

**A Repeated Sampling Experiment in Assessing the Validity of Benefit Transfer in
Valuing Non-market Goods**

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Abstract: This paper applies hedonic two-stage technique to investigate the effectiveness of the benefit-transfer methodologies in a statistically controlled repeated sampling experiment. Benefit transfers are carried out on several sets of one thousand pairs of random, non-overlapping sub-samples drawn from a Chicago housing sample. The study finds that even under extremely favorable conditions, quality of transferred benefits is rather poor. Moreover, there is no gain in precision in adopting function transfer over unit-value transfer. The quality of transferred benefits deteriorates in the presence of dissimilarities between two sites, and function-transfer appears more appropriate than unit-value transfer under this situation.

1. Introduction

Public projects are now-a-days subjected to increasing scrutiny. For instance, the Executive order 12291 (framed in 1981) and the Executive Order 12866 (framed in 1994) of the United States Office of Management and Budget require that every major regulatory project pass through a rigorous cost-benefit analysis. While cost of an environmental regulatory initiative is not so difficult to measure, measuring non-market benefits can often be challenging. Even though tools of non-market valuation are being developed and refined over the years, administering them in a policy site often turns out to be time consuming and costly. This has led the public authorities, involved in environmental regulatory initiatives, to rely more and more on benefits transfer as an alternative to the direct non-market valuation of environmental resources. Although, the application of benefits transfer techniques is on the rise, empirical and theoretical research on the applicability and reliability of the technique is, so far, limited. This paper uses the hedonic model of amenity valuation to empirically investigate, for the first time, the validity of the benefit transfer methodology and the reliability of the transfer estimates in a controlled statistical experiment, using a repeated sampling technique.

In the benefit transfer approach, average unit value of an environmental resource of interest, previously obtained in a project site (commonly called 'study site'), are transferred to a geographically or temporally separated new project site (commonly called 'policy site') to carry out cost-benefit analyses of environmental policies associated with the new project site (NOAA 1996). In the more refined benefit function transfer approach, instead of the average value, the estimated models of benefits are

transferred and adopted in the policy site to account for the key demographic and environmental variables peculiar to the policy site (see e.g. Loomis 1992).

Ascertaining the validity of benefit transfers from one site to another and the reliability of the transfer estimates is primarily an empirical exercise. Empirical tests that are attempted in the literature fall into two broad categories, namely *convergent validity tests* and *value surface tests*. While the former refers to testing of similarities between various statistical parameters obtained in the study sites and the policy site (e.g. Loomis 1992), the latter refers to a grand valuation model based on the existing studies, obtained either through meta-analysis or through some kind of aggregation exercise that can be utilized to carry out benefit transfer to a policy site (e.g. Smith et al. 1999)¹. Thus, the issues, such as, how the difference in the level of the environmental good of interest in the study site(s) and in the policy site affects the transfer, or what role does the demographic profile of the population play in transferring benefits from the study site(s) to the policy site are important in judging the appropriateness of benefits transfer?

Successful empirical investigation addressing validity of benefit transfers and the reliability of the transfer estimates often requires controlled statistical experiment in which the general statistical properties of the data can be systematically altered to see how the changes are impacted in the quality of the transferred benefits. This, in turn, requires the availability of information from a large number of data sets, both from the study sites as well as from the policy sites. In this paper such an exercise is made possible through a repeated sampling experiment whereby two non-overlapping samples are drawn repeatedly in a random manner from a large data set. Non-market benefits are then transferred from one sample to the other, and analysis of transferability is carried out in a

controlled setting². There is not a single study in the benefit transfer literature that systematically addresses the issues of benefit transfer using such an approach.

Empirical research in the applicability of benefit transfer is, so far, limited mainly to contingent valuation model and models based on recreational travel cost. Application of transferability of non-market benefits has rarely been attempted in hedonic property value studies. In this paper, a repeated sampling scheme is applied to a Chicago housing data set consisting of 3044 house sales. The willingness-to-pay (WTP) functions for amenities are first developed based on a two-stage hedonic analysis. In the next step, two non-overlapping sub-samples from the full sample are repeatedly drawn one thousand times. Direct measures of average marginal and non-marginal benefits of amenity improvement are then computed and compared based on each pair of thousand sub-samples to evaluate the applicability of 'unit value' benefit transfer. Finally, the WTP functions estimated based on each sub-sample are transferred to the other sub-sample and benefits based on function transfer are computed and compared to explore the appropriateness of the function-transfer approach.

It is generally believed that the applicability of benefit transfer largely depends on the degree of similarities between the study sites and the policy site (Feather and Hellerstein 1997, Loomis 1992). However, this hypothesis has never undergone a rigorous empirical test. Atkinson and Crocker (1992) in an interesting study explore transferability of the hedonic marginal price function across markets, under a Bayesian framework. They find that the marginal price functions for structural housing attributes, which do not vary from market to market, are generally transferable across markets, whereas the same for neighborhood attributes are not. In other words, similarities in the

structural attributes across markets allow transfer across markets, but dissimilarities in the neighborhood attributes across markets does not allow such transfer. Since the present study involves in random transferability within a single market, due to high degree of similarities within a market, the conditions of transfers are extremely favorable. It is thus interesting to see how the benefit transfer methodology performs in the present setting.

In short, the goal of the present research is to carry out a controlled statistical experiment based on a repeatedly drawn pair of random, non-overlapping sub-samples from a large data set to investigate the validity of the benefit transfer exercise from one sub-sample of the pair to the other and the reliability of the transfer estimates. The two most important results of the present research are: (i) in spite of an extremely favorable condition under which the transfers are carried out, both techniques, namely the unit-value transfer and the function transfer perform, in general, equally poorly; (ii) when conditions of transfer are made less favorable, performance of each technique gets worse, although the performance of function transfer remains slightly better than that of unit-value transfer.

The paper is organized as follows: The next section gives a short review of the literature. Section 3 discusses hedonic two-stage benefit estimation, presents the model to be used for the purpose of the study, and provides a short description of the data. In section 4, a repeated sampling procedure is described. In section 5, the results of the performance of the unit-value transfer and the function-transfer techniques are discussed. The role of the demographic differences and the differences in the levels of amenities between the study and the policy sites in the effectiveness of a transfer methodology, is also discussed in this section. Section 6 concludes.

2. Previous literature

Now-a-days benefit transfer methodologies are not only being used extensively to evaluate environmental regulatory policies, but also in major litigation cases involving natural resource damage assessment³. Time and resource constraints are the primary reasons why such an approach is adopted instead of a direct approach, in which models are particularly developed for the policy site in question for cost-benefit analysis. While there are numerous reasons to support the application of the benefit transfer technique, stakes are at the same time very high against its indiscreet use⁴. In order to provide appropriate guidelines for practitioners of this methodology, the need for refinement of the methodology has been strongly felt by researchers during the last decade (see e.g. Boyle and Bergstrom 1992, Desvousges et al. 1992, Smith 1992).

Loomis (1992) was the first to come up with a formal application of the benefit function transfer methodology. In a study of travel cost demand for recreational fishing he finds that transfer of demand equation across states or to an unstudied site within a state is a better alternative than a simple unit-value transfer. His approach to testing the equality of coefficients of the demand equation does not, however, ensure validity of the transfer methodology. Downing and Ozuna (1996) in a dichotomous choice contingent valuation (CVM) study find that even with statistically similar demand parameters, the presence of non-linearities in the model may lead to significantly different welfare estimates. The empirical results of Kirchoff et al. (1997) in their CVM study on recreational rafting demand also corroborate this fact. Browser and Spaninks (1999) include certain attitudinal factors peculiar to the study site in their CVM study and

conclude, based on a series of statistical tests, that though statistical equality of parameters may be necessary for a valid transfer, it is not sufficient to guarantee validity.

There is yet another line of research that seeks to improve the performance of the benefit transfer methodology. In an interesting empirical study Parsons and Kealy (1994) apply the random utility model (RUM) for lake recreational demand and investigate the performance of simple transfer, model transfer, and model transfer based on Bayesian updating. Different types of transfers are carried out in the study with and without certain behavioral information to investigate conditions necessary to improve performance. Although, the performance of the transfer exercises carried out in the study turns out good, the authors caution that this may be due to geographic similarities of the sites, similarities in the survey features and the simulated models. Such similarities, the authors state, are not very common in a typical benefit transfer exercise.

Feather and Hellerstein (1997) develop a calibration function to be transferred along with the benefit function to adjust for the biases arising from nonlinearities in the welfare function. In a recent study, Smith et al. (1999) develop an approach to calibrate a common preference function based on the estimates of three existing studies of non-market benefits, one based on travel cost, one based on hedonic property value, and the third based on contingent valuation. Their approach attempts to identify the preference parameters based on the available information from the existing studies and then uses the calibrated preference function to generate transferable benefit estimates.

On the whole, received literature on benefit transfer generally finds function transfer more appropriate in majority of the situations. However, to make function transfer more effective appropriate adjustments must be made to account for the

difference in the consumption levels of the amenity in question, differences in the socioeconomic and other exogenous factors of the natural environment that distinguish the policy site from the study site.

3. The two-stage hedonic property value model

3.1 The theory and the econometric issues

Benefit estimation using the hedonic property value model is carried out in two stages. In the first stage hedonic housing price function is econometrically estimated as a function of a set of all relevant structural attributes and neighborhood amenities. Theoretically, the hedonic price function is the non-linear locus of all the equilibrium points where the bid curve of each individual buyer and the offer curve of a competitive seller meet in the attribute space (Rosen 1974). The expression for the benefits of a marginal improvement in the amenity level can be obtained by taking the derivative of this market-determined hedonic price function. For a large improvement in the amenity level benefits must be determined from the households' individual WTP function. The WTP function for amenity improvement is econometrically estimated using the following condition for household utility maximization:

$$(1) \quad \frac{\partial P(\mathbf{z})}{\partial z_i} = \frac{\partial U(\mathbf{X}, \mathbf{z}, \mathbf{d}) / \partial z_i}{\partial U(\mathbf{X}, \mathbf{z}, \mathbf{d}) / \partial \mathbf{X}},$$

where P is the price of a house as the function of several attributes, \mathbf{z} is a vector of housing attributes (z_1, z_2, \dots, z_k), X is the composite, non-housing consumption, assumed numeraire, and \mathbf{d} is the vector of household demographics. The left-hand side of (1) is the marginal price or the benefit associated with a marginal change in an amenity level, and the right-hand side of (1) is marginal WTP or the marginal rate of substitution between an

amenity associated with housing and the composite, non-housing good X. The expression (1) is the uncompensated WTP function for an amenity. Under commodity constraints improvement in the amenity, say z_1 from its current level, say z_{10} to a new level z_{11} , the following expression gives the expression for Marshallian surplus, which is essentially, the area under the uncompensated WTP curve from the initial level to the improved level of the amenity (see, Cropper 1988, Freeman 1994, Chattopadhyay 1999):

$$(2) \quad \int_{z_{11}}^{z_{10}} \frac{\partial U / \partial z_1}{\partial U / \partial X} dz_1 .$$

There are several econometric issues that must be properly addressed in order to obtain reliable hedonic benefit estimates. For instance, reliable marginal WTP estimate must involve a correct choice of the functional form for the hedonic price function. In the present study a linear Box-Cox form is chosen for the hedonic price function. Also, the problem of multicollinearity is often a serious issue that comes in the way of reliable parameter estimates in the first stage⁵. The econometric issues in the estimation of the second-stage WTP function are even more challenging. The most important of them all is identifying the first stage parameters from the second stage parameters (Brown and Rosen 1982). This can be achieved through functional-form restrictions, which involve specifying a functional form for the second stage WTP function that is very different from the first stage hedonic price function (Mendelsohn 1985, Eppel 1987, Palmquist 1991). Functional-form restriction is imposed in the present study through the choice of a linear Box-Cox function in the first stage and a Diewert utility structure in the second stage. However, note that the absence of sufficient marginal price variation within a market may often lead to improper identification even if functional-form restrictions are imposed (Oshfeldt and Smith 1985). Some available alternatives to overcome this

problem is identifying segmented markets within a larger housing market (Michaels and Smith 1984), or modeling based on multiple markets (Palmquist 1984, Zabel and Kiel 1999). Unfortunately, identification of the second stage parameters is still not assured, since often multiple markets are unable to bring out sufficient marginal price variation.

Another potential problem in the second stage estimation of the WTP function is the problem of endogeneity. Endogeneity is caused when the marginal prices obtained in the first stage and the levels of an amenity are simultaneously determined. The problem of endogeneity is associated with non-linearities in the hedonic function. This problem makes OLS estimation at the second stage inconsistent. Appropriate technique that must be used in this situation is the 3SLS technique, which requires the availability of sufficient exogenous instrumental variables. Suitable exogenous instruments must be obtained either from the demographic characteristics of the households or by exploring the peculiarities within or across markets. In the present study, the 3SLS technique is adopted and several socio-economic characteristics of households are used as instruments. A multiple-market hedonic model has potential to generate sufficient instruments to tackle the problem of endogeneity. For a discussion on the endogeneity issue, reader may see Bartik (1987), Diamond and Smith (1985), and Epple (1987). For a detailed discussion on the hedonic theory and methodology, reader may refer to Rosen (1974), Quigley (1982), Palmquist (1991), Freeman (1994). For a rigorous empirical application of the two-stage hedonic model, reader may refer to Cropper et al. (1988), Chattopadhyay (1999), and Zabel and Kiel (2000).

3.2 Estimation of the marginal and non-marginal benefits

A linear Box-Cox hedonic price function of the following form is considered for the first-stage estimation in the present study⁶:

$$(3) \quad P(\mathbf{z})^{(\theta)} = \eta_0 + \sum_{i=1}^k \eta_i z_i^{(\lambda)}$$

where $P(\mathbf{z})^{(\theta)} = [(P(\mathbf{z}))^\theta - 1] / \theta$ and $z^{(\lambda)} = (z^\lambda - 1) / \lambda$, θ and λ are the transformation parameters, η_i are the coefficients of the hedonic price function, $\mathbf{z}: \{z_1, z_2, \dots, z_k\}$ is a vector of k housing attributes, $P(\mathbf{z})$ is, as before, the house price expressed as a function of the attribute vector \mathbf{z} .

A Diewert utility specification of the following form is considered for the second-stage hedonic estimation of the WTP function⁷:

$$(4) \quad U(\mathbf{X}, \mathbf{z}) = \sqrt{\mathbf{X}} + \sum_{i=1}^k (\alpha_i + \delta_i \mathbf{d}) \sqrt{z_i} + \frac{1}{2} \sum_{i=1}^k \beta_{ii} z_i,$$

where \mathbf{d} represents the vector of demographic characteristics of the household, \mathbf{X} is, as before, the numeraire non-housing good. The coefficients α_i and β_{ii} are the utility parameters associated with the level of amenities and the coefficient vector δ_i represents utility parameters associated with the socioeconomic characteristics of the household. The second-stage estimating equations are obtained from (1), which comes from household's utility maximization problem. Invoking (3) and (4) in (1) leads to the following system of second-stage estimating equations (WTP function for attributes)

$$(5) \quad \eta_i P^{1-\theta} z_i^{\lambda-1} = \sqrt{\frac{\mathbf{X}}{z_i}} (\alpha_i + \delta_i \mathbf{d} + \beta_{ii} \sqrt{z_i})$$

for $i = 1, 2, \dots, k$.

3.3. *Measuring benefits of amenity improvement*

Benefits of a marginal change in the amenity level are obtained using the left-hand side of expression (5) for each amenity associated with housing. Once the parameters of the hedonic price function are estimated, the estimate of marginal WTP can be computed. Due to non-linear specification of the hedonic housing price function WTP for a marginal change in the amenity level varies across individual households, depending on the level of consumption (z_i) of amenity 'i'. Average marginal WTP for an amenity can then be computed by taking the average of all the households in the sample.

Benefits of a large (non-marginal) change in the attribute level can be estimated based on the estimated values of the utility parameters α , δ , and β . For instance, if a regulatory initiative of the government results in a large improvement in air quality level associated with housing (say z_1) from level z_{10} (initial) to the level z_{11} (final), the benefits can be measured using the following Marshallian surplus expression⁸:

$$(6) \quad \int_{z_{11}}^{z_{10}} \frac{\partial U / \partial z_1}{\partial U / \partial X} dz_1 = \int_{z_{11}}^{z_{10}} \sqrt{\frac{X}{z_1}} (\alpha_1 + \delta_1 \mathbf{d} + \beta_{11} \sqrt{z_1}) dz_1 = 2 \kappa \sqrt{X},$$

where $\kappa = A_1(\sqrt{z_{10}} - \sqrt{z_{11}}) + B_1(z_{10} - z_{11})$, $A_1 = (\alpha_1 + \delta_1 \mathbf{d})$, $B_1 = \frac{1}{2} \beta_{11}$.

As in the case of marginal WTP, non-marginal WTP across all households in the sample are averaged to obtain the average Marshallian surplus associated with a large improvement in the amenity level.

3.4. *Data*

We consider the Chicago Primary Metropolitan Statistical Area (PMSA) as the residential market for the empirical study. The details of all the variables, their sources, the units in which they are measured, and the expected sign of the set of explanatory

variables in the first stage hedonic regression are given in Table 1. In brief, data on 3044 house sales in Cook and Dupage counties for the years 1989 and 1990 are collected from the U. S. Department of Housing and Urban Development. These housing data and the data on household demographics come from Federal Housing Administration (FHA) records on mortgages insured by FHA. The sample consists of sales of 3044 single-family, detached houses from 659 census tracts located in 103 city districts in the PMSA. For more detailed description of the data, reader may see Chattopadhyay (1999).

4. The hedonic benefits in repeated sampling experiment

In this section, the procedure of generating random pairs of sub-samples from the full sample of 3044 household level observations and the hedonic estimation based on each pair of sub-samples are discussed⁹.

4.1 Generating random sub-samples

The objective of the present study is to conduct a controlled experiment, which involves a pair of non-overlapping sub-samples, drawn randomly one thousand times, without replacement from the full sample. The purpose is to investigate i) how benefit estimates of amenities based on one sub-sample compare with the benefit estimates based on the other sub-sample in the pair, on average; ii) how the true benefit estimates based on the second sub-sample in the pair compare, on average, with the benefit estimates obtained using benefit functions transferred from the first sub-sample in the pair¹⁰.

The following five sets consisting of 1000 pairs of non-overlapping sub-samples each, are drawn: (i) a set with sub-sample sizes (304, 304); (ii) a set with sub-sample sizes (609, 609); (iii) a set with sub-sample sizes (913, 913); (iv) a set with sub-sample sizes (1218, 1218); (v) a set with sub-sample sizes (1522, 1522). The purpose of drawing

different sets with different sub-sample sizes is to ensure different degrees of similarity in the levels of amenities between the sub-samples in a pair, on average, across the sets. For example, since sub-sample sizes in set (ii) are larger than in set (i), the percentage difference in the amenity levels between the two sub-samples in pairs in set (ii) is, on average, smaller than in set (i). Similarly, the percentage difference in the amenity levels between the pair of sub-samples in set (iii) is, on average, smaller than in set (ii), and so on. It would thus be worthwhile to see how the degree of dissimilarities across the sets with regard to amenity levels is reflected in the performance of the unit-value transfers and the function transfers.

Following are the steps taken in sequence in conducting the repeated sampling experiment in the computer. First, the rectangular data set consisting of 3044 observations with 24 variables are read. Second, for each pair of sub-samples in a set described above, a block of 3044 uniform (0, 1) random numbers is generated. Third, the rectangular data set is sorted in increasing order of the random numbers. Randomization in the data set is achieved in this manner. Forth, sub-samples are drawn, for instance, in the case of set (i) the first sub-sample of the pair consists of the first 306 observations and the second sub-sample of the pair consists of the last 306 observations in the randomized data set. Fifth, the hedonic two-stage estimation is conducted for each of the pair of sub-samples and a measure of performance of each of the two techniques, namely the unit-value transfer technique and the function-transfer technique, is computed. All the preceding steps are repeated one thousand times to investigate how the two techniques perform, on average.

4.2 *Measuring the performance of the benefit transfer*

Marginal benefit of an amenity improvement is associated with the hedonic first-stage estimation. This is based on the linear Box-Cox regression, given in equation (3), of house price on eighteen explanatory variables. The set of explanatory variables consists of seven structural attributes and eleven neighborhood and city-specific amenities including the two air quality variables, namely PM10 and SULFUR. The details of each variable are given in Table 1.

For each pair of sub-samples marginal benefits are computed based on the expressions on the left-hand side of equation (5). These are then averaged over the sub-sample size to obtain the mean marginal benefit. The performance of the unit-value transfer technique in repeated samples is measured as percentage difference in the mean marginal benefits between the first sub-sample and the second sub-sample in the pair. For function transfer, the coefficient estimates of the first stage regression of the first sub-sample are transferred to the second sub-sample, and the left-hand side of equation (5) is computed for each household in the second sub-sample. These values are then averaged and the percentage difference between the true mean benefits, as explained in note 10, and the transferred mean benefits are computed to arrive at the measure of the performance of the function-transfer technique in repeated samples.

Non-marginal benefit of an amenity improvement is associated with the hedonic second-stage estimation. The 3SLS technique is adopted for the purpose to estimate the system of eighteen second-stage equations as in (5). The two demographic variables, namely RACE and CHILD are used as demand shifters¹¹. The variable INCOME is not used, since the variable X, which is, essentially, the difference between annual income

and annual expenditure on housing, already appears in a non-linear form in equation (5). The instrumental variables used for the 3SLS estimation are INCOME, its square, CHILD, its square, RACE, and MARSTAT.

For each pair of sub-samples non-marginal benefits for a 25 percent increase in the attribute level are computed based on the expression for benefits in equation (6). These benefits are then averaged to obtain mean non-marginal benefits associated with a 25 percent increase in the attribute levels. The performance of the unit-value transfer and the function transfer techniques in repeated samples are then evaluated in a similar fashion as in the case of marginal benefits.

5. The results

The average performance of the two techniques in a set of one thousand pairs of sub-samples is computed using the following formula:

$$(7) \quad \text{Performance} = \frac{1}{1000} \sum_{i=1}^{1000} \text{abs}[(a_i - b_i) / \{(a_i + b_i) / 2\}],$$

where in the case of unit-value transfer a_i = average benefit obtained from the first sub-sample of the i^{th} . pair and b_i = average benefit obtained from the second sub-sample of the i^{th} . pair. Similarly, in the case of function transfer a_i = true average benefit obtained from the second sub-sample of the i^{th} . pair and b_i = transferred average benefit obtained by transferring the benefit function derived from the first sub-sample to the second sub-sample of the i^{th} . pair. Thus, expression (7) gives the average percentage error in approximating the true benefit.

The results are reported in tables 2 through 6 for both marginal as well as non-marginal benefits. One important aspect of a reliable hedonic estimation is to see how frequently the benefit measures are of appropriate sign. Column 4 reports the number of

cases out of two thousand cases (one thousand pairs) in which the true average benefit turns out positive for an increase in the level of an attribute. Note that for an increase in the level of an attribute, the resulting welfare benefit may be positive or negative depending upon whether the attribute in question is an amenity or a disamenity. In the hedonic regression attributes, such as HAGE, PTAXES, and DFCL, and the pollution variables PM10 and SULFUR are disamenities¹². In the case of MSPEND contradictory sign is observed in majority of the cases¹³. It is interesting to see that, in general, most of the variables have appropriate sign in majority of the cases. It is also interesting to observe from tables 2 through 6 that as the sub-sample size increases from 306 (set (i)) to 1522 (set (v)), the frequency of appropriate sign increases.

Let us now turn our attention to column 2 and column 3 of tables 2 through 6, in which percentage errors in conducting the unit-value transfer and the function transfer in repeated samples are reported¹⁴. Note that in the present study unit-value transfers and function transfers are carried out under the following conditions. First, both the study (first sub-sample) and the policy (second sub-sample) sites are geographically and temporally identical. Second, the demographic and socioeconomic characteristics of the households being considered are, in general, very similar in the two sub-samples in each pair. Third, the amenities being considered are identical and their levels are very similar in both the study and the policy sites. Table 7 reports the average differences in the socioeconomic factors and the amenity levels between each of the thousand pairs of sub-samples in the six sets described before. It is clear that the socioeconomic and amenity level differences are negligible in all the sets. In short, the performance evaluation of the two approaches is carried out under extremely favorable conditions in the present study.

Thus, one would expect that the results of both the unit-value transfer and function transfer exercises should be within an acceptable level of accuracy. Observe, however, that when the sample size is as high as 306, only in the case of three out of thirteen amenities reported, namely WHITE, MEDINC, and DFCL, error in marginal benefits transfers are within 30 percent. When the sample size is as high as 1522, however, errors for seven out of thirteen amenities are reported to be within 30 percent. Percentage errors are, in general, high for both types of transfers. This is, however, not an encouraging result, since in most practical situations benefit transfers are carried out between the study sites and the policy sites that are dissimilar in many respects, such as time, location, socioeconomic factors, and the levels and the types of the amenity in question.

Observe also that the percent error in the unit-value transfer and the function transfer approaches are almost identical in tables 2 through 6. This implies that when conditions associated with a transfer are favorable, then statistically, there is no gain in precision in adopting the latter approach over the former. The implication of this important result in economic policies dealing with non-market valuation is that, if the policy site and the study sites were similar, adoption of the less costly unit-value transfer approach would be more appropriate than the costlier function-transfer approach.

Another important question, thus, is when the conditions of transfer were not favorable, or in other words, when the study site and the policy site were dissimilar, which methodology would be more appropriate - the unit-value transfer or the function transfer? In the next few paragraphs this issue is addressed in another repeated sampling experiment in which the degree of difference between the socioeconomic characteristics of households in two sub-samples of a random pair is made substantially high.

In order to investigate the impact of the difference in the socioeconomic characteristics of the households in the two sub-samples in a pair, following steps are undertaken with a particular focus on household income. First, the rectangular data set consisting of 3044 observations with 24 variables are read. Second, the data are sorted in increasing order of income. Third, the full, sorted sample is divided into two equal parts separated by a sub-sample of 608 observations in the middle; part (i) having the first 1218 observations and part (ii) having the last 1218 observations. Fourth, for each of the two parts, a set of 1218 uniform (0,1) random numbers is drawn without replacement and the observations in each of the two parts are then arranged in increasing order of the random numbers. Randomization is achieved in each of the two parts of the sample in this fashion. Fifth, two-stage hedonic estimation and transfer exercises are carried out for each sub-sample in a pair, where the first sub-sample consists of the first 913 observations from part (i) and the second sub-sample consists of the last 913 observations from part (ii). All the five steps described above are repeated one thousand times.

The repeated sampling scheme described above, are primarily intended to artificially increase the variation in income between the two sub-samples in each pair. The results of the transfer exercises are reported in table 8. Two very interesting findings come out of this table. First relates to the results of the overall performance of the transfer exercises in table 4 as opposed to the results reported in table 8. Note that both table 4 and table 8 are based on pairs of sub-samples of equal sizes. However, variation in socioeconomic characteristics between the two sub-samples in a pair in the case of the latter is far greater, on average, than in the case of the former. More specifically, percent differences, on average, between two sub-samples in a pair in the case of table 4 are,

INCOME: 1.5%, RACE 4.4%, CHILD: 4.2%, and MARSTAT: 3.3%, whereas percent differences in the case of table 8 are, INCOME: 48%, RACE 41%, CHILD: 16%, and MARSTAT: 16%. It is clearly seen that the average performances of both the unit-value transfer and function transfer approaches are, in general, much worse in table 8 compared to table 4, signifying that socioeconomic similarities have an important role to play in transfer performance.

The second finding is, perhaps, even more interesting. As discussed before, note that tables 2 through 6 report cases in which the pairs of sub-samples are quite similar with respect to both amenity characteristics as well as socioeconomic characteristics. As a result of this percent error in the unit-value transfer and the function transfer approaches are almost identical, implying there is no gain in precision in adopting the latter approach over the former. However, when income variation, and consequently, the variations in all the socioeconomic characteristics between the pairs of sub-samples are made artificially high, function-transfer seems to clearly outperform unit-value transfer in repeated samples, as shown in table 8. This is true for almost all the housing amenities and in the case of both marginal and non-marginal benefits. An important policy implication of this finding is that, when the study site and the policy site significantly differed with respect to the demographic profile of the population, function transfer would perhaps be the more appropriate approach than a simple unit-value transfer approach.

One major limitation of the present empirical study is that the two-stage hedonic approach adopted is based on single market and thus the econometric issues, such as the problem of identification and endogeneity may have come in the way of reliable benefit estimation, especially at the second stage. The second limitation is associated with the

specification of the hedonic price function at the first stage. Chattopadhyay (1999) finds that a linear Box-Cox specification performs well for the full-sample Chicago data, considered in this study. However, except for looking at the number of correct signs in repeated samples, performance of the linear Box-Cox specification in split samples, has not been elaborately addressed in the present study.

6. Conclusion

For evaluating the benefits of a proposed public project or assessing the damage caused to a natural resource, public authorities are relying increasingly on benefit transfer methodologies. This paper attempts, for the first time, to investigate the effectiveness of the benefit-transfer methodologies in a controlled statistical experiment in which a pair of random sub-samples are drawn repeatedly from a full sample and benefit transfers are carried out from one sub-sample to the other. The study applies the hedonic two-stage estimation technique to Chicago housing data and generates a number of interesting findings.

First, even when the conditions associated with a transfer between sub-samples of a pair are extremely favorable, that is when the two sub-samples have high degree of similarities there are substantial errors in transferred benefit estimates under both transfer approaches, namely the unit-value transfer and the function transfer approaches. This finding is discouraging, since benefit transfers are often carried out when the study and the policy sites are quite dissimilar. Second, the magnitudes of error in the two approaches are almost the same, signifying that there is no gain in precision in adopting the latter approach over the former. The implication of this finding in economic policies dealing with non-market valuation is that, if the policy site and the study site were

similar, then adoption of the less costly unit-value transfer approach would be more appropriate than the costlier function-transfer approach. The above results are based on five sets of thousand non-overlapping pairs of sub-samples.

Third, based on another set of one thousand non-overlapping pairs of sub-samples the study finds that socioeconomic similarities have an important role to play in transfer performance. One important finding is that high degree of dissimilarity results in poor quality of transferred benefits in the case of both transfer approaches. Another, more interesting result is that in the presence of socioeconomic dissimilarities the function-transfer approach outperforms the unit-value transfer approach in repeated samples. An important policy implication of this finding is that, when the study site and the policy site significantly differed with respect to the demographic profile of the population, function transfer would perhaps be a more appropriate approach than a simple, unit-value transfer.

Since the benefit transfer methods are becoming increasingly accepted policy tools in non-market valuation, it is necessary that appropriate guidelines be developed. Future research should focus on studies based on repeated sampling experiments across data sets and across valuation techniques to get a better perspective on how to improve and refine the present policy guidelines.

Note

1. For a more elaborate discussion on the two different kinds of tests, reader may see Boyle and Bergstrom (1992) and Bergstrom and De-Civita (1999).
2. Repeated sampling experiment is often suggested in statistical literature for out-of-sample predictive performance. It is often called a cross-validation methodology where a sample is randomly partitioned a large number of times into two parts - the sample observations and the out-of-sample observations. A cross-validation exercise fits a model to the sample observations and tests the model's goodness of fit on the out-of-sample observations to gauge the error in the out-of-sample prediction. Reader may see Geisser (1975), Efron (1986), and Guilley and Pace (1995) for a discussion and application of such a repeated sampling experiment.
3. See Bergstrom and De-Civita (1999) for an elaborate discussion on how public authorities in the United States and Canada use benefit transfer methodology, and how the methodology is used to settle court litigations.
4. See Smith (1992) for an involved discussion on the important role the benefit transfer methodology can play in non-market valuation and on the necessity of framing an appropriate set of guidelines for its usage.
5. Chattopadhyay (1999) adopts a flexible functional form approach on the same data set and finds that the linear Box-Cox form of the hedonic function provides reliable benefit estimates. For an empirical investigation into the functional-form issue, reader may see Chattopadhyay (1999). For interesting theoretical discussion on the functional-form issue, reader may see Halvorsen and Pollakowsky (1981), Cassel and Meldensohn (1985). Also see Atkinson and Crocker (1987) and Gilley and Pace

(1995) for some interesting empirical work to tackle the multicollinearity problem in the first stage hedonic estimation.

6. Chattopadhyay (1999) use six variants of a generalized quadratic Box-Cox functional form, namely linear, semi-log, double log, quadratic, linear Box-Cox, and quadratic Box-Cox. He finds that for the Chicago data, except for the two quadratic forms, the WTP for marginal and non-marginal changes in most of the housing amenities, including air quality, are quite comparable across functional forms.
7. Chattopadhyay (1999) uses both Diewert and translog utility functions for household preference. The estimates of average non-marginal WTP across preferences for the Chicago households are found quite comparable in that study.
8. Exact welfare measurement associated with a change in an amenity in the case of the hedonic pricing approach can be rather complicated. The expression in (6) assumes (i) that the hedonic housing price function does not change due to an exogenous change in the amenity level; (ii) households do not relocate in response to a change in the amenity level. Thus, the net benefits associated with a change in the hedonic price function and households' relocation decisions are not incorporated in equation (6). Benefits that may accrue to the suppliers of housing are also not considered. Since knowledge of such information is extremely hard to get, they are often ignored in most empirical studies. Thus, expression (6) can be regarded as the lower bound of the exact measure of benefits. For details on welfare measurement associated with an amenity change, reader may see Bartik (1988), Palmquist (1988). In a recent empirical study, Chattopadhyay (1998) ignores the above-mentioned benefits in a hedonic housing price model and compares the hedonic benefits with the benefits

obtained using the Ellickson (1981) bid-rent model. He finds that the two models generate similar estimates of Marshallian surplus associated with amenity changes. This signifies that the benefits mentioned above, that are ignored in the present study, may often be negligible.

9. Note that a full-sample hedonic estimation is not the purpose of the present study and thus, is avoided. For a full-sample analysis using the Chicago data, reader may see Chattopadhyay (1999).
10. In the present study the “true benefit estimates” are, essentially, the ones that are obtained by using benefit functions derived from the same sub-sample. Benefit estimates that are obtained by using benefit functions derived and transferred from the other sub-sample in the pair are called the benefit estimates based on function transfer.
11. In a full-sample study, although the amenity variable (z) turned out highly significant, the demographics RACE and CHILD turned out mostly insignificant at any acceptable level. However, these variables are still kept in the 3SLS regression as they are normally assumed to affect the price of attribute in an inverse demand (or willingness-to-pay) function.
12. The expected sign of the coefficient associated with each housing attribute in the first stage regression is given in Table 1 against each explanatory variable in parenthesis, except DFNI. On the one hand this variable signifies access in which case the lower the value, the higher the house price. On the other hand, DFNI may also be linked to highway noise and, as such the greater the value, the higher the house price. However, observe that for the Chicago data, in majority of the cases the sign of the

DFNI coefficient turns out negative, signifying that the impact of access overrides the impact of highway noise on the households.

13. In a full-sample analysis Chattopadhyay (1999) finds that coefficient associated with MSPEND is negative. It is found that during the period 1989-90, a substantial portion of municipal spending in Chicago was spent on police protection. A reasonable explanation could be that this variable might be picking up the negative effect of crime on house prices.
14. Percent errors are not reported for AIRCON, BATH, GARAGE, COOK, and OHARE, which are either dummy variables or the variables taking integer values including zero.

TABLE 1: DATA DESCRIPTION AND SOURCES

Variables	Definitions and sources
<i>Household's socio-economic characteristics</i>	
INCOME	Total annual income of the purchaser (\$). Source: FHA
RACE	Race of the purchaser, =1 if white, = 0 otherwise. Source: FHA
CHILD	Number of dependent children in the household (number). Source: FHA
MARSTAT	Marital status of the head of household =1 if married, = 0 otherwise. Source: FHA
X	Household's annual non-housing expenditure (\$). Obtained indirectly from house price and FHA monthly mortgage interest rate. Source: FHA
<i>Property Characteristics[@]</i>	
HPRICE	Contract sales price of the house (\$). Source: FHA.
ROOMS (+)	Total number of habitable room enclosures (number). Source: FHA.
LVAREA (+)	Total living area (ft ²). Source: FHA.
HAGE (-)	Age of the dwelling (years). Source: FHA.
LOTSIZE (+)	Total area of the lot (ft ²). Source: FHA.
AIRCON (+)	If the dwelling has central air-conditioning = 2, if window or wall air-conditioning = 1, if no air conditioning =0. Source: FHA.
BATH (+)	Number of bathrooms in the dwelling unit. Source: FHA.
GARAGE (+)	If built-in garage = 4, if carport = 3, if not built-in garage = 2, if on-site parking =1, if none = 0. Source: FHA.
<i>Neighborhood and City-specific Characteristics[@]</i>	
WHITE (+)	Percentage of white population in 1990 in the census tract in which the unit is located (%). Source: U.S. Bureau of Census (1990).
MEDINC (+)	Median 1990 income of the census tract in which the dwelling unit is located (\$). Source: U.S. Bureau of Census (1990).
DFCL (-)	Distance from the Loop area in downtown Chicago (0.1 mile). Source: Contemporary city maps.
DFNI (?)	Distance to the nearest highway entrance(0.1 mile). Source: City map.
PM10 (-)	Annual mean readings obtained for the years 1989 and 1990 from 24 monitoring stations in the Chicago metropolis (in $\mu\text{g}/\text{m}^3$). Source: Illinois Annual Air Quality Report.
SULFUR (-)	Annual mean readings obtained for the years 1989 and 1990 from 11 monitoring stations in the Chicago metropolis (parts per million (ppm)). Source: Illinois Annual Air Quality Report.
PTAXES (-)	Property tax rate prevailing during the year of purchase in the city where the unit is located (%). Source: Illinois Department of Revenue.
SSPEND (+)	Operating expenses per pupil in the school district where the dwelling unit is located (\$). Source: Annual Statistical Report 1989 and 1990 of Illinois State Board of Education.

TABLE 1 *continued*

MSPEND (+)	Expenditure per-capita by the municipal government during 1987 (\$). Source: Census of Government 1987
COOK (+)	Dummy variable = 1 if the unit is in Cook county, if in Dupage County = 0.
OHARE (+)	Dummy variable, =1 if the housing unit is within five miles radius of O'Hare business district and = 0 otherwise

[@]The plus or minus sign against each explanatory variable represents the expected signs in the first stage hedonic regression.

TABLE 2: PERFORMANCE OF BENEFIT TRANSFER (SUB-SAMPLE SIZE = 304)			
MARGINAL BENEFIT FOR AN INCREASE IN THE AMENITY LEVEL			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	202	172	1811
LVAREA	42	42	1995
HAGE	37	36	4
LSIZE	42	42	1999
PTAXES	35	35	1
WHITE	29	29	2000
MEDINC	23	23	2000
DFCL	23	23	0
DFNI	1190	929	698
PM10	429	486	338
SULFUR	106	104	118
SSPEND	1491	662	1391
MSPEND	387	506	329
Non-marginal benefit for a 25 percent increase in the amenity level			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	180	195	1811
LVAREA	43	43	1995
HAGE	40	40	4
LSIZE	41	41	1999
PTAXES	36	36	1
WHITE	230	180	1833
MEDINC	23	23	2000
DFCL	24	24	0
DFNI	422	393	1070
PM10	869	439	338
SULFUR	106	110	118
SSPEND	868	1285	1391
MSPEND	468	437	329

[@]Hedonic benefits are based on 2000 sub-samples

TABLE 3: PERFORMANCE OF BENEFIT TRANSFER (SUB-SAMPLE SIZE = 609)			
MARGINAL BENEFIT FOR AN INCREASE IN THE AMENITY LEVEL			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	75	75	1958
LVAREA	29	29	2000
HAGE	24	23	0
LSIZE	27	26	2000
PTAXES	23	23	0
WHITE	20	20	2000
MEDINC	16	16	2000
DFCL	17	16	0
DFNI	1371	640	533
PM10	150	153	145
SULFUR	57	57	24
SSPEND	911	732	1597
MSPEND	152	169	118
Non-marginal benefit for a 25 percent increase in the amenity level			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	75	75	1958
LVAREA	29	29	2000
HAGE	27	27	0
LSIZE	26	25	2000
PTAXES	23	23	0
WHITE	85	85	1970
MEDINC	16	16	2000
DFCL	17	18	1
DFNI	844	760	855
PM10	310	443	145
SULFUR	57	57	24
SSPEND	1170	587	1598
MSPEND	223	219	118

[@]Hedonic benefits are based on 2000 sub-samples

TABLE 4: PERFORMANCE OF BENEFIT TRANSFER (SUB-SAMPLE SIZE = 913)			
MARGINAL BENEFIT FOR AN INCREASE IN THE AMENITY LEVEL			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	56	56	1989
LVAREA	23	23	2000
HAGE	20	19	0
LSIZE	21	21	2000
PTAXES	18	18	0
WHITE	16	16	2000
MEDINC	13	13	2000
DFCL	13	13	0
DFNI	695	390	407
PM10	82	82	52
SULFUR	42	42	1
SSPEND	303	352	1713
MSPEND	75	75	47
Non-marginal benefit for a 25 percent increase in the amenity level			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	56	56	1989
LVAREA	24	24	2000
HAGE	22	22	0
LSIZE	20	20	2000
PTAXES	18	18	0
WHITE	70	70	1993
MEDINC	13	13	2000
DFCL	14	14	0
DFNI	3042	581	681
PM10	82	82	52
SULFUR	42	42	1
SSPEND	476	340	1713
MSPEND	75	75	47

[@]Hedonic benefits are based on 2000 sub-samples

TABLE 5: PERFORMANCE OF BENEFIT TRANSFER (SUB-SAMPLE SIZE = 1218)			
MARGINAL BENEFIT FOR AN INCREASE IN THE AMENITY LEVEL			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	46	46	1998
LVAREA	21	21	2000
HAGE	17	17	0
LSIZE	18	18	2000
PTAXES	16	16	0
WHITE	14	14	2000
MEDINC	11	11	2000
DFCL	11	11	0
DFNI	259	387	289
PM10	67	67	20
SULFUR	36	36	0
SSPEND	126	126	1818
MSPEND	61	61	15
Non-marginal benefit for a 25 percent increase in the amenity level			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	46	46	1998
LVAREA	21	21	2000
HAGE	20	194	0
LSIZE	17	17	2000
PTAXES	16	16	0
WHITE	60	60	1997
MEDINC	11	11	2000
DFCL	11	11	0
DFNI	771	533	470
PM10	67	67	20
SULFUR	36	36	0
SSPEND	139	139	1816
MSPEND	61	61	15

[@]Hedonic benefits are based on 2000 sub-samples

TABLE 6: PERFORMANCE OF BENEFIT TRANSFER (SUB-SAMPLE SIZE = 1522)			
MARGINAL BENEFIT FOR AN INCREASE IN THE AMENITY LEVEL			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	42	42	1999
LVAREA	19	19	2000
HAGE	15	15	0
LSIZE	16	16	2000
PTAXES	14	14	0
WHITE	13	13	2000
MEDINC	10	10	2000
DFCL	10	10	0
DFNI	127	127	200
PM10	58	58	3
SULFUR	32	32	0
SSPEND	96	96	1902
MSPEND	53	53	3
Non-marginal benefit for a 25 percent increase in the amenity level			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	42	42	1999
LVAREA	20	20	2000
HAGE	17	18	0
LSIZE	15	15	2000
PTAXES	14	14	0
WHITE	55	55	1999
MEDINC	10	10	2000
DFCL	10	10	0
DFNI	311	410	252
PM10	58	58	3
SULFUR	32	32	0
SSPEND	97	97	1901
MSPEND	53	53	3

[@]Hedonic benefits are based on 2000 sub-samples

TABLE 7: AVERAGE PERCENTAGE DIFFERENCE IN THE LEVELS OF AMENITIES AND SOCIOECONOMIC ATTRIBUTES BETWEEN TWO SUB-SAMPLES OF A PAIR					
Variable	Set (i)	Set (ii)	Set (iii)	Set (iv)	Set (v)
ROOMS	2.6	1.9	1.5	1.3	1.2
LVAREA	2.9	2.0	1.7	1.4	1.3
HAGE	3.7	2.6	2.2	1.9	1.7
LSIZE	5.5	4.1	3.3	2.9	2.6
AIRCON	7.1	5.1	4.0	3.5	3.2
BATH	3.0	2.1	1.7	1.5	1.4
GARAGE	5.4	3.8	3.1	2.7	2.4
PTAXES	1.0	0.7	0.6	0.5	0.5
WHITE	3.7	2.7	2.2	2.0	1.8
MEDINC	1.9	1.4	1.2	1.0	0.9
DFCL	3.2	2.4	2.0	1.7	1.5
DFNI	5.7	3.8	3.1	2.7	2.4
PM10	0.8	0.6	4.9	0.4	0.4
SULFUR	2.1	1.5	1.3	1.1	1.0
SSPEND	1.1	0.8	0.7	0.6	0.5
MSPEND	2.7	1.9	1.6	1.3	1.2
COOK	2.6	1.7	1.4	1.2	1.1
OHARE	40.1	26.1	20.7	17.9	15.6
INCOME	2.6	1.9	1.5	1.3	1.1
RACE	7.4	5.4	4.4	3.9	3.4
CHILD	7.5	5.3	4.2	3.7	3.4
MARSTAT	5.8	4.1	3.3	2.9	2.6

TABLE 8: PERFORMANCE OF BENEFIT TRANSFER UNDER LARGE VARIATION IN SOCIOECONOMIC CHARACTERISTICS (SUB-SAMPLE SIZE = 913)			
MARGINAL BENEFIT FOR AN INCREASE IN THE AMENITY LEVEL			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	155	149	1818
LVAREA	28	16	2000
HAGE	57	12	0
LSIZE	38	26	2000
PTAXES	84	55	0
WHITE	26	10	2000
MEDINC	8	9	2000
DFCL	15	12	0
DFNI	823	839	563
PM10	128	110	40
SULFUR	89	65	0
SSPEND	1315	921	1286
MSPEND	167	148	221
Non-marginal benefit for a 25 percent increase in the amenity level			
Variable	Unit-value transfer error (%)	Function transfer error (%)	Frequency of Positive benefits [@]
ROOMS	158	141	1818
LVAREA	28	16	2000
HAGE	99	52	2
LSIZE	45	17	2000
PTAXES	73	35	0
WHITE	802	529	1210
MEDINC	16	14	2000
DFCL	27	20	3
DFNI	360	687	977
PM10	124	101	40
SULFUR	41	25	0
SSPEND	1053	533	1287
MSPEND	155	204	223

[@]Hedonic benefits are based on 2000 sub-samples

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