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# Site Correspondence Effects in Benefit Transfers: A Meta-Analysis Transfer Function

By

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**Abstract:** Several factors can affect the validity and reliability of benefit transfers. This paper proposes the existence of a meta-valuation function and uses meta-regression analysis to estimate this function. The meta-valuation function controls for systematic effects of differences in sample and site characteristics on the magnitude of error associated with an experimental benefit transfer. Validity measures are derived through various specifications of multi-site and single-site travel cost demand models for hiking on a variety of trails in Colorado. The results show that some characteristics account for a large portion of error in the benefit transfer application. When the meta-regression analysis function is adapted for benefit transfer estimation, it results in more accurate and reliable transfer measures than traditional methods. (JEL Q20)

## 1. Introduction

Benefit transfer is the adaptation of existing information or data to new contexts. Benefit transfer has become a practical way to inform decisions when primary data collection is not feasible due to budget and time constraints, or when expected marginal payoffs from primary data collection are small. Primary research is conducted to address valuation needs for a specific resource, in space and time, while benefit transfer uses existing information about similar resources and conditions. Traditionally, the context of primary research is referred to as the study site, and the benefit transfer context is referred to as the policy site. Benefit transfers include two general approaches: value transfers and function transfers. Value transfers are the use of point estimates of value or range of point estimates of value. Function transfers entail the adjustment of a valuation (benefit or demand) function from a study site to characteristics of the policy site. The degree of correspondence between the study site and the policy site determines the validity of a benefit transfer.

Benefit transfer is potentially a very important tool for policy makers since it can be used to estimate the benefits of a study site, based on existing research, for considerably less time and expense than a new primary study (see, for example, *Water Resources Research* 28(3) (1992), and Krupnick (1993) for a discussion of the concept of benefit transfer and Brookshire and Neill (1992) and Desvousges et al. (1998) for reviews of the issues and problems involved with benefit transfer). The primary obstable to realizing this potential is developing an accepted framework for assessing the magnitude of error, termed generalization error, involved in benefit transfer (Rosenberger and Loomis, forthcoming; Smith and Pattanayak 2002).

Generalization errors arise when estimates from study sites are adapted to policy sites. These errors are inversely related to the degree of correspondence between the study site and the policy site. Validity measures have been used in past studies to test for the accuracy of benefit transfers (Table I). These measures specify the difference between the known value for a policy site[1] and a transferred value to the policy site. Little research has been conducted on the relationship between these measures and the factors that affect them. These factors include the quality and robustness of the study site data, the methods used in modeling and interpreting the study site data, analysts' judgments regarding the treatment of study site data and questionnaire development, other errors in the original study, and the physical characteristic, attribute, and market correspondence between the study site and the policy site (Bergland, Magnussen, and Navrud 1995; Boyle and Bergstrom 1992; Brouwer 2000; Desvousges, Naughton, and Parsons 1992). Protocols for conducting benefit transfers have been suggested as an attempt to minimize the effect of these factors on benefit transfer error (Rosenberger and Loomis 2001, forthcoming).

*[TABLE I ABOUT HERE]*

This paper presents the results of a project that goes beyond traditional tests of validity by relating validity measures to site correspondence factors and estimating a meta-valuation function. The practice of benefit transfer has a necessary, but generally implied, assumption that there exists a meta-valuation function from which values for a specific resource can be inferred. The validity or accuracy of benefit transfers depends on the robustness and stability of this valuation function and the degree of information existing for a specific resource. Other implicit assumptions not explicitly addressed in this paper include the ability to capture differences between the study site context and the policy site context through a price vector. This assumption is that the multi-dimensionality of site characteristics is reducible to a single dimension price variable (Downing and Ozuna 1996; Smith, Van Houtven and Pattanayak 2002).

A tertiary assumption is that values are stable over time, or vary in a systematic fashion that is captured in a price deflator index (Eiswerth and Shaw 1997).

This paper is an empirical test of our assumption regarding the existence of an underlying valuation function. If we treat individual, site-specific value measures as unbiased estimates of points on an underlying valuation function, then meta-regression analysis of these individual measures may enable us to estimate this valuation function. The resulting meta-regression analysis function should enable us to control for methodological differences in primary research and differences in site characteristics, resulting in more accurate benefit transfers. Primary research is traditionally reductionistic by collecting data and estimating values for a single site, without examining the broader valuation context. For example, individual site models cannot account for the effect of modeling decisions and site characteristics on site values because these factors are, by default, held constant. The valuation function places these individual studies in a broader context that models how values are related to factors across sites and studies.

To meet the objective of this paper, we have structured it as follows. A conceptual illustration of a meta-valuation function is provided. The site correspondence and the meta-regression analysis models are then developed, followed by a description of the data. Validity measures based on a traditional benefit transfer method using several multi-site and single-site travel cost models are calculated. These validity measures are then related to correspondence measures between the study sites and policy sites based on the physical characteristics of the sites and the characteristics of the sample populations. If there are statistically significant relationships between benefit transfer error and site correspondence, then we may be able to model these stochastic effects using meta-regression analysis. The meta-regression analysis benefit transfer function is estimated and applied, illustrating the gains in accuracy over the traditional benefit transfer methods used. The paper ends with a discussion of the results and issues encountered in this research.

## 2. Meta-Valuation Function

Figure 1 is a conceptual illustration of the proposed meta-valuation function. First, let us assume there is an underlying or meta-valuation function, *F(V)*. *F(V)* is a function that links the values of a resource (such as wetlands) or an activity (such as downhill skiing or camping) with characteristics of the markets and sites, across space and over time:

$$F(V) = [g(A); g(B); g(C)], \text{ where} \tag{1}$$

$$g_i(\cdot) = g_i(MK_i, SC_i, SP_i, T_i). \tag{2}$$

The meta-valuation function (*F(V)*) is the envelope of a set of study site functions (*g(.)*) that relates site values to characteristics or attributes associated with each site, including market characteristics (*MK*), physical site characteristics (*SC*), spatial characteristics (*SP*), and time (*T*). Market characteristics may include factors such as individual preferences, socio-economic status (income, age, education, health), socio-cultural characteristics (attitudes, beliefs, dispositions), and socio-political influences (institutions, regulations, citizen participation). Physical site characteristics may include factors such as quality and diversity of the site, resource composition and complexity, and other physically measurable and observable factors. Spatial factors may include distance from point of origin to the site, scope or scale of the site, geographic location of the site, and diversity of the surrounding region. Temporal factors may include such issue as stability of demand and supply and socio-cultural evolution (changes in tastes, values, preferences, knowledge). The degree that any of these sets of factors affects benefit transfer accuracy is an empirical question. Some research illustrates the efficiency gains from calibrating preference functions (Smith and Pattanayak 2002; Smith, Van Houtven and Pattanayak 2002).

*[FIGURE 1 ABOUT HERE]*

We hypothesize that primary research projects attempting to value a resource at a specific place, for a specific market, at a point in time, are randomly sampling from this function. How close the original research project gets to estimating the actual or 'true' value from the meta-valuation function depends on the quality of the research and the assumption that there is one true value for the resource at that place, for these people, at this point in time. Thus, in Figure 1, $g(A)$, $g(B)$ and $g(C)$ are independent site-specific functions estimating the value of the same (or similar) resource at three different locations. Assuming the primary research was conducted properly, *ceteris paribus*, the estimated 'true' value for each site is $V_{PA*}$, $V_{PB*}$ and $V_{PC*}$, respectively.

Benefit transfer validity tests typically assume the value estimated using primary research is the 'true' value for a site, or $V^P$. However, since $V^P$ is unobservable, primary research approximates it, $V_{pp}$. In terms of notation, let the subscripts be $s$ for a study site and $p$ for a policy site. In benefit transfer applications, the study site values $V_{ss}$ are used to inform the value of a similar, but unstudied, site. That is, $V_{ss}$ is transferred to a different, but similar site $j$, where site $j$ is the policy site. When the study site measure, $V_{ss}$, is transferred to the policy site, it becomes a transfer value, $V_{ps}$.[2]

$$V_{ps} = V^P + \delta_{ps}, \qquad (3)$$

where $\delta_{ps}$ is the error associated with the transfer of a benefit measure from site $i$ to site $j$. The empirical tests of the convergent validity, or accuracy in estimating $V^P$ by $V_{ps}$, presented in Table I are based on calculating the percentage difference between $V_{ps}$ and $V_{pp}$:

$$\%\Delta V_{ij} = [(V_{ps} - V_{pp})/V_{pp}] * 100 \qquad (4)$$

when $i \neq j$. Given equations (3) and (4), the convergent validity measures become $\delta_{ps}/V_{pp} * 100$.

There are two sources of variability in $\delta_{ps}$, and thus, errors in benefit transfers: (1) differences in the characteristics of the study site and policy site ($\phi_{ps}$); and (2) errors associated with estimating $V^P$ via $V_{pp}$ $(\varepsilon_i)$ (Woodward and Wui 2001). Figure 1 illustrates the potential generalization error associated with applying different benefit estimates to other sites. The individual site value distribution *g(C')* is a deviation from the 'true' distribution of the value for Site C (*g(C)*) by the amount $\varepsilon_C$. This source of error arises from poorly conducted primary research, such as poor sample design, questionnaire development, and other sources for bias (Mitchell and Carson 1989). Dealing with this form of error requires subjective judgments about the quality of primary research, and is beyond the scope of this paper.

The remaining form of error, which is the main thesis of this paper, is the error associated with the correspondence between the study site and policy site. In figure 1, $\phi_{CA}$ and $\phi_{CB}$ are the errors associated with using the distribution of value for Site A or Site B, respectively, to estimate the value for Site C given the differences in the site characteristics. For example, $\phi_{CA}$ is the error associated with adjusting *g(A)* by the characteristics of site C to estimate the value for site C, or $V_{PC(A)}$. This error arises in part because *g(A)* was not developed with the characteristics of site C in mind. However, the greater the correspondence, or similarity, of the two sites, the smaller the expected error (Boyle and Bergstrom 1992; Desvousges, Naughton and Parsons 1992).

Several of the studies listed in Table I support this hypothesis. Lower transfer errors resulted from in-state transfers than from across-state transfers (Loomis 1992; VandenBerg, Powell and Poe 2001). Socio-political differences are smaller for in-state transfers than for across-state transfers. In the Loomis et al. (1995) study, their Arkansas and Tennessee/Kentucky multi-site lake recreation models performed better in benefit transfers between the two regions (percent errors ranging from 1% to 25% with a nonlinear least squares models and 5% to 74% with the Heckman models) than either one when transferred to California (percent errors ranged from 106% to 475% for the nonlinear least squares models and from 1% to 113% for the Heckman models). This suggests that the similarity between the Eastern United States models implicitly accounted for site characteristic effects. VandenBerg, Poe and Powell (2001) show accuracy gains when they transfer values and functions within communities that have experienced groundwater contamination in the past, than transferring across states, within states, or to previously unaffected communities.

Several of the studies in Table I also support the hypothesis that generalization errors can be reduced by transferring functions instead of point estimates or values. Benefit functions enable the calibration of the function to differences between the study site for which the function was developed and the policy site to which the function is applied (Loomis 1992; Parsons and Kealy 1994; Bergland, Magnussen and Navrud 1995; Kirchhoff et al. 1997 (for the birdwatching model only); Brouwer and Spaninks 1999; and VandenBerg, Poe and Powell 2001 (pooled data models)). However, the gains in accuracy may be more a function of the similarity of the sites than the calibration of site characteristics in the function transfers. This is because most of the functions did not include variables measuring the physical differences between the sites, but socio-economic differences between the markets. Many of the physical differences important for calibrating values across sites are unmeasured in the original functions because these characteristics are fixed, or constant in individual site models.

## 3. Site Correspondence Effects

This paper focuses on the site correspondence factors affecting the validity of benefit transfers. Other factors such as time and research methodology are important, but they require additional assumptions that are beyond the scope of this paper. The correspondence between two sites, *i* and *j*, ($SC_{ij}$) is measured as the differences between study site *i* and policy site *j* based on observable measures of the distribution of market characteristics (age, gender, and income) and the distribution of physical characteristics (topography and other landscape features, resource qualities, and other measures of the physical attributes of the respective sites). We hypothesize that $\delta_{ij}$ is a function of several factors:

$$\delta_{ij} = h(\phi(SC_{ij}), \varepsilon_i) \tag{5}$$

where $\delta_{ij}$ is the generalization error associated with the transfer of study site measure *i* to policy site *j*. $\phi$, or the error associated with movements along the valuation function, is defined by $SC_{ij}$, which is a measure of the correspondence between characteristics of study site *i* and policy site *j*. $\varepsilon_i$ is the error associated with the study site measure. In equation (5), we hold $\varepsilon_i$ as a stochastic component of the study site.

Thus, the site correspondence model takes on the following form:

$$\%\Delta V_{ij} = h(\%\Delta SC_{ij}). \tag{6}$$

That is, the percentage difference in the value transfer from site *i* to site *j* ($\%\Delta V_{ij}$) is a function of the percentage difference in the characteristics of site *i* and site *j* ($\%\Delta SC_{ij}$), where $SC_{ij}$ includes characteristics of the sample population or market and physical characteristics of the study sites. Market characteristics can be measured in terms of the demographic profiles of the sample populations for the sites and the physical characteristics can be measured as the physical differences between the sites.

## 4. Meta-Regression Analysis Benefit Transfer Function

If we can identify the factors that determine the accuracy of benefit transfers, then, in theory, it should be possible to develop a transfer function that calibrates transfer measures ($V_{ps}$) based on these identifiable factors, resulting in more accurate estimates of $V^P$. We posit the existence of an underlying meta-valuation function based on aggregated individual preferences that determines individual site values and the distribution of the characteristics across all sites (figure 1). The valuation function (*F(V)*) illustrated in figure 1 is a cross-section of a multi-dimensional surface where the per unit total value for a site is a function of the characteristics of each site. This valuation function is an envelope function of individual site-value distributions (*g(A)*, *g(B)*, and *g(C)*) estimated from different studies. The goal of meta-analysis is to estimate this underlying meta-valuation function.

Meta-regression analysis is a statistical method for summarizing relationships between benefit measures and quantifiable characteristics of studies. Meta-regression analysis has been traditionally used to understand the influence of methodological and study-specific factors on research outcomes and to provide syntheses of past research (Stanley 2001). More recently, meta-regression analysis has been applied to benefit transfer (Desvousges, Johnson, and Banzhaf 1998; Kirchhoff 1998; Sturtevant, Johnson, and Desvousges 1998; Rosenberger and Loomis 2000b, 2001). One potential advantage of using meta-analysis functions for benefit transfer is the increased sensitivity of transfer estimates to characteristics of the policy site (Rosenberger and Loomis 2000b). This increased sensitivity is due, in part, to the robustness of the method to underlying distributions in primary data (Desvousges, Johnson and Banzhaf 1998). In Table I, Kirchhoff's (1998) results suggest that benefit function transfers outperform meta-analysis transfers. This is misleading in that the meta-analysis functions used in this study were not developed for benefit transfers, and the developers even cautioned against their use for benefit transfer purposes. However, in spite of these cautions, Kirchhoff (1998) found that existing meta-analyses outperformed or did as well as the benefit function transfers in Kirchhoff et al. (1997).

We define the meta-analysis valuation function as:

$$V_j = f(SC_j,\ \varepsilon_j). \tag{7}$$

That is, the benefit measure derived for site $j$ is a function of its market characteristics, its physical attributes, and error in the original study ($\varepsilon_j$). We can test whether the meta-regression analysis valuation function provides more accurate benefit estimates for a policy site than traditional benefit transfers. A hypothesis is:

$$H_0:\ \%\Delta V_{METAij} = \%\Delta V_{TRADij} \tag{8}$$

$$H_1:\ \%\Delta V_{METAij} < \%\Delta V_{TRADij}, \tag{9}$$

where $\%\Delta V_{METAij}$ is calculated in the same fashion as $\%\Delta V_{ij}$ ((2)). A one-tailed paired t-test may be used to test this hypothesis.

## 5. Data

### 5.1. SURVEY DESIGN

The data used in this analysis was collected in 1998 to investigate the effects of forest fires on the value of hiking and mountain biking (Englin, Loomis and Gonzalez-Caban 2001). Trails were selected in a stratified random sampling of past fire occurrences by age of fire and number of acres burned. Recreation users of the trails were sampled during July and August. Over a 35-day period, 10 trails were sampled on a weekday and a weekend day by intercepting recreation users as they returned to a trailhead parking area. They were provided with a statement regarding the purpose of the survey and a mail-back questionnaire. The questionnaire elicited information from the users about their primary activity on the trail, travel cost information (travel time, distance from home to the trail, travel costs, number of trips this year and last year to the current trail), and sociodemographics, among other questions. Table II provides a description of the variables used in this analysis. A total of 527 surveys were distributed with 354 being returned, for a response rate of 67 percent. For our purposes, we restrict the data to hikers and trails predominantly used by hikers in order to control for individual preference differences between hikers and mountain bikers. Therefore, the current sample consists of 127 respondents across six individual or combined trails in three National Forests. Some of the trails were combined based on similarity of characteristics and proximity to each other in order to improve the degrees of freedom in the analysis.

*[TABLE II ABOUT HERE]*

Three National Forests (NF) in Colorado (the Arapaho-Roosevelt NF, the Gunnison-Uncompaghre NF, and the Pike-San Isabel NF) were selected, providing a range of fire and trail characteristics (Table III). Two of the National Forests are along the front range of the Rocky Mountains with the other National Forest being interior to the mountains. The sample of 127 recreational hikers also provides a range of demographic characteristics (Table IV).

*[TABLES III AND IV ABOUT HERE]*

### 5.2. BENEFIT MEASURES

Figure 2 illustrates the development of the study site measures from various travel cost model specifications. Based on a single meta-database, several travel cost models are specified from various treatments of the data. These travel cost models are used to estimate Marshallian consumer surplus values $V_{pp}$ and $V_{ps}$. Table V provides an overview of the various travel cost variable specifications and whether sample and physical characteristics of the sites were included in the model specifications. The single-site, or trail-specific, models are assumed to provide measures of $V_{pp}$ for each trail ($j = 1,\ldots,6$). We assume the benefit measures based on these models is the 'true' value for each trail because each trail model's data is site-specific.

*[FIGURE 2 ABOUT HERE]*

The multi-site models provide the transfer values ($V_{ps}$). The multi-site models are general models of the value of hiking for a broader range of trails. Therefore, the benefit measures derived from these models are not specific to a single trail. Several specifications of multi-site models are developed. For the State Models, the entire database is used with three travel cost variable specifications, including an aggregate travel cost variable, forest-specific travel cost variables, and trail-specific travel cost variables. The N-1 models use the approach wherein data is pooled for all but the nth trail (Loomis 1992). These models result in ballpark estimates of the value to be transferred to the nth (or excluded) site. The Forest Models are developed from the data for a specific forest and two travel cost variable specifications, including a forest aggregate travel cost variable and trail-specific travel cost variables.

The basic form of the travel cost models is given by:

$$\ln Trips_{abi} = \alpha + \beta TC_{abi} + \gamma Demographics + \varphi Site\ Characteristics_i + \mu_{ab} + \varepsilon_i. \tag{10}$$

The dependent variable is the natural log of the number of hiking trips this year (a) and last year (b) to site *i*. Trips is a function of travel costs to site *i* this year (a) and last year (b), demographics of the respondent, and characteristics of site *i*. $\alpha$ is the intercept term and $\beta$, $\gamma$, and $\varphi$ are parameters to be estimated. $\mu_{ab}$ is the random panel effect accounting for the panel nature of the data (Rosenberger and Loomis 1999), and $\varepsilon_i$ is the common error component. A negative binomial random effects regression technique is used to estimate the various travel cost models.[3]

The benefit estimates derived from the travel cost models are measures of Marshallian consumer surplus. Consumer surplus is calculated by integrating the demand function (equation

(10)) over the relevant price or travel cost range, yielding consumer surplus per trip. The negative binomial random effects model is equivalent to a semi-log demand function. Therefore, consumer surplus can be simply calculated as $(-1/\beta_i)$, or –1 divided by the coefficient on travel cost (Adamowicz, Fletcher, and Graham-Tomasi 1994; Creel and Loomis 1990). In those models with forest- or trail-specific travel cost shift variables, the formula is $[-1/(\beta_1+\beta_2)]$.

Table VI provides the benefit measures for each of the travel cost models. The baseline measures are calculated from the trail-specific travel cost models and provide estimates of $V_{pp}$ for equation (3). The transfer measures of equation (3) ($V_{ps}$) are calculated from Model A through Model M (Table V). Table VI shows that there is a wide range of benefit measures from a low of \$12.12 per trip for Trail 1 to a high of \$248.85 per trip for Trail 4. Table VI also shows that there is an increase in the variability of hiking values as we progress from Model A (which provides a ballpark estimate of the value of hiking in Colorado), to more specific measures for a National Forest (Models B, D and F), to the value of hiking for a specific trail (Models C, E, G, and H through K).

*[TABLES V AND VI ABOUT HERE]*

### 5.3. VALIDITY MEASURES

Table VII provides the validity measures as percent differences ($\%\Delta V_{ij}$) ((2)) between the transfer value ($V_{ps}$) and the actual, or baseline value ($V_{pp}$). These measures provide an indication of the relative accuracy of the benefit transfer process when $V^P$ is known.[4] These measures are consistent with other empirical measures from the literature (Table I). The validity measures range from a low of about 4 percent underestimating the value of Trail 6 using Model G (a multisite forest model that includes Trail 6) to a high of over 900 percent overestimating the value of Trail 1 using Model C (a multisite state model with trail specific travel cost variables).

The average percent difference measures for each model ranged from an average of about 43 percent when using the forest-specific travel cost models with trail-specific travel cost shift variables (Models E and G) to over 200 percent when using the N-1 modeling strategy (Models H through M).

*[TABLE VII ABOUT HERE]*

There is not an apparent pattern to these validity tests. The state-level model with a single travel cost variable (Model A) does best for estimating the value for Trail 2, which has the largest number of individual observations in the model. By adding a forest-specific travel cost variable (Model B), the accuracy improves for nearly all trails. With the further addition of trail-specific travel costs variables (Model C), the state-level model accuracy improves for the two trails in the Gunnison/Uncompaghre Forest, but diminishing for the other trails and forests as compared to Model B. The forest level models with a generic travel cost variable (Models D and F) and those with trail-specific travel cost variables (Models E and G) generally perform better than the state-level models. This may be due to greater similarities within forests than across forests. The data splitting modeling approach (N-1 modeling, Models H through M) do not perform very well. This is potentially due to increasing the heterogeneity of the data underlying each model.

## 6. Estimating the Site Correspondence Model

This section estimates the site correspondence model. The validity measures presented in Table VII form the dependent variable in the site correspondence model (equation (6)). The explanatory variables are calculated in a similar fashion by applying equation (4) where $V_{ps}$ becomes demographic and site characteristic measures for site $i$, and $V_{pp}$ becomes the corresponding measure of the characteristic for policy site *j*. The specific form of the site correspondence model is:

$$\%\Delta V_{ijm} = \alpha + \beta_1\%\Delta GENDER_{ij} + \beta_2\%\Delta AGE_{ij} + \beta_3\%\Delta ELEV_{ij} + \beta_4\%\Delta GAIN_{ij} + \beta_5\%\Delta LONG_{ij} + \beta_6\%\Delta FIRE_{ij} + \beta_7\%\Delta WATER_{ij} + \beta_8\%\Delta PP_{ij} + \beta_9\%\Delta LP_{ij} + \beta_{10}\%\Delta ASP_{ij} + \mu_m + \varepsilon. \tag{11}$$

This model investigates the magnitude of the effect of differences in market and site characteristics between study site *i* and policy site *j* on the error associated with the transfer of a benefit measure from site *i* to site *j* using modeling strategy *m* (State, Forest, or N-1 models). In this model, $\mu_m$ is the panel-specific error component and $\varepsilon$ is the common error component.

The dependent variable ($\%\Delta V_{ijm}$) is of the panel data type; multiple observations are from the same source (modeling strategy). Identifying the strata or panels is an important component when dealing with panel data (Rosenberger and Loomis 2000a). In this case, the modeling strategy *m* is a potential source of panel effects. Three unbalanced panel strata are defined: (1) 18 validity measures are derived from applying the State Models A through C (Table VII), (2) ten validity measures are derived from applying the Forest Models D through G (Table VII), and (3) six validity measures are derived from applying the N-1 Models H through M (Table VII). A random effects generalized least squares regression technique is used because some of the regressors are invariant within a panel. A fixed effect estimator requires all regressors to have an intra-panel variance (Greene 1999).

Table VIII provides the results of the estimated site correspondence model. We have no prior expectations regarding sign and significance of the explanatory variables. The model has an adjusted-$R^2$ of 0.79. Interpretation of the estimated covariates is relatively straightforward. First, a significant variable in the regression indicates the variable has an effect on the accuracy of benefit transfers. Second, because the variables are unitless measures of percent difference between the study site and the policy site (equation (4)), a positive (negative) sign indicates that percentage differences between site characteristics and validity measures move with (against) each other. For example, a positive covariate means that when transferring a value from a short (long) trail to a long (short) trail the result is an overestimation (underestimation) of the policy site's value. Third, the larger the coefficient on each variable, the greater the effect on the accuracy of the benefit transfers.

*[TABLE VIII ABOUT HERE]*

Table VIII shows that the demographic variables (*%ΔGENDER, %ΔAGE*) are significant and positively related to the direction of error in benefit transfers, with differences in gender composition of the samples having over twice the effect as differences in the age composition of the samples. Differences in the lengths of the trails (*%ΔLONG*) are significant and positively related to the direction of error in benefit transfers. In descending order of the magnitude of their effect, differences in elevation (*%ΔELEV*), presence of water (*%ΔWATER*), and gain in elevation of the trail (*%ΔGAIN*) are significant and inversely related to the direction of error in benefit transfers. Tree cover type of the recreation sites, in particular the presence of lodgepole pine (*%ΔLP*) and aspen forests (*%ΔASP*), have somewhat significant, but opposite relationships with the resulting error in benefit transfers. However, tree cover type in Colorado is a function of elevation, although these variables are not statistically correlated in this dataset.

## 7. Meta-Regression Analysis Valuation Function

The final step in this analysis is to estimate the underlying valuation function for hiking values in Colorado's National Forests (equation (7)) using meta-regression analysis and to test for increased accuracy in benefit transfer over a traditional transfer approach (Table VII). The meta-regression analysis function acts as a calibration of the benefit measures to characteristics of the sites. The model treats each value measure (Table VI) as a random draw from the underlying valuation function. Therefore, the dependent variable in the regression analysis is composed of all benefit measures reported in Table VI.

The data for the meta-regression analysis function also is of the panel data type. The strata are the same as the site correspondence model above with the exception that there are now four strata: (1) 18 observations derived from the State Models A through C (Table VI); (2) ten observations derived from the Forest Models D through G (Table VI); (3) six observations derived from the N-1 Models H through M (Table VI); and (4) six observations derived from the Trail-specific models (Table VI). A random effects generalized least squares regression technique is used to fit the data. As noted above, a fixed effects specification is inappropriate because some of the panels are invariant in some of the regressors (Greene 1999).

The specific form of the empirical model is:

$$CS_{im} = \alpha + \beta_i TRAIL_i + \beta_6 ELEV_m + \beta_7 GAIN_m + \beta_8 LONG_m + \beta_9 FIRE_m + \beta_{10} PP_m + \mu_m + \varepsilon. \quad (12)$$

That is, consumer surplus ($CS_{im}$) for the $i^{th}$ trail using the $m^{th}$ travel cost model is a function of $TRAIL_i$ (a dummy variable identifying the trail where $i$ is Trail 1 through Trail 6 (Table III) with Trail 2 being the omitted variable), and site characteristic measures for trail-head elevation ($ELEV_m$), gain in elevation ($GAIN_m$) and length ($LONG_m$) of the trail, age of past forest fire events ($FIRE_m$), and ponderosa pine forest type ($PP_m$) for the $m^{th}$ model. $\mu_m$ is the panel-specific error component and $\varepsilon$ is the common error component. Several of the variables could not be included in the model because they were correlated with other characteristics of the trails or trail-specific dummy variables (e.g., *WATER* is a characteristic of Trail 3).

Table IX provides the results of the estimated meta-regression analysis valuation function. The adjusted-$R^2$ of the model is 0.72. Although only two of the variables (*Trail 3* and *LONG*) are significant at the 0.10 level or better, the majority of the other variables are significant at the 0.40 level or better. The coefficient estimates are the incremental consumer surplus per unit of the variable. The function can be adjusted to predict consumer surplus for a trail according to specific characteristics of the trail. Consumer surplus measures per trail are reported in Table X. These measures are calculated from the meta-regression analysis function by turning on (=1) or turning off (=0) the full effect of the trail-specific ($TRAIL_i$) and forest type ($PP$) dummy variables and adjusting each of the other variables according to the measure of the characteristic for a specific trail. If we use the same baseline consumer surplus measures as the target values used in previous assessments, validity measures ($\%\Delta V_{ij}$) can be calculated. These percentage difference measures range from –62 percent error to –2 percent error, with an average percent error of 20 percent (Table X).

*[TABLES IX AND X ABOUT HERE]*

We can now test the hypothesis (equations (6) and (7)) that the meta-regression analysis valuation function, when adapted as a benefit transfer function, provides more accurate measures of consumer surplus than using traditional benefit transfer approaches (Table VII). Table XI provides the results of one-tailed paired t-tests on the validity measures for the meta-regression analysis transfer (Table X) versus each of the different modeling strategies (by row comparison) in Table VII. The results show that we can reject the null hypothesis (equation (8)) that the two approaches result in equivalent levels of accuracy in favor of the alternative hypothesis (equation (9)) that the meta-analysis transfer approach is more accurate than the traditional value transfer approach for three out of six comparisons at the 0.10 significance level or better (Table XI). The three models that cannot be rejected at this significance level are those models that incorporate trail-specific travel cost shift variables (Model C) or the Forest models that are based on regional data (Models D and F, and Models E and G). At a significance level of 0.16 or better, we can reject the null hypothesis of equal accuracy in favor of the alternative hypothesis that the meta-analysis transfer is more accurate than the traditional approach (Table XI). This indicates that more specific modeling strategies result in more accurate benefit transfers.

*[TABLE XI ABOUT HERE]*

## 8. Discussion and Conclusions

This study investigated how differences in the market and physical characteristics of recreation sites are related to the errors associated with a benefit transfer process. In addition, an underlying valuation function was developed using meta-regression analysis. The valuation function statistically relates measures of physical attributes of recreation sites with their associated benefit estimates. This study does not provide definitive evidence regarding the methodology and outcomes described herein. However, it does begin the process of scientifically investigating the accuracy of benefit transfers and how different factors, as identified in the literature, affect them. As Bergland, Magnussen, and Navrud (1995) note, there is a need for research that specifically targets benefit transfers and/or is specifically designed for future benefit transfer applications. This study was undertaken for both of these reasons.

A site correspondence model is developed for hiking trips to several trails in Colorado. This model suggests that we can identify the effects of differences in the physical attributes of recreation sites on differences in value measures. Taking the constraints of the current dataset into account, we identified that error in the benefit transfer process was sensitive to differences in the sample's characteristics and differences in physical attributes of the sites. That is, a hiking trail is not necessarily a hiking trail, especially if their attributes are different such as degree of difficulty, landscape attributes, crowding, etc. It is not necessarily that these are different goods to be modeled differently, but that there are differences across the range of this good. That is, differences between measures of values for recreation sites are movements along an underlying valuation function. These differences must be captured in a broad model if the model is to perform reasonably well in benefit transfers. The meta-regression analysis valuation model we develop shows how the benefit transfer process is improved with models that are more sensitive to differences in the physical attributes of similar recreation sites. Our hypothesis test illustrates that valuation models sensitive to differences between sites performed better in benefit transfers than models providing ballpark estimates of value.

Resource managers and policy makers should consider the correspondence between their policy site and the available information from study sites. Lacking the ability to fully specify a meta-valuation function that takes into account the differences across the candidate study sites, resource managers and policy makers should choose candidate study sites by the degree to which they correspond, or are similar, to their policy site needs across physical attributes of the site and the affected market. By doing so, the literature and evidence provided in this study suggest that generalization errors may be minimized. Funding agencies and other interested parties should continue to support (and fund) primary research. It is primary research that samples from the meta-valuation function and provides information necessary in its empirical construction through the use of meta-analysis techniques. Without the addition of new information, the confirmation of existing information, and growth in our body of knowledge pertaining to the values of nonmarket goods, our ability to develop robust and valid benefit transfer functions is limited.

Two obvious improvements on this analysis can be identified. First, limitations of the data can be improved. For example, several of the single-site models, from which baseline or target values are derived, potentially suffer from small numbers problems. More observations for each of the models should improve their quality. In addition, the lack of modeling substitute sites may affect inter-site comparisons. Second, a broader range of physical attributes could be measured, especially using Geographic Information Systems technology, providing an added spatial dimension (Eade and Moran 1996). This may provide us with models that are more accurate, and subsequently more defensible, in applications to benefit transfers.

This analysis needs to be repeated under different circumstances. It would be interesting to see if a general pattern in the effects of different site characteristics emerges. This pattern, if it existed, could have a tremendous effect on how and what kind of data is collected in non-market valuation surveys. Another empirical question is whether there is a single meta-valuation function for all related goods and services (such as outdoor recreation) or whether different goods and services (such as recreation activities) have different valuation functions.

In general, evidence presented in this paper supports the need for primary research to target the development of benefit transfer models (Bergland, Magnussen, and Navrud 1995), or at least be more sensitive to potential use of primary research outcomes in benefit transfer applications. This sensitivity to benefit transfers would entail gathering and reporting data that may not be of immediate use in the primary research, but essential to developing valid and reliable benefit transfers. For example, insignificant covariate effects or explanatory variables that define the context of a study site (and are therefore constant for a site) are often not reported in primary research. However, in order to develop a meta-valuation function, these covariate effects and measures of other variables are necessary.

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## Notes

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[1] The known ('true' or actual) value for a policy site is derived from an original study designed to estimate a value for this site.

[2] Although we speak of value in the singular, the reader should recognize that benefit transfers quite often use multiple values to infer a value and its distribution for a policy site.

[3] The estimated travel cost models are available upon request from the authors.

[4] $V_{pp}$ is itself an approximation of the unknown but 'true' value of hiking at a specific site. Because this value is unknown, there is an error associated with it. For our present purposes, $V_{pp}$ as estimated is the assumed 'true' value, $V^P$, for each trail with no estimation error. This is the traditional approach used when testing the validity of benefit transfers.

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*Table I*. Summary of Benefit Transfer Validity Tests.

| **Reference** | **Resource/Activity** | **Value Transfer Percent Error**[a] | **Function Transfer Percent Error**[a] |
|---|---|---|---|
| Loomis (1992) | Recreation | 4 – 39 | 1 – 18 |
| Parsons and Kealy (1994) | Water\Recreation | 4 – 34 | 1 – 75 |
| Loomis et al. (1995) | Recreation | | |
| Nonlinear Least Squares Model | | --- | 1 – 475 |
| Heckman Model | | --- | 1 – 113 |
| Bergland et al. (1995) | Water quality | 25 – 45 | 18 – 41 |
| Downing and Ozuna (1996) | Fishing | 0 – 577 | --- |
| Kirchhoff et al. (1997) | Whitewater Rafting | 36 – 56 | 87 – 210 |
| | Birdwatching | 35 – 69 | 2 – 35 |
| Kirchhoff (1998) | Recreation/Habitat | | |
| Benefit Function Transfer | | --- | 2 – 475 |
| Meta-analysis Transfer | | --- | 3 – 7028 |
| Brouwer and Spaninks (1999) | Biodiversity | 27 – 36 | 22 – 40 |
| Morrison and Bennett (2000) | Wetlands | 4 – 191 | --- |
| Rosenberger and Loomis (2000a) | Recreation | --- | 0 – 319 |
| VandenBerg et al. (2001) | Water quality | | |
| Individual Sites | | 1 – 239 | 0 – 298 |
| Pooled Data | | 0 – 105 | 1 – 56 |
| Shrestha and Loomis (2001) | International Recreation | --- | 1 – 81 |

Adapted from and expanded on Brouwer (2000).

[a] All percent errors are reported as absolute values.

*Table II.* Description of Variables.

| **Variable** | **Description** |
|---|---|
| TC | Travel cost as individual's reported share of transportation costs plus time costs (1/3 wage rate * travel time) (dollars) |
| $TC*F_i$ | Interaction terms of TC and National Forest (i=3) (dollars) |
| $TC*T_i$ | Interaction terms of TC and Trail (i=6) (dollars) |
| GENDER | Dummy variable; 1 = male, 0 = female |
| AGE | Respondent's age (years) |
| EDU | Respondent's level of education (years completed) |
| INC | Gross annual household income of respondent (dollars) |
| ELEV | Trailhead elevation above sea-level (feet) |
| GAIN | Elevation gain of trail from trailhead to summit (feet) |
| LONG | Length of trail (miles) |
| FIRE | The negative of the age of a wildfire in the recreation area (years) |
| WATER | Dummy variable; 1 = presence of water (lake, stream) near trail, 0 = no water |
| CROWN | Dummy variable; 1 = extreme fire in past as evidenced by crown fire, 0 = otherwise |
| PP | Dummy variable; 1 = presence of ponderosa pine trees, 0 = otherwise |
| LP | Dummy variable; 1 = presence of lodgepole pine trees, 0 = otherwise |
| ASPEN | Dummy variable; 1 = presence of aspen groves, 0 = otherwise |

*Table III.* National Forest and Trail Summary Statistics.

| **National Forest/**<br>**Trail** | **N**[a] | **ELEV** | **GAIN** | **LONG** | **FIRE** | **WATER** | **PP** | **LP** | **ASPEN** |
|---|---|---|---|---|---|---|---|---|---|
| **Arapahoe/Roosevelt (Forest 1)** | | | | | | | | | |
| Mount Margaret (Trail 1) | 13 | 7800 | 100 | 5 | -50 | 0 | 1 | 0 | 0 |
| Grey Rock (Trail 2) | 52 | 5400 | 2055 | 6 | -8 | 0 | 1 | 0 | 0 |
| Kilpecker/Blue Lake (Trail 3) | 10 | 9400 | 1450 | 10 | -42 | 1 | 0 | 1 | 0 |
| **Pike/San Isabel (Forest 2)** | | | | | | | | | |
| Devil's Lookout (Trail 4) | 25 | 8900 | 600 | 3 | 0 | 0 | 1 | 0 | 1 |
| **Gunnison/Uncompaghre (Forest 3)** | | | | | | | | | |
| North Bank/Doc Park (Trail 5) | 6 | 8600 | 900 | 7 | -2 | 0 | 1 | 1 | 1 |
| Summerville/DoubleTop (Trail 6) | 21 | 8900 | 1400 | 9 | -50 | 0 | 0 | 1 | 0 |

[a] n = number of respondents per trail.

*Table IV*. Summary Statistics of Sample (n=127).

| **Variable** | **Mean** | **Standard Deviation** | **Range** |
|---|---|---|---|
| GENDER | 0.51 | 0.50 | 0 – 1 |
| AGE | 36.48 | 11.22 | 19 – 73 |
| EDU | 16.12 | 2.22 | 11 – 20 |
| INC | $68760 | 45326 | 5000 – 175000 |

*Table V.* Travel Cost Model Specifications

| **MODEL** | **TC** | **$TC_{FOREST}$** | **$TC_{TRAIL}$** | **Physical Char.** | **Sample Char.** | **#Obs.** |
|---|---|---|---|---|---|---|
| A - State | X | | | X | X | 254 |
| B – State | X | X | | X | X | 254 |
| C – State | X | | X | X | X | 254 |
| D – Forest | | X | | X | X | 150 |
| E – Forest | | X | X | X | X | 150 |
| F – Forest | | X | | X | X | 54 |
| G – Forest | | X | X | X | X | 54 |
| H – N-1 | X | | | X | X | 228 |
| I – N-1 | X | | | X | X | 150 |
| J – N-1 | X | | | X | X | 234 |
| K – N-1 | X | | | X | X | 204 |
| L – N-1 | X | | | X | X | 242 |
| M – N-1 | X | | | X | X | 212 |
| Trail 1 | | | X | | X | 26 |
| Trail 2 | | | X | | X | 104 |
| Trail 3 | | | X | | X | 20 |
| Trail 4 | | | X | | X | 50 |
| Trail 5 | | | X | | X | 12 |
| Trail 6 | | | X | | X | 42 |

*Table VI.* Baseline and Transfer Consumer Surplus Measures per Trip.

| | **Baseline Measures ($V_{pp}$)** | | | | | |
|---|---|---|---|---|---|---|
| **Model** | **Trail 1** | **Trail 2** | **Trail 3** | **Trail 4** | **Trail 5** | **Trail 6** |
| Trail | \$12.12 | \$60.38 | \$41.56 | \$248.85 | \$33.81 | \$46.57 |

| | **Transfer Measures ($V_{ps}$)** | | | | | |
|---|---|---|---|---|---|---|
| **Model** | **Trail 1** | **Trail 2** | **Trail 3** | **Trail 4** | **Trail 5** | **Trail 6** |
| A | \$81.93 | \$81.93 | \$81.93 | \$81.93 | \$81.93 | \$81.93 |
| B | 45.56 | 45.56 | 45.56 | 61.29 | 76.91 | 76.91 |
| C | 126.14 | 87.62 | 6.47 | 65.45 | 22.09 | 41.21 |
| D | 65.50 | 65.50 | 65.50 | --- | --- | --- |
| E | 22.43 | 46.73 | 7.37 | --- | --- | --- |
| F | --- | --- | --- | --- | 36.41 | 36.41 |
| G | --- | --- | --- | --- | 32.37 | 37.40 |
| H | 116.42 | --- | --- | --- | --- | --- |
| I | --- | 95.76 | --- | --- | --- | --- |
| J | --- | --- | 73.01 | --- | --- | --- |
| K | --- | --- | --- | 31.83 | --- | --- |
| L | --- | --- | --- | --- | 73.81 | --- |
| M | --- | --- | --- | --- | --- | 126.82 |

*Table VII.* Benefit Transfer Validity Measures Using Traditional Value Transfer Approach.

| **Model** | **Trail 1** | **Trail2** | **Trail 3** | **Trail 4** | **Trail 5** | **Trail 6** | **Average** **$\|\%\Delta V_{ij}\|$** |
|---|---|---|---|---|---|---|---|
| A | 575.99%[a] | 35.69% | 97.14% | -67.08% | 142.32% | 75.93% | 165.69% |
| B | 275.91 | -24.54 | 9.62 | -75.37 | 127.48 | 65.15 | 96.35 |
| C | 940.76 | 45.11 | -84.43 | -73.70 | -34.66 | -11.51 | 198.36 |
| D & F | 440.43 | 8.48 | 57.60 | --- | 7.69 | -21.82 | 107.20 |
| E & G | 85.07 | -22.61 | -82.27 | --- | -4.26 | -19.69 | 42.78 |
| H – M | 860.56 | 58.60 | 75.67 | -87.21 | 118.31 | 172.32 | 228.78 |

[a] Validity (percentage difference) measures = $[(V_{ps} - V_{pp})/V_{pp}]*100$ (Equation (4)).

*Table VIII.* Site Correspondence Model: Random Effects.

| **Variable** | **Coefficient** | **Standard Error** | **Significance Level** |
|---|---|---|---|
| Constant | 87.2429 | 121.34 | 0.47 |
| %ΔGENDER | 45.4459 | 11.93 | 0.00 |
| %ΔAGE | 22.4562 | 14.58 | 0.12 |
| %ΔELEV | -9.7922 | 5.72 | 0.09 |
| %ΔGAIN | -0.7929 | 0.32 | 0.01 |
| %ΔLONG | 12.3915 | 5.80 | 0.03 |
| %ΔFIRE | -0.0284 | 0.14 | 0.84 |
| %ΔWATER | -4.6403 | 1.92 | 0.02 |
| %ΔPP | 0.2824 | 3.75 | 0.94 |
| %ΔLP | -2.1720 | 2.41 | 0.37 |
| %ΔASP | 10.4403 | 8.12 | 0.20 |
| Adj-$R^2$ | 0.79 | | |
| # Obs. | 34 | | |

Dependent variable is $\%\Delta V_{ij}$, or validity (percentage difference) measures (Table VII).

*Table IX.* Meta-Regression Analysis Valuation Function: Random Effects.

| **Variable** | **Coefficient** | **Standard Error** | **Mean of Variable** |
|---|---|---|---|
| Constant | -2602.9263 | 2704.68 | --- |
| TRAIL 1 | 7.9950 | 11.15 | 0.175 |
| TRAIL 3 | -20.6873[a] | 11.17 | 0.175 |
| TRAIL 4 | -5.2568 | 12.52 | 0.125 |
| TRAIL 5 | -9.9429 | 12.20 | 0.175 |
| TRAIL 6 | 2.5347 | 12.04 | 0.175 |
| ELEV | 0.2381 | 0.20 | 7514.542 |
| GAIN | 0.5439 | 0.47 | 1341.859 |
| LONG | -75.8477[a] | 26.73 | 6.332 |
| FIRE | -8.9823 | 10.25 | -22.661 |
| PP | 618.0245 | 729.57 | 0.700 |
| Adj. –$R^2$ | 0.72 | | |
| # Obs. | 40 | | |

Dependent variable is consumer surplus per trip (Table VI).

[a] Variable is significant at the 0.10 level or better.

*Table X.* Meta-Analysis Consumer Surplus Estimates and Validity Measures.

| **Trail** | $\mathbf{V_{Ti}}$ | $\mathbf{V_{Pj*}}$ [a] | $\mathbf{\%\Delta V_{ij}}$ |
|---|---|---|---|
| Trail 1 | \$4.54 | \$12.12 | -62.54% |
| Trail 2 | 56.88 | 60.38 | -5.80 |
| Trail 3 | 35.16 | 41.56 | -15.40 |
| Trail 4 | 242.90 | 248.85 | -2.39 |
| Trail 5 | 29.36 | 33.81 | -13.16 |
| Trail 6 | 36.82 | 46.57 | -20.94 |
| Avg. $\lvert\%\Delta V_{ij}\rvert$ | | | 20.04 |

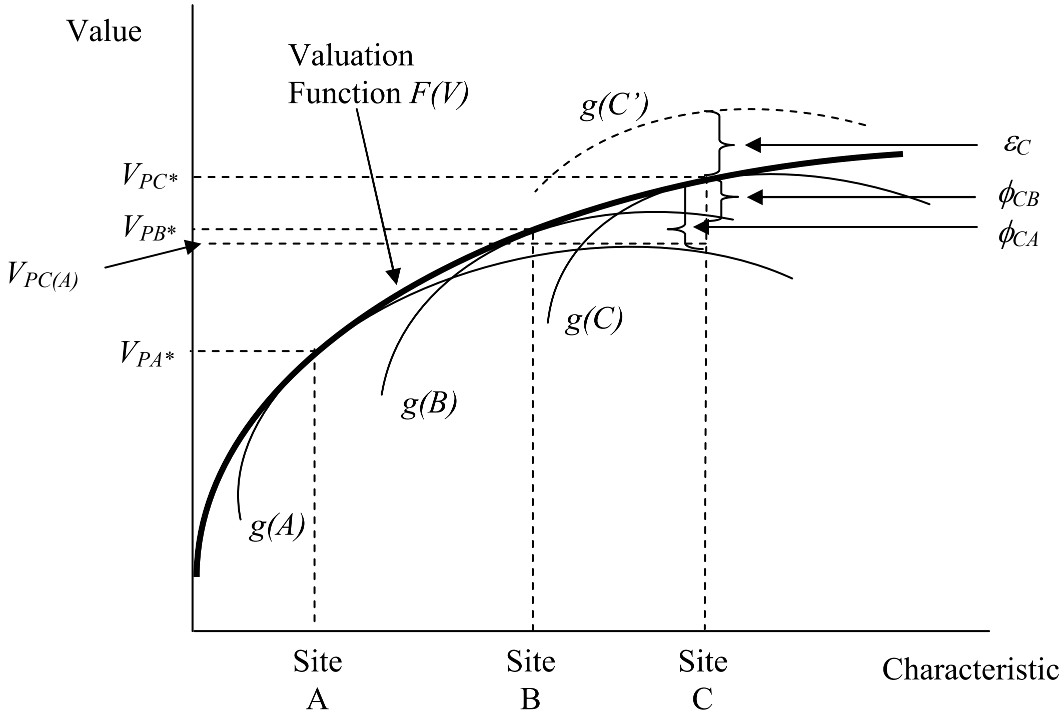
[a] From trail-specific models, see Table VI.

*Table XI.* Results of Hypothesis Tests.

| **Model Comparisons** | **t-Stat** | **Significance Level** |
|---|---|---|
| Meta vs. Model A | 1.95 | 0.05 |
| Meta vs. Model B | 2.36 | 0.03 |
| Meta vs. Model C | 1.26 | 0.13 |
| Meta vs. Models D, F | 1.13 | 0.16 |
| Meta vs. Models E, G | 1.45 | 0.11 |
| Meta vs. Models H – M | 1.76 | 0.07 |

Hypothesis Tested: $H_0$: $\%\Delta V_{METAij} = \%\Delta_{TRADij}$ vs. $H_1$: $\%\Delta V_{METAij} < \%\Delta_{TRADij}$.

(Rosenberger Fig. 1)



(Rosenberger Fig. 2)

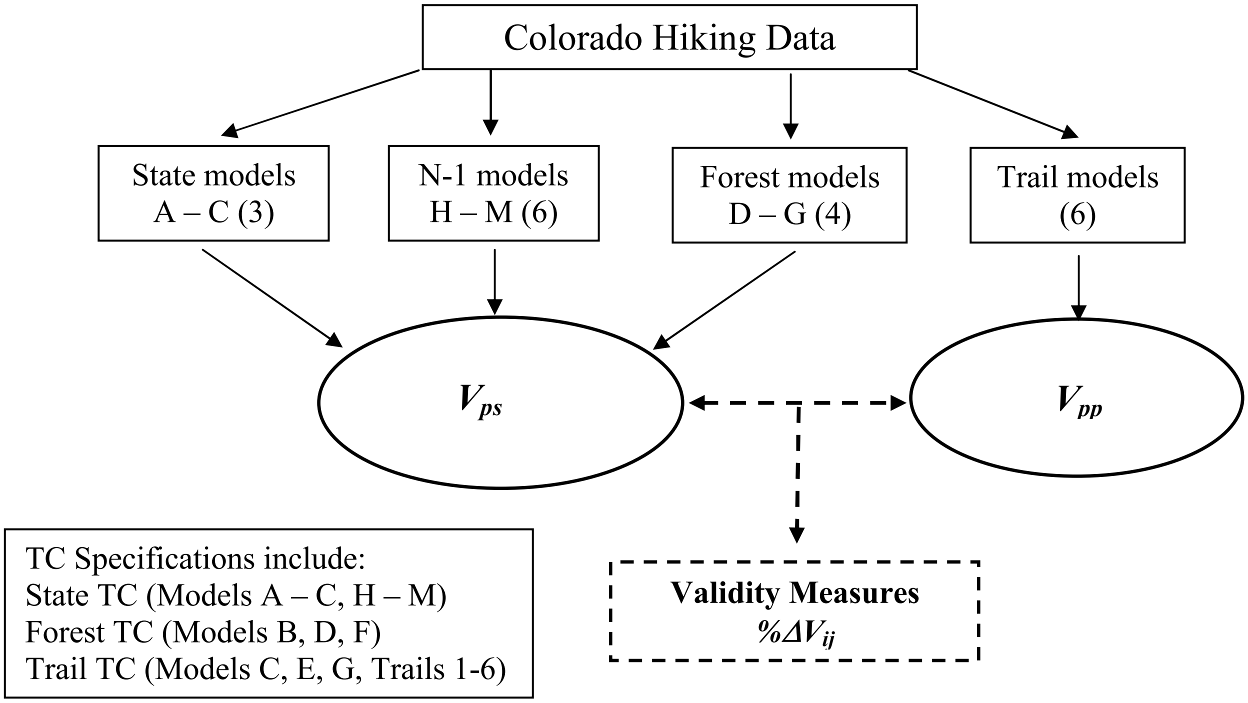


Figure captions:

Figure 1. Meta-Valuation Function and Benefit Transfer Error.

Figure 2. Travel Cost Models and Data Development.