because data screening and selection protocols can affect selection biases, the analyst should consider the potential for these biases and their potential effects on policy-site value predictions (Hoehn 2006; Nelson and Kennedy 2009; Rosenberger and Johnston 2009; Boyle and Woodridge 2018). This guidance is particularly relevant for systematic exclusion of grey literature studies. In addition, screening criteria for study quality (e.g., methodological standards, statistical criteria, plausibility of welfare estimates) can create or exacerbate selection biases. Although methods exist to identify and offset selection biases (Hoehn 2006; Stanley 2005, 2008; Rosenberger and Johnston 2009), these approaches cannot guarantee that all such biases will be identified and offset. Hence, it is imperative to include a broad set of study-site value estimates and conduct sensitivity analyses to identify the effects of potentially influential information on the transfer (Boyle et al. 2013, 2015).

3.4 Selection of a Transfer Method

The transfer method should be selected based on: (a) data availability, (b) steps required to harmonize study-site estimates with policy-site conditions, (c) insight from the literature regarding the accuracy of transfer methods under different circumstances, and (d) the intended uses of the resulting information.

Once potential study-site information has been identified the analyst must determine the type of benefit-transfer method to be applied. The method should be selected systematically based on the valuation context, as defined by such features as available data, similarities between study sites and policy sites, and the intended uses of the transfer. The analyst should justify the transfer method with respect to both theoretical and empirical criteria. As noted above, common approaches include adjusted and unadjusted value transfers, single-site or single-study function transfers, meta-function transfers (structural or reduced-form), and structural preference-calibration transfers.

In some cases, benefit transfers can also be implemented using integrated models that are embedded within partially/fully predesigned tools such as the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)[38] and the Natural Environment Valuation Online tool (NEVO),[39] among other integrated modeling systems (Tallis and Polasky 2009; Bagstad et al. 2013; Ferrini et al. 2015; Richardson et al. 2015; Bateman and Kling 2020). US EPA has recently developed BenSPLASH (Benefits Spatial Platform for Aggregating Socioeconomics and H_2O Quality), a modeling platform for quantifying the economic benefits of water quality changes in the US (Corona et al. 2020). These tools coordinate spatially explicit data, biophysical science and economic modeling of various types to provide insights into the provision and value of environmental and ecosystem service changes. Although tools of this type vary in design and content, their internal benefit-transfer (or economic value prediction) components rely on the same types of underlying approaches as all other benefit-transfers (e.g., different types of value and value-function transfers). For example, economic value predictions within BenSPLASH rely on an embedded water quality value meta-analysis (Corona et al. 2020). The guidance outlined here is relevant for all benefit transfers, whether the transfer is designed from the ground up or implemented using a predesigned software tool. Documentation accompanying these tools (or associated

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[38] https://sweep.ac.uk/portfolios/natural-environment-valuation-online-tool-nevo/, accessed April 1, 2021.

[39] https://naturalcapitalproject.stanford.edu/software/invest, accessed April 1, 2021.

publications) should be used to evaluate the underlying data and analytical methods, and thereby assess whether best practices have been applied.[40]

Key questions relevant to choosing among different benefit-transfer methods include:

- *For value transfer* How similar are study sites and policy sites across relevant dimensions? Is there a single study that provides information sufficient to transfer the study-site estimate directly, perhaps with adjustments (e.g., income) to the policy site? Alternatively, are there several study sites providing values that, when averaged and perhaps adjusted, can provide an accurate and credible estimate of the policy-site value? Would validity be improved through adjustments that are more readily accommodated through function transfers, as applicable to the benefit-transfer context? Does the weight of evidence on site similarity support a value transfer over other transfer methods that allow for greater calibration of study-site estimates to match policy-site conditions?
- *For single-site or single-study function transfer* Is there an individual study site that provides an estimated function to support a policy-site value prediction or a study that estimates a similar function using primary data collected from multiple sites? Does the function allow calibrations necessary to compute an accurate and credible policy-site value? Is it reasonable to expect that the available study-site benefit function is applicable to the policy site, e.g., based on the observed degree of consistency across conditions at the two sites? Or, alternatively, can the information from multiple primary study sites used to estimate the benefit function—for example within a random utility model of recreation demand—collectively represent conditions at the policy site? Does information available at the policy-site provide sufficient information to populate the available benefit function, and thereby produce calibrated benefit estimates?
- *For structural preference-function transfer* Is there sufficient study-site and value estimate information to compute a structural preference-function that supports an accurate and credible policy-site value prediction? Is there evidence to support maintained assumptions necessary to inform model structure? How would a structural approach compare to others in terms of the capacity to use available study- and policy-site information to inform the transfer?
- *For meta-analysis function transfer* Is there an existing meta-function that provides the basis for valid and credible transfer or is there sufficient study-site and value-estimate data to estimate a new meta-function that supports a calibrated policy-site value prediction?[41] Do the study sites and their value estimates collectively provide sufficient variation to support accurate and credible prediction of a policy-site value? Does the content of the literature enable estimation of a credible meta-analysis? Does information available at the policy-site provide sufficient information to populate the available meta-function, and thereby produce calibrated benefit estimates?

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[40] For example, InVEST provides online documentation which may be used to evaluate the extent to which economic components rely on best practices applicable to specific benefit-transfer applications. See https://naturalcapitalproject.stanford.edu/software/invest, accessed April 1, 2021. Similar documentation for NEVO is available at https://www.leep.exeter.ac.uk/nevo/documentation/, accessed May 20, 2021.

[41] The benefit transfer literature frequently overlooks the distinction between estimating a new meta-regression analysis to support a benefit transfer and using an existing meta-analysis. There are important differences between these two types of benefit transfer. For example, the latter does not require the compilation of new metadata but does require that the properties of the already-existing meta-analysis be evaluated with respect to policy-site conditions and benefit-transfer needs. In addition, the quality of meta-regression models and suitability for value prediction vary (Boyle and Wooldridge 2018).

No single benefit-transfer method can be considered universally superior to others across all possible circumstances, and questions such as these imply the tradeoffs that are involved in the selection of a transfer method. For example, can a single or few closely matching study-site value estimates represent comparable policy-site values, compared to those produced by a single study-site equation that allows greater calibration to policy-site conditions (Rolfe et al. 2015c)? Benefit functions estimated using primary data collected over multiple study sites can potentially provide more flexible and broadly applicable predictions (Bateman et al. 2013), but estimation of these functions requires assumptions and procedures beyond those typically required for otherwise similar single-site functions.[42]

Meta-functions allow the analyst to incorporate variables that are fixed for individual studies or sites but vary across different studies or sites; this variation may enhance the capacity of the resulting benefit function to calibrate value estimates to policy-site conditions. However, the estimation and use of meta-regression models for benefit transfer implies procedures and questions that are not present for other types of transfer (Nelson and Kennedy 2009; Nelson 2015; Boyle and Wooldridge 2018). Compared to alternative approaches, the added structure of preference calibration approaches can add theoretical rigor (Smith et al. 2002, 2006). However, the advantages of theoretical consistency must be considered against the possible disadvantages, such as an inability to use potentially relevant information, or sensitivity of estimates to structural assumptions (Smith et al. 2006; Kling and Phaneuf 2018; Moeltner 2019; Newbold et al. 2018b). Considerations such as these should be contemplated in the context of available data to support the transfer and vary from one application to the next.

These tradeoffs also make clear that the choice of method is intertwined with available study-site data and the credibility of study-site value estimates. For example, the policy-site value definition and valuation context guide study-site selection, while the theoretical definition of the desired policy-site value prediction guides the selection of value information from each study. The choice of transfer method then depends, at least in part, on the availability of information determined by these prior or concurrent decisions. Hence, the selection of transfer method is best viewed as being jointly determined with other choices in the transfer process, as implied by the intertwined nature of benefit-transfer procedures in general (Fig. 1). Because of this joint determination, decisions on the transfer method may require recursion to prior steps in the analysis to review data availability to support a proposed transfer method and perhaps the search for additional data or consideration of additional data adjustments.[43]

Analysts should select transfer methods that promote the greatest possible consistency of transfer value estimates with the desired policy-site value, allowing for calibrations that are implemented as part of the transfer. Insight into accuracy can be drawn from the literature that compares the performance of different types of transfer procedures under different circumstances (Brouwer 2000; Engel 2002; Rosenberger and Stanley 2006; Boyle

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[42] For example, when estimating a single benefit function using primary data from multiple study sites, one assumes implicitly that the function can provide a valid representation of conditions and behavior across all sites. Similar assumptions are implied when estimating and using meta-functions.

[43] For example, an initial data search may suggest the availability of data suitable for development of a meta-regression analysis. Once an initial decision is made to pursue this type of transfer, additional data collection may be required to complete the metadata, especially in terms of regressors specified in the meta-equation, necessitating a return to data search and review of coding procedures. If sufficient study-site meta-data are not ultimately available to estimate a meta-function, then the analyst must revisit the transfer-method decision—for example, considering a value- or single-site function transfer instead.

et al. 2010; Kaul et al. 2013; Rosenberger 2015; Johnston et al. 2018). It is important to recognize, however, that much of this literature applies some form of convergent-validity testing. These tests investigate if two or more transfers provide comparable estimates or if the transfer estimate is comparable to an estimate from an original study that is designed to produce that same value. Although this research can be informative, the true value is almost always unknown. Hence, similarity of welfare estimates is an indicator of validity but cannot confirm validity. Thus, when selecting transfer procedures, the analyst should consider the weight of evidence across the literature with attention to applications similar to the current topic.

Value transfers require the greatest similarity between the study site(s) and the policy site, so that the prediction of the policy-site value can rely on simple calibrations such as adjusting for inflation and purchasing power parity (Rolfe et al. 2015c). In general, unadjusted value transfers are one of the least accurate transfer methods and not recommended when a suitable benefit function transfer is possible. Value transfers are usually chosen only when there is insufficient data to support other approaches for the given policy-site application.

In contrast, the ability to adjust study-site value estimates according to observable differences between study and policy contexts via function transfers can promote accuracy, *ceteris paribus*. Summary research provides robust evidence to support this insight (e.g., Kaul et al. 2013; Rosenberger and Stanley 2006; Rosenberger 2015). Hence, function transfers are usually preferred when a study site provides a function that is a good match for policy-site conditions or when information may be drawn from multiple sites or studies that collectively match policy-site conditions, and thus allow estimation of a multiple-site benefit function, meta-function or development of a preference calibration approach.

This guidance does not apply universally, however. Sometimes an adjusted value transfer can provide the most accurate estimate, e.g., when the transfer is to a new policy application over the same region and population as the study-site. In fact, some studies suggest that value transfers are more accurate when study and policy contexts are very similar (Brouwer 2000; Barton 2002; Bateman et al. 2011a; Johnston and Duke 2010). There is also evidence suggesting that value transfers with simple income or purchasing-power adjustments may perform well in international transfers (e.g., Ready et al. 2004; Lindhjem and Navrud 2008, 2015; Czajkowski and Ščasný 2010; Bateman et al. 2011a; Kosenius and Markku 2015; Andreopoulos and Damigos 2017; Czajkowski et al. 2017; Artell et al. 2019).[44] One type of transfer, for value of statistical life estimates, is almost implemented as a value transfer, despite the fact that meta-analyses have been conducted on this topic (Brouwer and Bateman 2005; Mrozek and Taylor 2002; Viscusi and Aldy 2003; Lindhjem and Navrud 2015; Viscusi 2015).[45] Considering the breadth of evidence available in the literature, value transfers should proceed with caution and justification of how the study-site value estimates match the policy-site value question either directly or with simple adjustments.

Depending on the study-site data available, one may have a choice among alternative types of function transfers. For example, one may use a function from one study site (e.g.,

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[44] Some evidence suggests that adjustments for income inequality may also be relevant within some contexts (Baumgärtner et al. 2017; Meya et al. 2021).

[45] The value of statical life estimates are drawn from analysis of many study-site values but, once estimated, the same VSL is used in many policy analyses, sometimes with simple adjustments (Aldy and Viscusi, 2008; De Blaeij et al. 2003; Hammitt and Robinson 2011; Viscusi and Aldy 2003).

a recreation demand model) or generated by different types of data-syntheses (e.g., a meta-function or a calibrated preference function). There is a growing consensus of the advantages of methods that synthesize data from multiple sources due to the capacity of multiple study sites to collectively represent policy-site conditions.[46] There are also advantages of structural approaches that can ensure theoretical properties such as adding up, diminishing marginal utility and other preference characteristics.[47] However, there is no clear consensus on how analysts should balance theoretical considerations with other dimensions relevant to validity and reliability, such as the empirical performance of estimated models or convergent-validity evidence from the literature.[48] There can be "a tradeoff between improved statistical fit that can be achieved by allowing additional model flexibility …" within approaches that relax strong structural specifications designed to ensure theoretical properties (Newbold et al. 2018b, p. 544).

In summary, the choice among different benefit transfer methods involves a complex consideration of multiple factors that include theoretical structure, data availability, statistical precision, and matching transfer estimates to policy-site conditions. Further, the validity and reliability of transfers depend on factors such as the amount and variation in study-site data, data coding and econometric analysis. Given influences such as these, a single-site function transfer between closely matching study- and policy sites might be more accurate than a transfer conducted via a meta-function estimated with data from multiple less-well-matched study-sites. In other cases, the collective variation across multiple studies that inform the estimation of the meta-function may provide better transfer estimates.

The selection of method may be further influenced by the precision necessary to support different types of decisions. For example, higher degrees of precision are generally required as one moves from scoping the general magnitude of potential benefits and costs, to conducting benefit–cost analysis that informs high-impact decisions or calculation of compensatory damages for litigation (Navrud and Pruckner 1997; Johnston and Rosenberger 2010).[49]

Benefit transfers are typically conducted in resource constrained conditions and these constraints may also limit the type of transfer selected. Yet, these conditions are not an excuse for a poorly executed or justified transfer. If sufficient supporting information or resources to execute the transfer are not available, then a transfer should not be conducted. If an analyst encounters technical challenges in carrying out a transfer, then it is incumbent upon them to identify a person who has the expertise to assist.

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[46] For example, see Boyle et al. (2009, 2010), Rosenberger and Phipps (2007), Johnston and Rosenberger (2010), Johnston and Thomassin (2010), Kaul et al. (2013), Lindhjem and Navrud (2015), Rolfe et al. (2015b), and Boyle and Wooldridge (2018).

[47] See Smith et al. (2002, 2006), Smith and Pattanayak (2002), Phaneuf and Van Houtven (2015), Newbold et al. (2018b), and Moeltner (2019).

[48] For example, see discussions in Boyle et al. (2009, 2010), Johnston and Rosenberger (2010), Johnston and Moeltner (2014), Moeltner and Rosenberger (2014), Kling and Phaneuf (2018), Newbold et al. (2018b), Smith et al. (2002, 2006), Smith (2018), and Moeltner (2019).

[49] For discussions of precision needs for benefit transfer in different policy contexts, see Bergstrom and De Civita (1999), Navrud and Pruckner (1997) and Olander et al. (2017).

3.5 Data Adjustments

Study-site data adjustments should be used to harmonize information across studies and enable well-defined value estimates for policy sites. These adjustments should be consistent with the value definition, valuation context, theoretical foundation for the transfer, and available study- and policy-site value information.

The ability of transfer procedures to produce well-defined value predictions using study-site data depends on consistent data measurement and interpretation. There are two dimensions to this recommendation. First, study-site information must be reconciled to clearly defined units of measurements that are relevant for the policy site.[50] Second, when transfers involve the synthesis of data across multiple study-sites, information across these study sites must be reconciled similarly. The latter is particularly important because benefit transfers often use value estimates from multiple studies, which requires the reconciliation of variable measurements across sites and sometimes even for different value estimates within studies. This applies both to value information and other types of data involved in the transfer.

To ensure data consistency across study- and policy-sites, all data used within transfer procedures should be reviewed to determine if adjustments are necessary. These adjustments should be consistent with the commodity and welfare recommendations that define the transfer value estimate and guide the transfer. The rationales and methods for all adjustments should be transparent and enable replication.

In many cases the data needed for a transfer are not provided in consistent measurement units across studies, so variables must be transformed.[51] Required conversions often include, but are not limited to, the conversion of value information into a common monetary metric and a standard year, together with steps required to reconcile measures of the increments or decrements of change valued. Adjustments may also be required for the geospatial scale of changes—or the areas or distances over which changes occur. There is a growing literature on spatial dimensions of benefit transfer such as these (Bateman et al. 2006; Martin-Ortega et al. 2012; Perino et al. 2014; Ferrini et al. 2015; Schaafsma 2015; Johnston et al. 2017a, 2019). Transformations may require information beyond that provided in study-site documentation and the analyst may be required to make additional assumptions when converting information to common units.[52]

Among the most basic adjustments within any benefit transfer is the conversion of value estimates to a common base year using a consumer price index or equivalent means to account for inflation (Eiswerth and Shaw 1997). Adjustments for income, purchasing power parity or exchange rates may be appropriate when these features vary across study sites (Czajkowski and Šcasný 2010; Hammitt and Robinson 2011; Zhai 2011; Barbier et al.

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[50] For example, water quality valuation studies have used many different types of water quality measures when estimating values, including different types of water quality indices or ladders (Johnston et al. 2005, 2017a, 2019; Van Houtven et al. 2007; Walsh and Wheeler 2013). As described by Johnston and Bauer (2020), various steps are typically required to reconcile water-quality measurements available for the policy site with the measures used to qualify water quality within valuation studies or meta-analyses. Similar steps are required when comparing values across studies, for example as part of a meta-regression analysis.

[51] For example, some studies might report value estimates per household whereas others might provide estimates per person for a common unit of change but for different years.

[52] For example, transformations between values per household and values per person require information on the number of persons per household, along with assumptions on how to consider adults versus children when making this transformation.

2017; Czajkowski et al. 2017). Another core adjustment is the conversion of value esti-mates to a common metric. For example, a recreation-demand study might report welfare estimates on a per-trip basis, while another study might report an otherwise similar value on a per-day basis. Other studies might report total site access value. There might also be a time dimension of the reported values. For example, stated-preference value estimates might be measured as a one-time payment, a fixed number of payments over a specified number of years, or a fixed ongoing payment.

Adjustments of variables to well-defined, comparable units of measurement can require the analyst to address challenging questions, such as:

- What type of conversion is most logical (or perhaps requires the fewest assumptions), and does this type of conversion align with information needs at the policy site?
- Does study-site documentation contain the information needed to make the conversion? For example, does a study that reports values on a per-trip basis also document the average number of days per trip when other studies report per-day value? Alternatively, do the studies reporting per-day values report the average number of days per trip?
- If study-site documentation does not provide the information to make the conversion, can auxiliary information be used to make a defensible conversion? For example, does *another* source in the literature report average days per trip for the same site or study area that would support a conversion of value/trip or value/day?
- Are additional assumptions required and are they credible? For example, conversions between annual payments for a fixed period and lump-sum payments require a discount rate assumption.
- When estimating a meta-analysis or preference calibration, can control variables be reconciled to common units of measurement? For example, some studies might report average income per household while other studies might report income ranges or omit income data.
- Does the selected transfer method include internal mechanisms to accommodate data that are *not* in identical units of measurement?[53]

When conducting a value transfer, such considerations mostly concern the value esti-mate, for example accommodating for income differences across sites. For a function trans-fer from a single study site, the issue can concern the measurement of regressor variables at the policy site *vis a vis* their measurement within the previously estimated benefit function, along with any adjustment required of the value prediction from the study-site function to match policy-site conditions.[54] Considerations of this type are of primary importance for meta-function transfers or other data synthesis approaches, because reconciliation of multi-ple variables across many sites may be required.

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[53] For example, structural benefit transfer methods can include mechanisms to calibrate between otherwise identical Marshallian and Hicksian welfare measures. Meta-regression analyses often include moderator variables that identify inconsistencies across included value measures (e.g., values measured as recurring annual payments versus lump-sum payments), allowing the model to estimate systematic differences associ-ated with different measurement units. Model-based procedures of this type can at least partially reduce the need for some types of data adjustments.

[54] For example, a study-site benefit function might incorporate water quality change measured via a stand-ardized water quality index (Walsh and Wheeler 2013), whereas quality data at the policy site might be available in other units (e.g., changes in Secchi depth).

Many variables within a benefit function—such as measures of environmental quality—may be measured differently across sites and require adjustments so that they can be compared. These adjustments are not always straightforward and multiple approaches may be used to compare otherwise similar data (Boyd et al. 2016). For example, as noted above, different metrics or indices may be used to measure water quality change (Johnston et al. 2005, 2017a, 2019; Van Houtven et al. 2007; Walsh and Wheeler 2013). Common measures include dissolved oxygen, clarity, concentrations of toxic substances, and others. Water quality indices or ladders are also common. Similarly, air quality might be measured as PM10, PM2.5, deciviews, or in other units. Summary measures might also be used (similar to water quality indices), such as the Air Quality Index employed by US EPA that summarizes multiple dimensions of air pollution.[55] Although different types of scales can be used to reconcile variables within a transfer, ambiguously defined measurements such as "high, medium and low" should be avoided unless these categories are determined using a well-defined underlying measurement scale that permits replication; the same guidance is relevant for new valuation studies (Boyd et al. 2016; Johnston et al. 2012, 2017b).

3.6 Auxiliary Data

Auxiliary data that are not provided in study-site documentation and that can enhance transfer accuracy should be used when available.

It is rarely the case that a credible benefit transfer can be implemented using only data available from the publications that provide study-site value estimates. Study-site data often require augmentation with secondary data to assist in calibrating these estimates. Auxiliary data may be required because some information is not reported consistently across study sites (e.g., average income for the sample) or to describe study-site conditions (e.g., data on substitutes). Such auxiliary data can facilitate matching benefit-transfer predictions to policy-site conditions beyond what is possible using information from study-site documentation alone. The full complement of relevant auxiliary data may not be fully understood until after relevant study sites have been identified and a transfer method is selected. The availability of such auxiliary data may also influence the selection of the transfer method, so that recursive decisions may be needed on transfer methods (Fig. 1).

Certain types of auxiliary data are commonly required. Examples include consumer price index information used to convert study-site value estimates to current monetary units. Other commonly used types of data include income and other demographic information from census data or purchasing power parity adjustments relying on data from the World Bank or other organizations (World Bank 2020; e.g., Ready et al. 2004; Czajkowski and Ščasný. 2010; Van Houtven et al. 2017). Additional auxiliary data may be required to populate variables within a benefit-function transfer. For example, a single-site function transfer requires data for the explanatory variables to develop the policy-site value estimates, e.g., information on substitutes and complements, data on geospatial features such as the areas affected (e.g., the size of a waterbody over which water quality will improve) or distances between households and environmental changes. These and other types of auxiliary data can assist in calibrating the transfer-value estimate to policy-site conditions.

Meta-function transfers often provide the opportunity to use a larger number of variables to calibrate transfer predictions. To construct variables for features that vary across studies

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[55] See, e.g., https://www3.epa.gov/airnow/aqi_brochure_02_14.pdf, accessed April 19, 2020.

auxiliary data are frequently required. Illustrative examples include data on baseline conditions and changes in environmental quality, regional or landscape characteristics in meta-analyses of hedonic property value studies (e.g., Smith and Huang 1995; Klemick et al. 2018), or data on water body, landscape, population, and market characteristics in meta-analyses of water quality or wetland values (e.g., Van Houtven et al. 2007; Brander et al. 2012a; Moeltner et al. 2019; Johnston et al. 2005, 2017a, 2019). Auxiliary data of this type is frequently derived from GIS data layers on a myriad of environmental, landscape and population characteristics, thereby providing a source of consistently measured and often quality-controlled information that may be applied to all observations in the metadata.

Auxiliary sources may also be used to fill in missing values. For example, some studies document income and others do not, and income data from the census might be used to fill in missing values or to provide a consistent measure of this explanatory variable across all study-site value estimates. As another example, Moeltner et al. (2019) used GIS data on wetland areas that were missing from a subset of study-sites.

If data are missing for some observations on a study-site characteristic, the analyst must decide if this omission is so grievous that the study should be excluded, if auxiliary data can be used as a suitable replacement, or if data imputation should be employed to replace missing observations. If the analyst decides to use auxiliary data to populate missing observations, then they must also decide whether external data should be used to populate all observations for the variable or only those for which data are missing. For example, if data on income are missing for some observations but not others, the analyst considering auxiliary data can either (a) use census data to provide consistent income measures for all observations, or (b) use census data to fill in missing income values only. There is a tradeoff in choices of this nature. Whereas the former option ensures consistent measurement of income across all observations, it discards study-provided data that may provide a more accurate measure of income for the studied sample.

Additional issues must be considered when seeking to populate missing data. For example, when auxiliary data are used to populate this missing data, the observation framings should be as similar as possible to the study-site context. Continuing with the income example, census tracts should be selected that match those from which the study-site sample was drawn. Data measurement and consistency concerns should be a primary factor determining how the data are developed using combinations of study-site, auxiliary and imputed data. Ramifications for econometric estimation should also be considered (Boyle and Wooldridge 2018).

The extent of data augmentation should also reflect time, cost, accessibility, and data relevance. As in all empirical analyses, one must balance the benefits of additional data (in terms of validity and reliability) with the cost and feasibility of obtaining the data. In today's increasingly data-rich environment, data needed to enhance transfer accuracy can often be obtained with little difficulty. However, matching data, such as GIS data measured in different spatial dimensions, can be time consuming. The analyst should justify the use of axillary data to enhance transfer estimates while acknowledging data limitations.

3.7 Data Analyses

Transfer methods should adhere to recommended practices for the underlying analytical methods that are applied. These include the use of established theoretical and empirical methods for all types of transfers and additional best practices for the estimation and use of meta-analysis.

Benefit transfers rely on a wide range of underlying procedures—including theory to interpret findings, econometric methods to predict values and biophysical modeling/data to predict changes in environmental conditions—for which guidance is provided in broader research literatures. It is beyond the scope of this paper to provide guidance on all aspects of good practice related to these underlying methods. Transfer procedures should hence adhere to practices recommended in the broader scientific literature, beyond guidance specific to benefit transfer. To a certain extent this recommendation is obvious and parallel to that which would apply to any form of economic analysis. As a result, and because best-practices vary according to factors such as data availability and the selected transfer method, we illustrate it using only a few often-encountered examples.

Relevant recommendations include guidance found in economic theory, statistics and econometrics literatures, along with guidelines applicable to the use and interpretation of results from valuation methods used to support the transfer. Additional best practices apply to the estimation and use of meta-regression models for economic value prediction (Nelson and Kennedy 2009; Boyle and Wooldridge 2018). Guidance from the biophysical, health and spatial sciences (or other fields such as engineering) may be applicable to implement and/or interpret non-economic components of benefit-transfer procedures. Adherence to applicable best practices such as these may require guidance from experts in these disciplinary fields. Practitioners should obtain guidance of this type as needed to support benefit-transfer applications.

Regardless of approach, all transfer methods should provide study-site value estimates consistent with the theoretical and contextual foundations outlined in prior recommendations. Empirical methods should flow directly and transparently from the conceptual and theoretical foundations for the transfer. The analyst should verify that the values or functions used to support the transfer have been produced in ways that are consistent with both recommended practices for the underlying valuation methods and the intended uses of the information within benefit transfer procedures (Freeman et al. 2014; Champ et al. 2017; Johnston et al. 2017b; Bishop et al. 2020; Lupi et al. 2020). Guidelines such as these can be used to help validate the original study-site value information, provide confidence that measurement errors are minimized, and ensure that study-site value information is used in a way that is generally consistent with its theoretical and empirical foundations. Beyond this general recommendation, best practices generally increase in sophistication and rigor as transfer methods become more complex.

Value transfers should describe how study-site conditions match policy-site value conditions and should justify adjustments made to calibrate the study-site value to policy-site conditions (e.g., Rolfe et al. 2015c). Calibrations should follow practices found in the literature to enhance accuracy for each type of adjustment, for example the transformation of values to account for variations in income (Czajkowski and Ščasný 2010; Hammitt and Robinson 2011; Barbier et al. 2017; Czajkowski et al. 2017). Ad hoc calibrations (i.e., those not supported by application-specific context or generalizable empirical/theoretical evidence) should generally be avoided. Study-site values used in the transfer and value adjustments should be documented. If the transfer involves multiple study-site estimates, for example the transfer of a measure of central tendency from prior estimates (mean or median), then error bounds for the value of pooled study-site values should be reported, along with the measure of central tendency. Any weights or other transformations of the data that are applied when calculating these central-tendency measures should be documented and justified with respect to the same criteria.

When a study-site benefit function is used to implement the transfer, the analyst should consider the extent to which the estimated equation reflects key economic concepts such

as diminishing marginal utility, substitutes and complements, anticipated spatial and temporal patterns, and selection effects, as relevant to the valuation context.[56] The capacity of the function to accommodate one or more theoretical constructs or expectations should be viewed within the context of study- and policy-site conditions. For example, as noted above, while diminishing marginal utility is expected for many types of transfers, there are others for which this pattern is not required to ensure validity and reliability. Transfers may occur for situations wherein constant marginal utility is a reasonable assumption.[57] The analyst must further decide if the function prediction applies directly to the policy site or whether further calibration may be needed to meet policy-site conditions. For example, does the function contain covariates that allow a customized value prediction that reflects the policy-site baseline condition, change to be valued, affected population characteristics (such as income) and other relevant site features? Any further calibrations to the value prediction should follow the same guidance relevant to value transfers.

Estimated benefit functions may allow for the calculation and reporting of error bounds on the value prediction. This can provide some insight on the potential reliability of the transfer. Inferences of this type imply an "as-if" assumption that the study-site value estimates provide insight on what the characteristics of the policy-site values *would be* if parallel study-site value estimation were to be replicated at the policy site and resulted in the same coefficient and standard error estimates. However, the insight that can be drawn through such approaches is limited, and the analyst should consider whether these errors are likely to apply similarly to the policy-site prediction. The factors that influence the comparative validity and reliability of study-site estimates and policy-site predictions are complex, and a "more valid or reliable" study-site estimate does not necessarily imply that the policy-site prediction will share similar properties. The validity and reliability of all benefit-transfers depend on the study-site value estimates and the methods used transfer these estimates, where both can influence errors in value predictions.

Best-practice expectations for meta-function transfers must address two distinct issues. First, because all meta-function transfers involve *functions*, one must consider recommended practices applicable to all types of study-site function transfers. The analyst should also describe how study site-values in the meta-data collectively encompass policy-site conditions and address any concerns with transfers outside the range of the data (Newbold et al. 2018a; Johnston and Bauer 2020). These recommendations apply whether one uses an existing meta-function drawn from the literature or instead estimates a new benefit function using meta-regression analysis.

A second set of considerations is related to the econometric synthesis of data from multiple studies. These are relevant whether one is estimating a new meta-function or evaluating a preexisting meta-function. In either case, one should verify that data assembly and estimation procedures align with best practices for meta-analyses in general (Florax

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[56] The literature provides insight into the relevance of concepts such as these for benefit transfer (e.g., Bateman et al. 2006, 2011a; Brouwer 2006; Zandersen et al. 2007; Rolfe and Windle 2008; Rosenberger and Johnston 2009; Boyle et al. 2010; Johnston and Rosenberger 2010; Bliem and Getzner 2012; Fetene et al. 2014; Schaafsma et al. 2014; Schaafsma 2015; Lew and Wallmo 2017; Loureiro and Loomis 2017; Johnston et al. 2017a, 2018; He and Poe 2020).

[57] As a case in point, choice experiments often produce linear utility functions based on an implied assumption that considered changes are sufficiently close to the margin. Analysts should consider this issue when determining whether a choice-experiment benefit function is suitable for policy-site transfers, but this type of linearity should not be used as a prima facie litmus test to automatically exclude such functions (Carson et al. 2015).

et al. 2002; Stanley and Doucouliagos 2012; Stanley et al. 2013), along with best practices specific to benefit-transfer applications (e.g., Bergstrom and Taylor 2006; Nelson and Kennedy 2009; Nelson 2015; Rolfe et al. 2015b; Boyle and Wooldridge 2018).[58] These should include best practices in econometrics relevant to the use of meta-analyses to support the prediction of nonmarket values.[59] Among these, meta-functions should incorporate independent variables that capture key dimensions that are relevant for value prediction, along with variables that assist in calibrating value estimates to policy-site conditions. These include variables to account for such features as the baseline and extent of change being valued, geospatial dimensions of the change, relevant substitutes and complements, population characteristics such as income, and control variables that have been shown to be significant in study-site documentation. Issues discussed above related to welfare- and commodity-consistency are important to ensure validity.

Similar guidance applies to preference-calibration transfers, as these also require the use of data from multiple source studies. Development of these models requires attention to maintained assumptions on the structure of the utility function, as these are influential features in computing the policy-site value estimate. The logic supporting the assumed structure of preferences should be explained and assumptions defined clearly. Wherever possible, it can be informative to compare the empirical performance and value predictions of these predictions to those from reduced-form counterparts (Newbold et al. 2018b; Moeltner 2019), as such analyses can help reveal any tradeoffs that are implicit in the added theoretical structure. Conversely, it can be instructive to illustrate the consequences of using reduced-form (non-structural) approaches in terms of failures to achieve desirable theoretical properties. For example, how badly do reduced-form value predictions violate the theoretical properties that are assured by structural approaches, and what are the practical implications of these violations?

Insight on transfer errors may be obtained from convergent-validity tests that have investigated similar methods, as reviewed by sources such as Brouwer (2000); Rosenberger and Stanley (2006) and Rosenberger (2015). Kaul et al. (2013), and the convergent validity studies cited therein, provide further evidence on the potential magnitude of these errors.[60] This literature provides insight on issues ranging from the general performance of value versus benefit function transfer to more specific topics such as the extent to which convergent validity is enhanced by data synthesis approaches, transfers over quantity versus quality changes, the incorporation of spatial variables within transfer procedures, and different types of site similarity, among others (Rosenberger and Stanley 2006; Boyle et al. 2010; Kaul et al. 2013; Rosenberger 2015; Johnston et al. 2017a). When interpreting potential error bounds, it is important to consider not only the empirical evidence but factors that

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[58] Johnston et al. (2018) review the recent meta-analysis literature with respect to best practices such as these. A similar review of earlier meta-analyses in the literature is provided by Nelson and Kennedy (2009).

[59] As described by Boyle and Wooldridge (2018), econometric requirements for meta-analyses used to predict values can differ from similar models used to synthesize and characterize a literature. For example, the former implies greater attention to consistent measurement of the dependent variable, the importance of specifications that allow for potential nonlinearities, and can imply that different regression techniques should be used (e.g., OLS is generally preferred to WLS when the goal is value prediction).

[60] Older reviews are provided by Brouwer and Spaninks (1999) and Brouwer (2000), among others. Also see Boyle et al. (2010). Recent evidence suggests that median transfer errors are in the general vicinity of 35–45%, with Kaul et al. (2013) reporting a median error of 39% and Rosenberger (2015) finding median errors of 36% for function transfers and 45% for value transfers. These errors vary widely over different applications.

could not be controlled for in the transfer analyses that might increase or decrease random error, or that might bias estimates upward or downward.

3.8 Aggregation and Scaling

The extrapolation and aggregation of transfer-value estimates to the policy-site population should follow best practices established for welfare and benefit–cost analyses. Any benefit scaling should be justified with respect to the type of commodity and change in question, within the context of policy-site conditions.

A focus of benefit transfer is to develop study-site value estimates that are generalizable to policy-site population(s). For the most part, aggregation procedures for these estimates are similar to those within other policy applications involving primary study data, and similar guidance applies.[61] In original valuation studies, best practices for aggregation depend on factors such as sampling method, sample selection and response rates, and the use of appropriate adjustments to achieve results that represent the target population.[62] Additional analyses may be required to determine the extent of the market, or the areas or populations for which non-zero values exist (Loomis 1996, 2000; Bateman et al. 2006; Vajjhala et al. 2008), or to accommodate spatial heterogeneity (Bateman et al. 2006; Addicott and Fenichel 2019). The specifics of these considerations vary across studies and applications.[63] Assuming that appropriate steps were taken to achieve a representative sample for the primary study, the resulting value estimates may then be projected to the target population, either as representative (e.g., mean) values or using procedures that allow for heterogeneity across the population, depending on information needs.

Parallel concerns are relevant for benefit transfer. However, in addition to original-study concerns, benefit transfers face further questions related to generalizability, or the extent to which calibrated benefit-transfer estimates may be generalized to policy-site populations (Bateman et al. 2011b; Ferrini et al. 2015). The representativeness of the policy-site value estimate is influenced by such factors as the selection of study-site data and any adjustments to these data. These procedures form the foundation for policy-site values that are designed to represent the affected population. Accordingly, procedures used to aggregate predicted values over the policy-site population should be consistent with the prior procedures used to calibrate individual values to policy-site conditions. Moreover, the capacity of a transfer to calibrate for the effects of potentially important variables, such as income or spatial effects, may influence the extent to which the resulting information can be accurately applied to policy-site populations and how aggregation should be implemented.

In general, conditional on appropriate calibration of study-site data to reflect policy-site conditions, subsequent aggregation of predicted policy-site value estimates should follow established procedures for welfare and benefit–cost analyses (Brent 2006, 2009; Farrow and Zerbe 2013; Just et al. 2004; Zerbe and Bellas 2006). While the literature on

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[61] For example, see the guidance of Johnston et al. (2017b) applicable to the aggregation of stated-preference estimates. Theoretical issues related to welfare aggregation are discussed by Just et al. (2004).

[62] For example, within recreation demand modeling, the use of on-site versus general population sampling, together with the type of model that was estimated, influence sample representativeness and the ability to aggregate estimates in various ways (Lupi et al. 2020).

[63] For example, within a hedonic property value study, do homes that sold during the studied period represent all homes within the studied area? Within a stated preference study, do survey respondents represent the studied population?

benefit-transfer accuracy emphasizes the initial value prediction (e.g., per individual or household), choices and assumptions employed in aggregating value predictions to the target population size often have a greater impact on aggregate-benefit estimates than variations in other procedures (Bateman et al. 2006). This is also the case for original valuation studies. Thus, robustness analyses should be applied in the aggregation process, as it applies elsewhere in the transfer.

Some benefit transfers also include the *scaling* of benefit estimates over different affected areas or quantities of change (Bockstael et al. 2000; Bateman et al. 2006, 2011b; Brander et al. 2012; Rolfe and Wang 2011; Ferrini et al. 2015; Johnston et al. 2015b; Schaafsma 2015). This is a distinct issue from benefit aggregation. Aggregation typically involves the expansion of per household (or per person) value estimates over market areas (or groups of households within a population) to produce population-level welfare estimates. In contrast, scaling typically refers to the projection of values over different *quantities of change*[64] *or affected geographic areas* than were reflected in study-site data. For example, Brander et al. (2012, p. 397) describe geographical scaling-up as "the transfer of values that have been estimated for localised changes in individual ecosystem sites to assess the value of changes in multiple ecosystem sites within a large geographic area (e.g., country or region)." A stylized example considering only the quantity or scope of change would be scaling-up a value estimate from a study that considered a 1% change in regional bird populations to predict the value of a 20% change in the same type of bird populations. Scaling down would involve an opposite extrapolation.

Modest scaling adjustments are often encountered within benefit transfers, as the changes in environmental conditions (quantities or qualities) and affected geographic areas are rarely identical across study- and policy-sites. However, scaling procedures can jeopardize validity if the resulting value predictions violate theoretical or empirical expectations. Hence, benefit transfers should consider the potential implications of scaling procedures for validity and reliability, with respect to theory, prior empirical evidence, and policy-site conditions. Large-scale, linear (unadjusted or multiplicative) scaling of benefit estimates should generally be avoided, unless defensible means can be identified to calibrate the resulting estimates for patterns such as diminishing marginal utility, geospatial distance decay and other types of value heterogeneity, or evidence can be provided that scaling of this type is appropriate for the case considered. These types of considerations will vary across the type of environmental changes considered, the type of study-site information that is available, and the policy context (Bateman et al. 2006, 2011b, 2013; Rolfe and Windle 2008; Rolfe and Wang 2011; Brander et al. 2012; Ferrini et al. 2015; Schaafsma 2015; Artell et al. 2019; Johnston et al. 2019).

Multiple approaches may be used to accommodate differences in quantities of change and affected areas between study- and policy-sites. These can be implemented in ways that are consistent with theory, empirical expectations, and recommended practices for welfare analysis. Examples include the use of benefit functions that allow variations in marginal values as a function of the quantity of change or affected areas, and hence enable scaling to be applied in a way that is consistent with theoretical expectations and prior findings in the literature. Structural preference calibration approaches may be specified to accommodate the influence of quantities of change, affected areas, and other features of the valuation

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[64] We use the term "quantities" in a general sense to reflect the scope or magnitude of change in environmental conditions, realizing that these changes can represent environmental qualities (e.g., water quality) or quantities (e.g., hectares of forest).

context. One might provide evidence that marginal value for the change is not expected to vary substantially as a function of the proposed scaling (e.g., the social cost of carbon, Ferrini et al. 2015). In other cases, the quantities and areas of change may be similar across study sites and policy sites, so that scaling is not expected to influence marginal values in a substantive manner. However, naïve, large-scale "scaling up" or "scaling down" of unadjusted values can produce estimates that lack credibility (Bockstael et al. 2000; Rolfe and Wang 2011; Brander et al. 2012; Richardson et al. 2015; Johnston et al. 2018). Hence, the validity of any value scaling should be considered with respect to the methods that are applied, policy-site conditions and expectations for value predictions.

3.9 Robustness Analysis

Robustness analyses should explore the sensitivity of policy-site value estimates to decisions such as those associated with the selection of studies and value estimates, the transfer procedures that are applied, and assumptions about the extent of the market.

Robustness analyses to evaluate the sensitivity of value predictions are helpful to understand the impact of analysts' assumptions and decisions in the transfer process. As discussed above, the credibility of any empirical investigation depends on weight-of-evidence considerations. Robustness investigations can help provide this weight of evidence and are advisable when information is available to support them. Results of a single robustness analysis cannot (alone) establish or discredit an approach (Boyle et al. 2013, 2015). However, robustness analyses can provide the analyst with potential lower and upper bounds on the transfer estimate or perhaps a direction of potential bias. Such analysis also allows decision makers to decide if the study-site value estimate is sufficiently accurate to support a decision.

The types of robustness evaluations that should be conducted depend on the transfer method applied, the availability of information to inform the analysis, and the level of precision required to support the decision at hand. These investigations should not be undertaken for their own sake and not all investigations can or should be undertaken for any specific application. Rather, robustness analyses should be designed strategically based on insights from theory, the empirical literature, and assumptions and challenges applicable to each application. Considerations such as these should be used to identify aspects of the analysis that might substantially affect policy-site value estimates.

Examples include analyses that evaluate how analyst choices and assumptions affect the policy-site value estimate or whether the robustness-identified variation in value estimates is sufficient to potentially change a policy decision (Boyle et al. 2013, 2015). Among the most relevant are investigations to evaluate potential error bounds for the policy-site value prediction and the effects of assumptions and methodological choices on these error bounds. Although most reliability testing in the literature emphasizes absolute value errors, there may be situations in which the sign or direction of errors is also relevant (Boyle et al. 2010). As applicable to the types of analyses that support value predictions, robustness testing can extend to non-economic components of benefit-transfer procedures, including biophysical and geospatial analyses (e.g., the use of alternative ecological production functions (Bateman et al. 2011b) or biophysical measures to quantify environmental change (Walsh and Wheeler 2013; Zhao et al. 2013)).

As an illustration, when adjustments are made to convert study-site values to a common measurement unit, the analyst might consider if other choices/assumptions could have been

made and what the implications might have been.One might also consider whether there is a second-best study-site value estimate and the extent to which this estimate provides different insight regarding potential policy-site values, while noting differences in conditions of both study sites vis-a-vis the policy site. When a study function is used, one might consider the sensitivity of transfer results to alternative sources of explanatory variables used in the prediction, or alternative sources of the benefit function. When meta-analyses are estimated, one can consider the impact of influential observations within the metadata or the treatment of methodological covariates within value predictions.[65] When structural transfers are used, one might consider the impact of assumptions on the structure of utility. If more than one benefit-transfer procedure is possible, such as value- and function-transfer, these alternative approaches can be compared to investigate convergent validity.

Where possible, it can also be useful to report the results of sensitivity analysis that evaluates the impact of different measurement conventions on key results (e.g., Walsh and Wheeler 2013; Zhao et al. 2013). Analyses of this type can be informative if conversions depend on researcher-imposed assumptions (e.g., the discount rate) or when seemingly innocuous decisions regarding measurement units for explanatory variables have a major impact on benefit-transfer predictions (Johnston and Zawojska 2020). These and other types of investigations can help engender confidence that due diligence was applied when developing value estimates, and to identify components of the transfer that might have a large impact on these estimates.

Many areas of the literature provide sparse insight into robustness testing. However, the literature *does* provide insight into the robustness of meta-function transfers. For example, when an original meta-function is estimated, leave-one-out convergent validity tests can be conducted in which study sites and/or study-site value estimates are omitted from the analysis one at a time, with each omitted observation then used as an individual hold-out sample for validity testing (Brander et al. 2007; Lindhjem and Navrud 2008; Stapler and Johnston 2009; Boyle et al. 2013, 2015). Analysis of this type can provide insight into the sensitivity of various outcomes, including meta-function coefficient estimates, value predictions and possibly transfer errors.

As with all types of robustness testing, care is warranted when interpreting results.

For example, just because a study or value estimate, groups of studies or value estimates, or another analyst decision is shown to be influential does not mean they invalidate the transfer or should be excluded. The analyst must use discretion when determining how to proceed based on the results of such evaluations. For example, it is possible that influential studies/observations are more closely related to the policy site than non-influential studies/observations, and in such cases should be retained. It is also possible that influential and non-influential studies or observations combine to collectively describe the policy site and provide information necessary to support the policy-site value prediction. In such cases, the potential influence of one or more studies may be a statistical artifact related to the data available to support the transfer. Hence, caution should be exercised before omitting studies. Considerations such as these speak to the importance of the weight of evidence when investigating the robustness of transfer estimates.

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[65] Studies such as Johnston et al. (2006), Moeltner et al. (2007) and Stapler and Johnston (2009) explore how value predictions vary depending on the treatment of study methodology within meta-functions used for benefit transfer.

3.10 Reporting

Reporting should document all key components of the transfer exercise. This should include reporting on key study- and policy-site characteristics, data used in the transfer, transfer procedures, analyst assumptions and resulting value predictions.

Complete and transparent reporting is a key component of replicability, which is a foundation of credible scientific investigation (Huntington-Klein et al. 2021). Benefit-transfer reporting should follow the same type of best practices applicable to all types of value estimation (Loomis and Rosenberger 2006). Documentation should report the full suite of procedures and assumptions employed, starting with study-site selection and following through to value aggregation and robustness testing. Comprehensive and transparent reporting is necessary for users of transfer estimates to evaluate maintained or implied assumptions, the theoretical foundations of the transfer, and methods that are applied. This documentation not only supports the scientific credibility of the transfer estimates but also ensures that the policy-site value predictions are used appropriately. As many of these reporting expectations are described as part of the prior recommendations, we limit the discussion here only to aspects of reporting that were not covered sufficiently above.

As the foundation for benefit transfer credibility rests largely on content validity, documentation should explain how methods and assumptions are consistent with best practices such as those described here. No single article can provide detailed guidance for the nuances of all types of transfer applications, so reliance on insights from other literature is critical. Where there are deviations from recommended practices, the justifications for such deviations should be explained. When there is no clear guidance, the logic for assumptions and methodological choices should be justified. These are among the areas where robustness analyses are important.

A distinct aspect of benefit transfer is its reliance on previously provided study-site information from published or grey literatures. Accordingly, analysts should identify studies and data sources used within transfer procedures as well as those considered but not used. One should report key descriptive information and results gleaned from each study, such as reporting on the valuation procedures used and the observations drawn from each study (Nelson and Kennedy 2009 and Boyle and Wooldridge 2018). Summaries of relevant data (e.g., WTP estimates derived from each study and how they were obtained or calculated) should be provided. If the number of studies and their value estimates is too large to permit inclusion of this information in published documents, supplemental or online appendices can be used. Reporting should also describe the methods used to select studies and observations used within the transfer.

Stanley et al. (2013) provide consensus reporting guidelines for economic meta-analysis, including recommendations for literature searching, compilation and coding. Similar guidelines are relevant to all benefit-transfer methods and reporting. Among the items recommended by Stanley et al. (2013, p. 392) is a "full report of how the research literature was searched," including but not limited to "the exact databases or other sources used," "the precise combination of keywords employed" and "the date that the search was completed." Also recommended is a "full disclosure of the rules for study (or effect size) inclusion/exclusion," along with "a list of all studies included and a description of why others were excluded," and "an explicit description about how measured effects are comparable."

Other data collection and screening protocols should be reported, as relevant to the transfer and as described above. For example, where and how auxiliary data are used,

and the sources of those data should be documented. Documentation should describe whether information on variables such as household income was derived from primary studies or gathered from auxiliary sources. If information is obtained directly from primary study authors, this should also be reported. Other procedures used to obtain data should also be described (e.g., requests for relevant studies through identified email lists), including data sources used.

Finally, a key issue in any benefit transfer is whether the value prediction is sufficiently accurate to support the decision at hand. Thus, reporting should include all transfer analysis procedures and adjustments, including robustness analyses as well as information on potential error bounds for the policy-site value estimate. However, an inability to provide specific types of information on transfer accuracy (e.g., error bounds on predictions) should not be used as prima facie grounds to dismiss transfer procedures as invalid.[66] In cases such as these, the reasons why specific reporting is infeasible should be described, and the analyst should attempt to draw on insights from the literature that might shed light on the validity of the estimate.

Complete and clear reporting enables users to make a weight of evidence evaluation regarding the appropriateness of the methods that were applied and the credibility of the transfer estimate. As a foundation for credibility, many economic journals further encourage authors to post data and code in ways that enable direct replication of key results. These initiatives are not restricted solely to benefit transfer. Although public posting of this type need not be a required element of benefit-transfer reporting (and can be precluded if the transfer involves private information), when possible, it can help to promote transparency and credibility.

4 Research to Advance Benefit-Transfer Practice

Past works discuss research needs for benefit transfer.[67] Building on this prior work, we emphasize a few key impediments to benefit-transfer practice for which research and attention are warranted. These are issues that were encountered repeatedly when developing consensus around the recommendations presented above.

First, original valuation studies are not typically conducted or documented in a manner that supports benefit transfers. This can lead to questions regarding the suitability of specific types of study-site data for policy-site benefit-transfer applications. Research is needed to document whether and how different types of study-site information can (or cannot) be used to support credible transfers. For example, Lovell et al. (2004, p. 26) note that "many valuation studies […] estimate the value of an arbitrarily large change in the resource for illustrative purposes without considering what the plausible range of changes might be for a real policy."[68] In addition, primary studies often report values for small geographical areas, whereas policy applications are often made at the state, multi-state or national level (Newbold et al. 2018a; Johnston and Bauer 2020). Questions may also be raised regarding the shelf-life of study-site value estimates (Boyle et al. 2017; Smith 2018).

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[66] For example, some types of value transfers may not permit one to calculate expected error bounds, if insufficient study-site reporting is available.

[67] For example, see Wilson and Hoehn (2006), Rosenberger and Johnston (2009), Boyle et al. (2010), Johnston and Rosenberger (2010), Johnston et al. (2015c, 2018), and Smith (2018).

[68] The issue is also discussed by Newbold et al. (2018a).

Past works have called for additional emphasis on the provision of high-quality, well-documented estimates of non-market values designed to meet benefit-transfer needs (McComb et al. 2006; Johnston and Rosenberger 2010; Loomis and Rosenberger 2006; Rosenberger and Johnston 2009). However, "pressure from publications to create novel methods or formulations has resulted in an abundance of studies that are distant from the day-to-day needs of policy makers" (McComb et al. 2006, p. 471), and a "lack of adequate [empirical] studies for benefit transfer" (Loomis and Rosenberger 2006, p. 344). Related concerns include inconsistent reporting of study-site conditions and study methods (Loomis and Rosenberger 2006) and a lack of consistent variable measurement across studies.

The literature has not yet proposed a solution to these ongoing challenges, all of which relate to the content of the primary-study valuation literature. Some could be ameliorated, however, by enhanced reporting requirements within peer-reviewed journals, such as a requirement for original studies to provide descriptive information for all key variables that documents data sources and units of measurement, along with other reporting elements described in the literature (Loomis and Rosenberger 2006). Reporting of this type could be incorporated into supplementary documentation such as online appendices.

More research is needed on benefit-transfer accuracy, including the relevance of different types of site similarity and potential calibrations. Among these needs, greater insight is required into the dimensions of site similarity or consistency that are most important for calibrating value predictions. As described by Johnston et al. (2018, p. 186), "research considering different dimensions of similarity often emphasizes case study results showing variously that (a) some but not all transfers are valid, (b) some but not all dimensions of similarity or associated adjustments influence transfer validity and reliability (e.g., Czajkowski and Ščasný 2010; Bateman et al. 2011a; Östberg et al. 2013; Moeltner and Rosenberger 2014; Brouwer et al. 2016; Andreopoulos and Damigos 2017; Czajkowski et al. 2017)." This research alone is not sufficient to guide decisions regarding the role of site similarity within transfers. Generalizable insight is required into the how dimensions of site similarity and value calibrations to study-site conditions influence benefit-transfer accuracy.

These investigations should be conducted for plausible and likely policy applications and not simply for cases where two or more value estimates are conveniently available investigate convergent validity. The current convergent-validity literature is dominated by tests in which the results of otherwise identical valuation methods are compared across sites. Tests such as these can provide insight regarding validity and reliability. However, "the capacity of these case studies to generalize is unclear, and it is not always evident that identical research designs *should* be applied across multiple sites" (Johnston et al. 2018, p. 220). The common practice of comparing the results of identical research designs across multiple sites may not provide an accurate perspective on the types of errors that occur in actual decision-making contexts, where primary study valuation methods are tailored to individual conditions at each study site and vary, sometimes substantially, across sites (Carolus et al. 2020).

The selection of transfer methods within the literature is also endogenous and determined by available data. For example, data synthesis methods tend to be illustrated in the literature under different conditions (e.g., when there is a well-developed research literature) than those where site-to-site methods are applied. Due to this endogeneity, it can be difficult to disentangle the effects of benefit-transfer procedure(s) from those of available study-site information and study applications. Ambiguities such as these can lead to inconclusive guidance for practice.

Reflecting these information needs and research challenges, we encourage novel and purposeful investigations of benefit transfer accuracy that enable the effects of site similarity, transfer assumptions and procedures, and other considerations to be more clearly identified. Research is also needed to bridge the gap between the structural benefit-transfer literature (which tends to emphasize consistency of predictions with predetermined theoretical criteria) and other work in benefit transfer that emphasizes empirical performance and accuracy (e.g., considering empirical criteria such as econometric performance and convergent validity). These approaches should coordinate economic theory, innovative research design and external evidence to provide insight unavailable from current approaches. This research should be conducted in a systematic, predesigned and experimental manner that controls for factors that have confounded prior tests. This suggestion does *not* imply that current benefit-transfer testing procedures should be discontinued—this literature improves important information to inform transfer procedures. However, novel approaches are critical to further advance methods.

5 Conclusions

The development of consensus guidance for benefit transfer is challenging, in part because the method is applied when practical constraints preclude the use of primary studies to estimate values. In such constrained contexts, the imposition of overly rigid methodological requirements may prevent benefit estimation entirely. Hence, excessively stringent best practice requirements can have an unintended and perverse effect of *reducing* policy efficiency—because imperfect but nonetheless informative benefit transfer estimates of value may be replaced with a default assumption of *zero* quantifiable value for environmental and natural resource improvements (Boyle et al. 2017). Hence, although there are advantages of best practice standards in terms of harmonizing methods and enhancing the validity and reliability (and therefore credibility) of benefit-transfer estimates, there can be disadvantages if inflexible guidance leads to the elimination of imperfect-but-useful information from decision-making.

In the context of contingent-valuation studies designed to estimate study-site values Diamond and Hausman (1994) asked "is some number better than no number?". Some may ask a similar question for benefit transfer: Can the reuse of existing valuation information provide estimates of sufficient quality to support decision making? Our response is that this concern relates to the roles benefit transfer could play within decision-making and should be answered in relation to different decision-making contexts. For example, if the transfer is a probing exercise to determine if an original study is warranted, then the "quality bar" for acceptability may not be so high. On the other hand, if information from the transfer is used to support a major decision that will have large benefits and costs and/or may affect many people, and the study will be influential in the final decision, then more rigor is warranted. However, even in this case*, some number may well be better than no number*, conditional on the provision of sufficient information for decision-makers to evaluate the potential accuracy of the resulting information.

For example, suppose a policy-site value estimate indicates that the benefits of a policy greatly exceed the costs, even if the error bounds on the value estimate are large and one assumes the lowest possible benefit within these bounds. In cases such as these, benefit transfers can enhance policy efficiency, even if the point estimates are inaccurate.

Considerations such as these are contextual and should be evaluated on a case-by-case basis. As a metaphor, most common household cooking thermometers are inaccurate by scientific standards, yet their use can still reduce the probability of illness due to under-cooked food. These devices provide useful information that improves decisions, despite their inaccuracies. However, there may be other circumstances wherein more accurate measurements are required.[69]

With these goals in mind, this article has proposed practical guidance to support valid and reliable transfers. The guidance is intended to inform the development of methods that balance the need for credible information with a recognition that decisions are made within a constrained setting. A second but equally important goal is to encourage research to improve these methods over time. Where there is disagreement on the recommendations we have presented, we hope that this will spur future work. With this latter goal in mind, we emphasize that the proposed guidance is meant to inform benefit transfer methods used to inform decision-making and is not meant to restrain methods used for exploratory research and publication. If research designs to explore alternative benefit transfer methods require techniques that depart from the suggested practices, we encourage this to expand knowledge. Moreover, although we have provided recommendations that are broadly applicable, all studies must consider context-specific aspects.

In closing, we welcome those who lend their efforts and expertise to improving this influential method of policy analysis. We hope that this paper encourages the use of benefit transfer to support decision-making and stimulates research in this important area of inquiry.

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