Economies of Scale in Costs of Land Acquisition for Nature Conservation

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Abstract

Market failure results in more human conversion of ecosystems for development and other uses than likely socially desirable. In response, many government agencies and nonprofits focus on conservation, often acquiring land rights to establish protected areas on which further conversion of ecosystems is precluded. The protected areas created vary greatly in size, even within a particular conservation program. Here we examine the costs that conservation organizations face when acquiring sites for protection and pay particular attention to the consequences of this variability in protected area size. We use as our case study parcels in Central and Southern Appalachian forest ecosystems that were protected through fee simple acquisition and using easements by The Nature Conservancy, a nonprofit land trust. We compare these sites to unprotected areas similar to the protected areas in terms of site characteristics as identified by post-hoc matching methods. When comparing average costs, we found parcels protected under by fee simple transactions cost less than matched unprotected parcels, and that average costs of protecting parcels using easements were lower still. We also found that acquisition costs of protected areas achieve economies of scale under fee simple transactions. However, these economies of scale were often weaker than those present when considering matched, unprotected parcels. Parcels protected by easements did not show economies of scale with area. We were able to identify a subset of transactions where the agreed price was reduced to reflect an explicit donative intent on the part of the seller. For this subset of transactions, we found that the presence of donative intent disrupted any kind of systematic relationship between lot size and acquisition costs for conservation. Our findings imply that to achieve cost effective conservation,

conservation organizations will need to strategize with respect to parcel size and contract type. For example, when acquiring parcels under a fee simple transaction, economies of scale in acquisition costs provide an incentive for conservation organizations to favor larger parcels, reinforcing ecological arguments that favor protecting larger protected areas. Also, by quantifying the cost differential between fee simple and easement acquisitions, we provide a benchmark for evaluating how much greater the ecological benefits of fee simple acquisition would have to be to provide the most effective option for conservation.

Keywords: Protected Area Size, Economies of Scale in Size, Spatial Econometrics

JEL Classification: Q57, Q24, Q51

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Natural ecosystems provide a range of goods and services like carbon sequestration and provision of habitats for plants, animals, and micro-organisms (MEA 2005a; 2005b). However, private land use decisions generally fail to capture the value of related ecosystem services (TEEB 2009). The resulting market failure causes more conversion or clearing of ecosystems for development and other uses than likely socially desirable. In response, many government agencies and nonprofits focus on conservation, often acquiring land rights to establish protected areas on which further conversion of ecosystems is precluded (Aycrigg et al. 2013; Fishburn et al. 2013; IUCN 2013). To do this, land rights commonly have to be purchased, and property owners compensated; thus, conservation organizations are under pressure to devise land acquisition strategies as cost effectively as possible.

Protected areas vary in all manner of characteristics. One particularly striking gradient is simply their size variation, which can range widely even within a particular conservation program (Davies, Kareiva, and Armsworth 2010; IUCN 2013; IUCN and UNEP-WCMC 2014). There is also variation in the type of protection strategy employed. For example, in the US, there is an increasing reliance on protecting land through easements in which a conservation organization acquires only a limited set of property rights associated with land ownership, in contrast to the more traditional fee simple acquisition strategy, in which conservation organizations buy land parcels outright (Stein and Kutner 2000; Fishburn et al. 2009a; LTA 2011).

Faced with resource constraints, a conservation organization active in land protection must pursue a cost effective investment strategy to maximize progress towards its conservation objectives (Naidoo et al. 2006). For conservation organizations in the US, the need for identifying cost effective strategies is brought into sharper relief by the ongoing federal budget crisis and economic turmoil triggered by the recent recession, which has impacted many conservation programs with budget cuts (Bakker et al. 2010). Spending by governmental entities and the conservation nonprofit sector on land conservation programs has diminished since the start of the recession. For example, total annual rental payments for the Conservation Reserve Program (CRP) declined by 7% during 2008–2013 (from $1.8 billion to $1.69 billion) (USDA Farm Service Agency 2013). In addition, many nonprofit land trusts active in protecting ecosystems from conversion are having to rethink their land acquisition strategies in light of the changed economic circumstances they now face.

Objective and Hypotheses

Here we seek to examine how the costs of protected area acquisition are affected by key characteristics of the parcels being protected. We specifically emphasize both the size of the protected areas, and also whether they were protected under a fee simple or easement transaction. In addition, we examine how any donative intent on the part of the grantor affects the acquisition price faced by a conservation organization; often landowners sell properties to conservation organizations for below fair market value with the residual amount intended as a donation (i.e. for tax purposes).

In particular, we sought to determine whether acquisition costs show economies of scale with area while controlling for the effects of other covariates. Past studies have found that recurring, annual stewardship costs associated with managing protected areas show economies of scale with area (e.g. Armsworth et al. 2011). In contrast, the potential influence of economies of scale with area on the costs associated with acquiring protected areas in the first place does not appear to have been previously considered.

We use as our case study areas acquired by The Nature Conservancy (TNC) to protect Central and Southern Appalachian forest ecosystems of the US (referred to as “protected areas”). TNC is an international conservation nonprofit, but operates a land-trust like business modelwithin the US where this organization has invested over 2010 USD $8 billion through a combination of fee simple and easement acquisitions since 1951 (Fishburn et al. 2013). By focusing on areas protected by a single organization, we are able to ensure comparability of available data and reporting standards across land transactions. At the same time, we are still able to span variation in protected area strategies because TNC is structured into semi-independent state chapters that follow somewhat different protected area strategies (Fishburn et al. 2009b). Like protected areas elsewhere, areas protected by TNC vary greatly in their size (i.e. from a minimum of 0.2 hectares to a maximum of 2,327 hectares in our dataset).

We compare TNC’s protected areas with other, similar locations in terms of site characteristics (referred to as “unprotected areas”). We identify these matching “control” sites using the statistical technique of propensity score matching (Rosenbaum & Rubin 1983, see below for details). We also examine records provided to TNC by professional real estate appraisers at the time acquisitions were being considered, which include comparator parcels. However, we found appraisers use a variety of disparate methods (or site characteristics) to identify what they considered to be meaningful comparator parcels for a given transaction. Because of this heterogeneity in identifying and reporting comparator parcels across appraiser reports, we focused our analyses on the comparison with parcels identified by our statistical matching process in the main text. We briefly discuss data, models, and results that are based on the comparator parcels identified by the appraisers in the Appendix and treat them as supplemental information rather than the focus of our study.

We first examine how the average cost per hectare of acquiring sites compared between parcels protected by TNC and statistically matched, unprotected parcels. Then, we focused in more detail on how acquisition costs were affected by the area of the parcel being acquired. Specifically, we tested whether (1) acquisition costs of protected areas under a fee simple and easement transaction show economies of scale and, if so, whether their magnitudes differ between fee simple and easement transactions, (2) acquisition costs of similar unprotected areas also show economies of scale with area and, if so, whether these economies of scale differ from any found for protected areas, and (3) donative intent on the part of the grantor affects any economies of scale with protected area size.

Formally, our test for economies of scale in acquisition costs with parcel area is whether the elasticity of acquisition cost with respect to area is significantly less than 1. Previous empirical studies have commonly found diminishing marginal implicit price of land area under hedonic price models (e.g. Davis, Kareiva, and Armsworth 2006; Braden et al. 2008; Cho et al. 2009). Because the price of land under the hedonic price models refers to the acquisition cost of unprotected areas used in our research, the diminishing marginal implicit price of land is equivalent to the elasticity of the acquisition cost with respect to unprotected areas being less than 1.

Hypothesis 1 tests whether these results apply to properties protected by TNC under fee simple and easement transactions, and Hypothesis 2 tests whether these results apply to the wider land market within which our protected area transactions take place. All else being equal, the presence of any economies of scale in acquisition costs of lands for conservation indicates that larger land parcels should be prioritized for protection as part of a cost effective conservation strategy. To test for differences in any economies of scale between these sets of transactions (protected vs unprotected), we compare the elasticities of acquisition cost with respect to area that we find. Comparing the elasticities in this way allows us to evaluate whether any differences in the use of small or large protected areas result from a choice among available parcel sizes by TNC or whether they simply reflect parcel sizes available for acquisition in relevant markets having other desired characteristics.

Finally, we observed that the fair market value of properties is often larger than the acquisition price paid by TNC, because landowners may sell at below market value by way of making a charitable donation in which the donation is usually claimed as a tax deduction. Hypothesis (3) examines if economies of scale with protected areas represent a differential willingness of owners of large and small tracts to make charitable donations by accepting less than fair market value.

Significance of the Analysis

Our research contributes to the literature in three ways. First, we provide the first rigorous test and comparison of the economies of scale with area between transactions made by a conservation organization (the treatment group) versus transactions without such involvement (the control groups). We identify these control groups using statistical matching because it allows matching each protected area to land transactions not purchased for conservation but with similar characteristics. The comparisons between the treatment and control groups help isolate the difference in economies of scale with area under a fee simple and an easement transaction and those under unprotected sites while controlling for the effects of other site characteristics.

Second, we focus on the actual costs of protected areas. Identifying what areas should be a priority for protection from among many possibilities is an organizing question in conservation research (Margules and Pressey 2000; Moilanen, Wilson, and Possingham 2009; Wilson et al. 2009). Increasingly, the emphasis in that literature is falling on cost effectiveness approaches that seek to combine data on spatially heterogeneous costs of protecting particular sites with data on the ecological benefits of so doing. However, most studies lack data on the actual costs of protected areas and rely instead on proxy data for their economic cost estimates such as county-level average agricultural land values (e.g. Murdoch et al. 2007; Fuller et al. 2010; Withey et al. 2012). When proxies have been compared to actual costs of protected areas, they have been found to perform poorly (Armsworth 2014). Moreover, these proxy measures typically assume that costs of establishing protected areas scale linearly with area. However, when estimating economies of scale with protected areas, we are able to estimate statistically meaningful economies of scale of area by including nonlinear dependence of actual costs on protected area size.

Third, we use information provided by TNC offices to differentiate land transactions with and without grantors' donative intent, adding another level of detail missing in past studies on costs of protected areas. Specifically, estimates made for TNC by professional appraisers at the time of transactions (Appendix) revealed instances in which TNC was able to acquire properties at below fair market value. Internal organization documents (see below) combined with conversations with TNC staff allowed us to identify all instances in our dataset in which grantors' deliberately sold at below fair market value for the stated intent of claiming a tax deduction for charitable donation. By accommodating rare and accurate information about grantors' donative intent in the empirical model, we empirically test Hypothesis (3) that donative intent on the part of the grantor affects economies of scale with protected areas.

Data

Protected areas include 182 TNC transactions made by fee simple and easement transactions between 2000 – 2009 (inclusive) in three eco-regions (Cumberlands & Southern Ridge and Valley, Southern Blue Ridge, and Central Appalachian Forest), 10 states (AL, GA, KY, MD, NC, PA, SC, TN, VA, and WV) and over 70 counties (see figure 1).[1] The information about TNC protected areas was collected from TNC documents describing each transaction from their Conservation Lands database. From the TNC documents, we collected transaction information including acquisition cost, size, grantor or landowner type (i.e. private individuals or others including corporations, nonprofits, etc), contract type (i.e. fee simple or easement), take-out partner (i.e. did TNC intend to retain the property or transfer it to another nonprofit organization or a state or federal agency for long-term stewardship), motivation for protection (i.e. presence or absence of rare or imperiled species; presence or absence of perceived threat of development), and location information.

Alternatively, the unprotected areas identified using statistical matching were selected from all parcels of 25 counties in 10 states that were transacted between any grantor and grantee between 2000-2009 (inclusive; see *Matching protocol* section below for how specific matched unprotected areas were selected and which transactions were omitted from consideration). These transactions were identified using data from county tax assessment offices and geographical information systems (GIS), for which we collected associated acquisition cost, size, and location information.

We assigned additional economic, demographic and environmental data to both TNC protected areas and unprotected areas used in statistical matching. We collected relevant data (i.e. population density, vacancy rate, and median household income) for parcels from census-block group data for 2000 and 2007. We assigned the economic and demographic data of the closest census year prior to the transaction to both protected and unprotected areas within the boundaries of the census-block groups. Specifically, the census-block group data for 2000 was assigned to transactions made during 2000 – 2006, and the census-block group data for 2007 was assigned to sites protected during 2007 – 2009 using the spatial join tool in ArcGIS (ESRI 2012).

Distance to nearest landmarks (i.e., major city, park, hospital, water body, and major highway) for both protected and unprotected areas was measured using the "Near analysis" tool in ArcGIS 10.0 (ArcGIS Resource Center 2013). Distance was measured between parcel centroids and the centroids of the nearest: major city with a population of 10,000 or more; local, state, or national park; hospital; or water body. Distance was also measured between parcel centroids and the nearest point on polylines representing major interstates or state highways. Shape files of the cities, parks, hospitals, water bodies, and highways were acquired from ESRI Data & Maps 10 (ESRI 2011). Average values of elevation and slope within protected and unprotected area boundaries were calculated using the Zonal Statistics tool in ArcGIS 10.1 (ESRI 2012) based on raster grids from the 30-meter Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) Version 2 (V2) (NASA JPL 2011).

We used dummy variables to control for possible differences in acquisition costs between TNC eco-regions (TNC 2013). Of the three eco-regions, we used the Southern Blue Ridge eco-region as a reference dummy variable. Further, because the transaction period for both protected and unprotected areas was over 2000 – 2009, we needed to control for changes in market conditions over those 10 years not accounted for in the model. Thus, acquisition costs were adjusted to 2000 dollars using a state-level housing price index (FHFA 2013), and the median household income was adjusted to 2000 dollars using a consumer price index (BLS 2013). Additionally, dummy variables for the year of the transactions were included.

Empirical Model

In this section, we first describe statistical matching procedures used to identify unprotected areas, and then we specify acquisition cost models for protected and unprotected areas under consideration of potential sample selection biases and spatial structure with location information.

Statistical Matching Protocol

For statistical matching, we collected parcel level data from 25 of the 70 counties (see above) where TNC protected area transactions were made. Ideally, these data would have been available from all 70 counties; however, heterogeneity in how different counties store and manage these data made this impractical. Consequently, we developed a strategy whereby the total 70 counties were grouped into a handful of submarkets which shared reasonably close characteristics to one another relative to the other submarkets (Grigsby et al. 1987). These submarkets were then used as units for implementing the matching protocol under the assumption that similar properties of parcels are shared within each submarket (i.e. each protected area was paired to an unprotected area from within its submarket regardless of whether the two parcels were within the same county owing to the data availability issues outlined above).

We used a two-step clustering method to subdivide the 70 counties into submarkets by shared characteristics (Chiu et al. 2001). In the first step, we pre-clustered 70 counties by constructing a likelihood function and selecting the optimal number of clusters using the Akaike information criterion (AIC). We created a matrix containing Euclidean distances between all pairs of pre-clustered counties (Zhang, Ramakrishnon, and Livny 1996). In the second step, the pre-clustered groups of counties were treated as individual observations, and they were regrouped using agglomerative hierarchical clustering. The average agricultural land value, per capita income, population density, and eco-regions at the county levels were used as variables in the clustering method, which yielded three submarkets (See figure 1 for the submarket delineation, spatial distributions of each county under the submarkets, and number of protected areas in each county.)

Once the 70 counties were divided into the three submarkets, a group of candidate parcels was chosen to use for the matching protocol by screening out sales of parcels unlikely to share similar attributes with the protected parcels. The screening process was necessary due to the unbalanced number of observations between protected and unprotected areas using the statistical matching (i.e. each county contained 1 – 12 protected area parcels, while parcel data representing unprotected area received from each county office contained 40,900 – 119,151 parcels). The efficiency of the propensity score matching was improved by screening out the following parcels: (1) sales made outside of the TNC transaction period, 2000 – 2009, to exclude parcels under different market conditions, (2) sales below $1,000 to exclude those transactions which are likely gifts, donations, or inheritances and do not reflect true market value, (3) sales with positive structure (i.e. building) values to exclude parcels with development, and (4) sales of parcels defined as developed by land use classification recorded by county officers (i.e. commercial, industrial, residential, transportation, traffic, and institutional land uses) and/or the National Land Cover Database (2001; 2006) to exclude developed parcels (Homer et al. 2007; Fry et al. 2011).[2]

Once the screening process was done, we superimposed the candidate parcels for matching over the boundaries of current protected areas obtained from the Protected Areas Database of the United States (PAD-US) (USGS 2013). We then excluded any candidate parcels that are parts of the protected areas included in all federal and most state conservation lands and many privately protected areas at regional and local scales (USGS 2013). The exclusion of existing protected areas was needed to build a sample of legimitaely unprotected areas by screening out transactions that may have resulted in protected area creation through organizations other than TNC.

We employed a post-hoc protocol to match each protected area individually with candidates from the unprotected areas taken from the delineated submarkets; this omitted those protect areas with donative intent that were excluded at the second stage of the Heckman's two-stage model (see details in the following section). We implemented two matching algorithms: Mahalanobis distance matching (Rubin 1980) and nearest propensity score matching (Rosenbaum and Rubin 1983). Both algorithms used three matching criteria: (*a*) size of parcels and transaction years, (*b*) size of parcels, transaction years, and population density at the census-block group level, and (*c*) size of parcels, transaction years, population density and median household income at the census-block group level, and distance to the closest major city with a population greater than 10,000. The combination of different matching algorithms and criteria were used as sensitivity tests. Mahalanobis distance matching with criteria (*a*), (*b*), and (*c*) are referred to as "Model 1", "Model 2", and "Model 3", respectively, and the nearest propensity score matching with criteria (*a*), (*b*), and (*c*) are referred to as "Model 4", "Model 5", and "Model 6", respectively.

Regression Model Specification

A log-log cost model using the Cobb-Douglas functional form (Chambers 1988; Filippini and Zola 2005) was developed to test the three hypotheses we laid out in the Objective and Hypotheses section. In developing the cost model, we dealt with issues of (*i*) observations with donative intent for the protected areas and (*ii*) spatial structure of the cost models.

To address issue (*i*), we adopted two separate Heckman's two-stage models. In the first stage, we estimated two probit models of transactions occurring with or without donative intent (i.e. one model where transactions occurred with donative intent as 1, and 0 otherwise; the other model where transactions without donative intent as 1, and 0 otherwise). Then, we estimated the two cost models separately for transactions occurring with and without donative intent in the second stage after corrections for sample selection biases using the two sets of inverse Mills ratios (IMRs) obtained from the first stage.

To address issue (*ii*), we tested the spatial structure of the cost models for the samples with location information (i.e. protected parcels with and without donative intent and unprotected areas using the post-hoc matching). Spatial structure is suspected in the cost models because the acquisition cost of one site may be influenced by the acquisition costs of other sites in its neighborhood as acquisition cost depends heavily on the real estate market in which a common mantra is "location, location, location" (Mueller and Loomis 2008). In particular, we tested spatial dependences among acquisition costs (referred to as "spatial lag") and spatial correlation (referred to as "spatial error") between the acquisition costs and the errors (Anselin and Lozano-Garcia 2009). We used the robust spatial Lagrange multiplier (LM)-lag and LM-error statistics to test if the aspatial model is rejected against corresponding spatial lag and spatial error models using different spatial weight matrices (Anselin 1988).

For protected areas without donative intent, aspatial models were rejected over both the spatial lag (robust spatial LM-lag statistics of 1.26 – 46.59) and the spatial error models (robust spatial LM-error statistics of 0.98 – 33.56) for 7 of 9 different spatial weight matrices (critical value = 3.84). Based on these test results, we specified a spatial general model (Heckman 1979; Diao 2014) for the log-log cost model of protected areas without donative intent, with corrections for sample selection biases using the sets of IMRs obtained from the first-stage probit models. The spatial general model takes into account both a spatially lagged dependent variable and a spatial autoregressive error term as follows:

(1)
$$\ln(C_i) = \alpha_0 + \rho \sum_{j=1}^{J} w_{i,j} \ln(C_i) + \alpha_1 \ln(S_i) + \sum_{l=1}^{L} \beta_l \ln(X_{li}) + \gamma N_i + \sum_{m=1}^{M} \delta_m D_{mi} + \omega(N_i \times \ln(S_i)) + \eta IMR_i + u_i, \quad u_i = \lambda \sum_{n=1}^{N} w_{i,n} u_i + \varepsilon_i$$

where $\ln(C_i)$ denotes the natural log of the acquisition cost for parcel *i*; $w_{i,j}$ is an (*i*, *j*) element of spatial weight matrix (*W*); $\ln(S_i)$ is the natural log of protected area size for parcel *i*; $\ln(X_{li})$ is the natural log of l^{th} non-dichotomous variables including economic and demographic characteristics of surrounding communities (i.e. median household income, population density, and vacancy rate at the census census-block group level) and distance to nearest landmarks (e.g. major city; local, state, or national park; hospital; water body; state or interstate highway); $N_i = 1$ if the transaction is fee simple, 0 if conservation easement; D_{mi} is the m^{th} dichotomous variables representing the eco-region; characteristics of TNC parcels (i.e., transaction type, take-out partner, grantor or landowner type, motivation to protect species, and motivation to protect from development) and years of transactions, α, β, γ, δ, ω, and η, are parameter estimates; ρ and λ are parameter estimates of a spatially lagged dependent variable and error term (hereafter, referred to as "spatially dependent parameters"), respectively; $w_{i,n}u_i$ is a spatially lagged error term; and ε_i is a random error term.

In the case of protected areas acquired when there was donative intent on the part of the grantor, aspatial models were rejected over both the spatial lag (robust spatial LM-lag statistics of 0.2 – 40.3) and the spatial error models (robust spatial LM-error statistics of 0.1 – 12.6) for 3 of 11 different spatial weight matrices (critical value = 3.84; see table 1). In addition, the iterative procedure of the maximum likelihood estimator (MLE) for the spatial general model did not converge. We suspect the non-convergence for the MLE may be associated with (*i*) a complete or semi-complete separation issue due to minimal variation in acquisition costs for this subset of transactions; the acquisition cost for 78% (or 74 out of 95) of this subset of properties was zero; and (*ii*) the high correlation between acquisition costs and spatially lagged acquisition costs (i.e., > 0.8 for any given spatial weight matrix). The iterative procedure of the maximum likelihood estimator is known to fail to converge under instances of complete separation (Altman et al. 2004). Given the circumstances, we estimated the aspatial model of the log-log cost model for the protected areas with donative intent after corrections for sample selection biases using the sets of IMRs obtained from the first-stage probit models.

For the cost models of matched unprotected areas, the robust spatial LM-lag statistics ranged from 0.01 to 167.92, and the robust spatial LM-error statistics ranged from 0.00 – 181.98 for Models 1 through 6, which suggest that the aspatial models are rejected over both the spatial lag and the spatial error models for at least 5 of 9 different spatial weight matrices (critical value = 3.84) (see table 1). Based on the results of the tests, the cost model of the unprotected areas for the six models was also estimated using the spatial general model with the same variables on the right side of equation (1), excepting the IMR and dichotomous variables representing take-out partner, grantor or landowner type, motivation to protect species, and motivation to protect from development.

Given the natural-log transformed dependent and independent continuous variables and the interaction term between the dummy variable indicating transaction type (i.e. fee simple or conservation easement) and the size variable, the elasticities with respect to change in size for fee simple and conservation easements for the spatial general model (i.e. TNC-protected and 6 models of unprotected areas) were calculated as:

(2)
$$\text{elasiticity}\big|_{N_i=1,\text{ fee simple}} = \frac{\partial \ln(\mathrm{C}_i)}{\partial \ln(S_i)} = \left(\mathrm{I}-\rho W\right)^{-1}\left(\alpha_1+\gamma\right)$$
$$\text{elasiticity}\big|_{N_i=0,\text{ easement}} = \frac{\partial \ln(\mathrm{C}_i)}{\partial \ln(S_i)} = \left(\mathrm{I}-\rho W\right)^{-1}\alpha_1$$

The elasticities with respect to change in size for fee simple and conservation easements for the aspatial general model were calculated as:

(3)
$$\text{elasiticity}\big|_{N_i=1,\text{ fee simple}} = \frac{\partial \ln(\mathrm{C}_i)}{\partial \ln(S_i)} = \alpha_1+\gamma$$
$$\text{elasiticity}\big|_{N_i=0,\text{ easement}} = \frac{\partial \ln(\mathrm{C}_i)}{\partial \ln(S_i)} = \alpha_1$$

Above calculated elasticities less than one indicate economies of scale in size, whereas those greater than one indicate diseconomies of scale in size, and those equal to one indicate constant economies of scale in size (Latzko 1999).

Empirical Results

In this section, we first compare the summary statistics of explanatory variables between protected areas and matched unprotected areas. Next we provide the comparison of average acquisition costs and economies of scale in size between fee simple and easements for both protected and unprotected areas. We then provide short descriptions of other factors affecting acquisition costs.

Summary Statistics between Protected and Matched Unprotected Transactions

Table 2 compares the summary statistics of the protected areas and matched unprotected areas for Models 1 – 6. Here we discuss how the samples of protected and unprotected areas compare in terms of the right-hand variables included in equation (1); we discuss how costs compare (the left-hand variable) in sections that follow. Because the statistical matching intends to select unprotected areas similar to the protected areas in terms of parcel characteristics, we compared summary statistics between the protected and matched unprotected areas using the variables: size of parcels (Models 1 – 6), transaction years (Models 1 – 6), census-block group level population density (Models 2, 3, 5, and 6) and median household income (Models 3 and 6), and distance to the closest major city (Models 3 and 6).

Mean size was slightly greater for the protected areas than for matched unprotected areas, but there were no consistent differences in mean values for the census-block group data between protected and matched unprotected areas. For example, mean values of population density and median household income were greater or smaller for the unprotected than protected areas depending on the choice of the matching algorithm, while the mean for vacant units was greater for the protected than unprotected areas. Distances to the nearest landmarks, parks, hospitals, water bodies, and highways were all closer for the unprotected than protected areas, while proximity to the nearest major city did not a clear pattern.

We tested for differences between the three right-hand variables (above) believed to be most different between our protected and matched unprotected areas (above) using paired t-tests (Welch 1947). We obtained t-values of 0.019 – 0.045 for differences in size, 0.000 – 0.003 for differences in median income, and 0.678 – 1.767 for differences in distance to the nearest major city between protected and matched unprotected areas for Models 1 through 6. These paired t-test results are encouraging, suggesting that (*i*) the choice of post-hoc matching algorithm does not appear to be a critical factor in terms of the identification of matched unprotected areas and (*ii*) there is no significant difference between protected and matched unprotected areas for the variables we considered at the 5% level (i.e. p-value > 0.05 for all test statistics).

Comparison of Average Acquisition Costs

Average acquisition costs per hectare are significantly lower for parcels protected using easements than for those that TNC acquired through fee simple acquisition based on apaired t-test (t-value = 8.534, p-value = 0.000) (see table 4). That easements should cost less is expected, because with an easement TNC are only acquiring a subset of the property rights that are associated with the full fee title. When comparing protected to matched unprotected areas, we found that protected areas cost significantly less. Importantly, we found that the average cost of protected areas was lower even after (*i*) excluding transactions where there was donative intent on the part of the grantor in the first stage of the Heckman procedure; (*ii*) relying on statistical matching to identify unprotected areas that shared a range of characteristics with those that were protected and (*iii*) controlling for the effect of unmatched, but potentially important, covariates. Moreover, we found the same result when using professional appraisals (Appendix) instead of our statistical matching process to identify a set of comparator, unprotected areas; average costs of protected areas are again significantly lower than similar unprotected areas. These results suggest either that TNC are selectivity favoring as protected areas parcels that cost less than comparable parcels across a range of characteristics, or that the particular negotiation dynamic present in a conservation land transaction is one that lends itself to securing a lower price than is achieved in similar land transactions that do not involve a conservation organization as the buyer.

Comparison of Economies of Scale with respect to Size

Table 3 shows the parameters of the cost model for (*i*) protected areas with donative intent after correction for sample selection bias, (*ii*) protected areas without donative intent after corrections for sample selection bias, spatial lag, and spatial error, and (*iii*) unprotected areas using 6 different matching algorithms after corrections for spatial lag and spatial error. The elasticities of the given explanatory variables for the spatial general model are nonlinear and complicated by the spatial lag of acquisition cost (ρ), thus not equal to the parameter coefficients (β) (see table 3).

Table 4 compares average cost per acre and elasticities in acquisition cost with respect to size that accommodate the spatially dependent parameter (ρ), as expressed in the equation (2), between the protected areas under a fee simple and an easement transaction and their corresponding unprotected areas using matching algorithms. The corresponding elasticities for the protected areas with donative intent were not included in table 4 because the parameter coefficient of the lot size variable and its interaction term with contract type were not significant from the model using protected transactions with donative intent.

The elasticities in acquisition cost with respect to size are 0.757 and 1.185 for protected areas under fee simple and easement transactions, respectively, and are both significantly different from 1 (p-value = 0.000) at the 5% level based on the Wald test (hereafter significance at the 5% level is referred to as “significant”). The elasticity significantly less than 1 for fee simple transactions shows economies of scale, whereas the elasticitiy significantly greater than 1 for easement transactions shows diseconomies of scale. Furthermore, the elasticity of size between fee simple and easement transactions is also significantly different by the Wald test (p-value = 0.000). These results suggest that when comparing between candidate parcels for protected area creation, all else being equal, conservation organizations have an incentive to favor larger parcels over smaller ones when using fee simple transactions, but that the opposite appears to be true when using easement transactions.

The elasticities in acquisition cost with respect to size for the protected areas with donative intent were not significant for both fee simple and easement transactions, so economies of scale in size in this case could not be defined. In fact, donative intent of grantors was found to disrupt any kind of systematic relationship (i.e. economies or diseconomies of scale) between lot size and transaction cost, perhaps because the majority of such transactions (i.e. 74 out of 95) were fully donated.

The elasticities in acquisition cost with respect to size were 0.496 – 0.726 for unprotected areas matched to areas protected under fee simple transactions. These unprotected areas show consistent economies of scale with size in all of our models. Moreover, the elasticities of size of the matched unprotected areas using Models 1 and 3-6 were significantly (even if marginally so) lower from areas protected by fee simple transactions (p-value = 0 – 0.052). In contrast, the elasticities for the matched unprotected areas using Model 2 were not significantly different from areas protected by fee simple transactions (p-values = 0.955).

Similarly, elasticities in acquisition cost with respect to size were 0.539-0.688 for unprotected areas matched to parcels protected with easements. Again, these findings suggest consistent economies of scale with size among the unprotected areas chosen by the statistical matching approaches. Moreover, in all cases, these elasticities of acquisition cost with size were significantly lower than the corresponding elasticity for areas protected by easements (p-value = 0.000 for all models).

Our results demonstrate that unprotected areas achieve significantly better economies of scale with size than the protected areas they are matched to, and that this difference is greatest for the comparison to areas protected by easements. Similarly, when using professional appraisals to identify comparable transactions, we also find clear economies of scale for comparator deals, although there was only a significant difference for comparison to areas protected by easements (Appendix).

Other Factors Affecting Acquisition Costs

Here we provide brief descriptions of estimation results of other explanatory variables used as control variables in the cost models (i.e. except lot size and the interaction term between contract type and lot size).

The parameter estimates from the model for protected areas created with grantor donative intent show that transactions with non-private individual grantors or landowners, development threat, and lower population density increase acquisition costs. They also show that transactions farther away from the nearest park and transactions made in 2004, 2005, 2007, and 2009 relative to those made in 2000 increase acquisition costs.

The parameter estimates of the protected transactions without donative intent suggest that acquisition costs increase for parcels farther away from the nearest hospital, with lower average slope, in the Southern Blue Ridge eco-region relative to deals made elsewhere, and for deals made in 2000 relative to deals made in 2005. The positive spatial lag parameter (ρ) and negative spatial error (λ), respectively, suggest positive spatial spillover in acquisition costs and negative spatial spillover in random shock in a spatially significant omitted variable that affects acquisition cost for the protected transactions without donative intent.

The signs and significances of the parameter estimates for the explanatory variables and spatial parameters of the unprotected areas suggest that lot size is the only variable that consistently has significant effects on acquisition costs, while the rest of variables show variable and inconsistent effects on acquisition costs across models.

Conclusions

Given ongoing patterns of habitat loss but limited budgets for expanding existing protected area networks, it is imperative that what resources are available for establishing new protected areas are allocated efficiently. As well as better evaluating the ecological benefits of protecting particular locations, this will require more carefully accounting for the costs of protected areas (Ferraro 2003; Naidoo et al. 2006; Armsworth 2014). We examined how the costs of acquiring protected areas compared to the costs of acquiring unprotected areas nearby. We paid particular attention to understanding economies of scale in costs of land acquisition. We used 182 protected areas obtained by fee simple and easements transactions between 2000 and 2009 by TNC to protect Central and Southern Appalachian forest ecosystems as our case study.

First, for the comparison of average costs, we found that protected areas acquired by TNC through fee simple transactions cost less than similar unprotected areas properties identified through both a range of differing matching techniques, as well as by professional appraisers. This suggests that when evaluating a set of possible parcels for acquisition, TNC either select low cost options or are able to negotiate particularly favorable prices with sellers. Regardless, this finding cautions that attempts to infer the cost of protected area acquisition, even if based on closely matched rural land transactions, may over-estimate the actual costs that a conservation organization like TNC would face.

We also found that the average cost of easement acquisitions was much lower than for areas protected through fee simple transactions, as would be expected. Other studies have sought to estimate the value of conservation easements and have found a range of values for the average cost of easements relative to full purchase. For example, Casey et al. (2008) showed that the area-weighted average cost of easement acquisitions is about $3,540/ha (or 62%) lower than the area-weighted average cost of fee-simple transactions using data from18 states in the US. However, our results suggest potential limitations of past comparisons. Normally, the cost of easements has been evaluated relative to sales data of fee simple acquisitions that were not bought by the same conservation buyer (Sheehan and Fowler 2012). Our results make clear that, where possible, the more meaningful comparison might be between areas acquired through easement and fee simple transactions by the same conservation organization. Of course, that easements cost less per hectare to acquire does not suggest that they necessarily provide a better deal for conservation, because the ecological benefits of protecting parcels with easements versus fee simple transactions will also differ, albeit in ways that are not yet well-understood (Rissman and Merenlender 2008). But quantifying the cost differential, as we have done, provides a benchmark for evaluating how much greater the ecological benefits of fee simple acquisition would have to be, or how much lower other costs (e.g. annual stewardship costs) would have to be, for a fee simple acquisition to provide a more cost effective option for conservation.

We also examined whether conservation land transactions showed economies of scale in acquisition cost with the size of the parcel being protected. We found that fee simple transactions achieve economies of scale with size. This implies that when comparing two possible parcels that could be acquired through a fee simple arrangement, all else being equal, conservation organizations like TNC should favor the larger parcel. Researchers have long emphasized possible ecological benefits of protecting larger parcels of land (Maiorano et al. 2007; 2008; Leverington et al. 2008; Smith et al. 2010; Worboys et al. 2010); here we found that a different case can be made for favoring larger parcels based on acquisition costs. The resulting economies of scale in acquisition costs will reinforce any economies of scale in annual stewardship costs associated with managing these properties once protected (Balmford et al. 2003; Strange et al. 2006; Ausden 2007; Armsworth et al. 2011). Further, our finding of economies of scale in acquisition costs is not something unique to parcels being acquired by conservation organizations. Instead, we found that transactions of unprotected areas typically achieved significantly better economies of scale in size than protected areas. However, despite costing much less overall, we did not find economies of scale in acquisition costs of easements. Rather we found the opposite, suggesting that when easements are being favored as a means of protecting land, the incentive to favor larger parcels that we observe for fee simple transactions no longer applies. Finally, we found that the donative intent of grantors disrupts any kind of systematic relationship between lot size and transactions cost for the protected area regardless of contract type: fee simple or easement arrangements.

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Table 1. Lagrange Multiplier Test Results to Detect Spatial Dependences

Weight matrices	Structure of spatial dependence	Protected	Unprotected					
			Mahalanobis matching			Nearest propensity score matching		
			Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Inverse distance	Spatial error	30.549*	96.370*	7.639*	14.460*	15.653*	5.642*	13.353*
	Spatial lag	35.684*	167.915*	29.896*	36.718*	87.198*	9.856*	21.255*
K nearest neighbor (KNN)								
K=3	Spatial error	0.978	1.053	3.749	20.250*	5.945*	4.841*	3.955*
	Spatial lag	1.261	5.161*	24.353*	41.539*	11.313*	11.176*	4.573*
K=5	Spatial error	13.640*	0.975	21.300*	20.935*	4.476*	5.262*	4.014*
	Spatial lag	28.118*	10.729*	64.096*	5.321*	7.775*	7.523*	10.729*
K=10	Spatial error	13.335*	8.950*	181.980*	24.591*	9.108*	4.999*	8.95*
	Spatial lag	14.750*	6.722*	306.338*	22.617*	22.313*	7.105*	6.722*
Thiessen polygon	Spatial error	13.964*	0.312	16.949*	0.171	0.265	6.794*	0.035
	Spatial lag	4.999*	0.188	8.794*	0.039	0.129	7.041*	0.011
KNN × Inverse distance								
K=3	Spatial error	33.561*	7.611*	7.549*	7.444*	2.473	0.002	1.475
	Spatial lag	46.592*	20.530*	6.585*	20.363*	5.752*	0.862	3.743
K=5	Spatial error	10.828*	27.029*	13.139*	10.698*	3.038	4.468*	3.934*
	Spatial lag	6.837*	57.624*	22.864*	41.294*	7.167*	6.616*	6.431*
K=10	Spatial error	17.775*	28.182*	14.205*	12.799*	4.051*	5.091*	7.028*
	Spatial lag	17.353*	61.605*	32.257*	46.222*	5.978*	8.087*	12.031*
Thiessen polygon × Inverse distance	Spatial error	11.366*	11.902*	0.154	0.331	0.194	4.151*	0.927
	Spatial lag	3.005	29.340*	0.330	0.067	0.603	5.156*	2.283

Note: * indicates statistical significance given critical level of 3.84 at the 5% level.

Table 2. Summary Statistics of Variables

Variable	Protected	Unprotected					
		Mahalanobis matching			Nearest propensity score matching		
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Acquisition cost	270.21	1171.53	802.97	811.21	854.43	1107.53	435.12
(thousand dollars)	(685.49)	4010.82	2795.25	3096.67	3259.95	4505.91	1239.86
Size (ha)	136.49	110.73	115.38	109.54	101.92	93.87	84.61
	(300.48)	(298.27)	(308.17)	(310.35)	(302.15)	(325.16)	(325.32)
Contract type (1 if fee simple, 0 if easement)	0.63	0.67	0.67	0.68	0.65	0.62	0.64
	(0.48)	(0.47)	(0.47)	(0.47)	(0.48)	(0.49)	(0.48)
Take-out partner (1 if TNC, 0 otherwise)	0.85	-	-	-	-	-	-
	(0.36)	-	-	-	-	-	-
Landowner type (1 if private individual, 0 otherwise)	0.75	-	-	-	-	-	-
	(0.44)	-	-	-	-	-	-
Motivation by species protection (1 if rare or imperiled species, 0 otherwise)	0.23	-	-	-	-	-	-
	(0.42)	-	-	-	-	-	-
Motivation by threat of development (1 if motivated by development threat, 0 otherwise)	0.84	-	-	-	-	-	-
	(0.37)	-	-	-	-	-	-
Population density (population per ha by census block group)	0.19	0.48	0.21	0.27	0.50	0.20	0.20
	(0.19)	(0.65)	(0.20)	(0.22)	(0.66)	(0.17)	(0.20)
Vacant rate (number of vacant housing unit / total housing unit by census block group)	0.23	0.15	0.16	0.18	0.13	0.16	0.15
	(0.18)	(0.12)	(0.11)	(0.12)	(0.10)	(0.13)	(0.11)
Median household income ($, by census block group)	35324.96	37236.07	34418.26	35201.46	37618.41	40147.65	36160.61
	(8763.40)	(14708.60)	(11379.47)	(9362.53)	(13906.85)	(14130.02)	(11052.85)
Distance to the nearest major city with 10,000 or more population (km)	29.75	32.33	35.11	28.17	32.07	32.49	28.22
	(14.97)	(16.35)	(16.38)	(11.18)	(17.19)	(17.71)	(12.81)
Distance to the nearest local,	7.19	8.81	9.76	9.04	8.85	9.63	11.65

state, national park (km)	(7.95)	(7.55)	(8.29)	(7.55)	(7.21)	(8.78)	(8.46)
Distance to the nearest hospital (km)	14.64	14.71	16.91	16.54	14.86	16.34	17.07
	(8.11)	(6.57)	(6.51)	(6.73)	(6.93)	(6.85)	(6.49)
Distance to the nearest water body (km)	18.60	16.72	17.92	16.25	18.18	17.57	19.44
	(12.02)	(10.16)	(10.98)	(10.14)	(10.70)	(10.06)	(11.32)
Distance to interstate or state highway (km)	2.64	2.03	2.74	2.24	2.02	2.62	2.76
	(2.04)	(1.73)	(2.32)	(1.94)	(1.89)	(2.67)	(2.55)
Average slope (degree)	13.80	10.57	11.55	10.32	9.85	10.48	10.02
	(6.65)	(5.37)	(6.27)	(4.6)	(5.15)	(5.55)	(5.15)
Average elevation (meter)	566.82	449.66	475.13	453.24	419.01	440.5	410.78
	(309.42)	(291.26)	(302.73)	(303.45)	(258.59)	(295.38)	(300.40)
Ecoregion: Cumberlands & Southern Ridge and Valley	0.35	0.40	0.46	0.39	0.42	0.35	0.38
	(0.48)	(0.49)	(0.50)	(0.49)	(0.50)	(0.48)	(0.49)
Ecoregion: Central Appalachian Forest	0.37	0.26	0.23	0.27	0.20	0.21	0.21
	(0.48)	(0.44)	(0.43)	(0.45)	(0.40)	(0.41)	(0.41)
Ecoregion: Southern Blue Ridge	0.23	0.34	0.31	0.34	0.38	0.45	0.41
	(0.42)	(0.48)	(0.46)	(0.48)	(0.49)	(0.50)	(0.49)
year 2000	0.07	0.08	0.08	0.07	0.06	0.09	0.09
	(0.26)	(0.26)	(0.27)	(0.25)	(0.24)	(0.29)	(0.28)
year 2001	0.08	0.09	0.09	0.08	0.10	0.06	0.12
	(0.27)	(0.28)	(0.28)	(0.27)	(0.31)	(0.23)	(0.32)
year 2002	0.11	0.11	0.11	0.11	0.14	0.12	0.09
	(0.31)	(0.32)	(0.31)	(0.31)	(0.35)	(0.33)	(0.29)
year 2003	0.07	0.08	0.08	0.08	0.06	0.11	0.06
	(0.25)	(0.26)	(0.27)	(0.27)	(0.24)	(0.31)	(0.24)
year 2004	0.06	0.05	0.05	0.07	0.05	0.09	0.05
	(0.23)	(0.22)	(0.23)	(0.25)	(0.23)	(0.28)	(0.22)
year 2005	0.05	0.05	0.05	0.05	0.07	0.04	0.04
	(0.22)	(0.22)	(0.23)	(0.23)	(0.25)	(0.19)	(0.21)
year 2006	0.10	0.09	0.10	0.10	0.10	0.13	0.08
	(0.31)	(0.29)	(0.30)	(0.30)	(0.30)	(0.33)	(0.27)

year 2007	0.17	0.16	0.16	0.16	0.15	0.12	0.14
	(0.38)	(0.36)	(0.37)	(0.37)	(0.35)	(0.33)	(0.35)
year 2008	0.14	0.15	0.14	0.14	0.15	0.13	0.13
	(0.35)	(0.36)	(0.35)	(0.35)	(0.36)	(0.33)	(0.33)
year 2009	0.15	0.15	0.13	0.13	0.12	0.13	0.20
	(0.36)	(0.36)	(0.34)	(0.34)	(0.32)	(0.33)	(0.40)
Observation	182	160	149	147	164	159	160

Table 3. Estimate Results of the Log-log Cost Model for the Protected Areas and Matched Unprotected Areas

Variable	Protected		Unprotected					
			Mahalanobis matching			Nearest propensity score matching		
	With donation	No donation	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
ln(size)	1.031	1.198*	0.637*	0.703*	0.561*	0.601*	0.653*	0.547*
	(0.878)	(0.108)	(0.117)	(0.118)	(0.095)	(0.103)	(0.111)	(0.102)
Contract type	11.330	3.537*	0.110	-0.378	-0.278	0.076	0.342	-0.027
	(6.667)	(0.692)	(0.546)	(0.567)	(0.406)	(0.466)	(0.357)	(0.345)
ln(size × contract type)	0.684	-0.433*	-0.127	0.020	0.062	0.043	-0.006	-0.014
	(1.296)	(0.105)	(0.133)	(0.137)	(0.101)	(0.134)	(0.120)	(0.117)
Take-out partner	-6.201	-0.370	-	-	-	-	-	-
	(3.278)	(0.271)	-	-	-	-	-	-
Landowner type	-4.97*	0.213	-	-	-	-	-	-
	(2.431)	(0.205)	-	-	-	-	-	-
Motivation by species protection	3.753	-0.025	-	-	-	-	-	-
	(2.337)	(0.185)	-	-	-	-	-	-
Motivation by threat of development	9.594*	-0.412*	-	-	-	-	-	-
	(2.745)	(0.182)	-	-	-	-	-	-
ln(pop density)	-4.817*	-0.086	-0.134	-0.186	0.015	0.003	0.166	0.000
	(1.984)	(0.154)	(0.164)	(0.217)	(0.121)	(0.163)	(0.249)	(0.200)
ln(vacant rate)	-1.865	-0.239	0.106	0.111	-0.055	0.137	0.188	0.314
	(2.157)	(0.151)	(0.234)	(0.293)	(0.185)	(0.216)	(0.334)	(0.291)
ln(Median income)	7.337	0.218	0.654	0.001	0.487	0.852	1.023	0.948
	(4.664)	(0.257)	(0.523)	(0.687)	(0.467)	(0.51)	(0.761)	(0.688)
ln(Distance to the nearest major city)	2.192	-0.186	0.454	-0.358	-0.005	-0.311	0.172	-0.035
	(3.046)	(0.147)	(0.319)	(0.404)	(0.299)	(0.289)	(0.434)	(0.369)
ln(Distance to the nearest park)	0.625*	-0.009	0.032	-0.019	0.002	0.036	0.111*	0.010
	(0.228)	(0.014)	(0.035)	(0.035)	(0.018)	(0.029)	(0.044)	(0.032)
ln(Distance to the nearest hospital)	-2.093	0.329*	-0.738*	-0.275	0.011	-0.421	-0.156	-0.705
	(2.220)	(0.142)	(0.296)	(0.330)	(0.226)	(0.218)	(0.362)	(0.399)

ln(Distance to the nearest water body)	-0.238	-0.215	0.08	0.078	0.119*	0.120	0.030	0.173
	(1.353)	(0.111)	(0.064)	(0.069)	(0.05)	(0.068)	(0.102)	(0.137)
ln(Distance to the nearest major highway)	-1.341	-0.034	0.088	0.312*	0.307*	0.271*	0.053	0.031
	(1.060)	(0.060)	(0.115)	(0.133)	(0.089)	(0.138)	(0.137)	(0.122)
ln(average slope)	0.175	-0.111*	-0.306	0.121	0.034	-0.325	0.383	0.604*
	(0.566)	(0.022)	(0.313)	(0.305)	(0.265)	(0.308)	(0.324)	(0.301)
ln(average elevation)	-0.109	-0.045	0.027	-0.262	0.413	0.231	-0.088	-0.014
	(2.399)	(0.099)	(0.408)	(0.399)	(0.255)	(0.358)	(0.446)	(0.327)
Cumberlands & Southern Ridge and Valley	-4.106	-1.314*	-0.376	-0.144	-0.289	0.161	-1.492*	-0.158
	(3.160)	(0.220)	(0.539)	(0.607)	(0.265)	(0.380)	(0.735)	(0.524)
Central Appalachian Forest	-6.206	-0.951*	0.269	1.117	0.781*	0.767	-0.004	0.509
	(3.242)	(0.182)	(0.791)	(0.901)	(0.285)	(0.524)	(0.826)	(0.712)
year2001	4.586	0.251	-0.121	0.779	0.383	-1.244*	0.406	1.176*
	(7.144)	(0.380)	(0.515)	(0.520)	(0.468)	(0.625)	(0.700)	(0.536)
year2002	-1.142	-0.257	0.303	0.914	-0.170	-0.200	0.268	1.097
	(5.813)	(0.354)	(0.492)	(0.507)	(0.489)	(0.631)	(0.585)	(0.563)
year2003	10.173	-0.143	-0.403	0.772	0.341	-0.688	-0.043	0.304
	(5.372)	(0.370)	(0.540)	(0.523)	(0.506)	(0.691)	(0.550)	(0.604)
year2004	13.596*	-0.626	-0.126	0.570	0.307	1.429*	0.253	0.153
	(4.687)	(0.564)	(0.605)	(0.585)	(0.518)	(0.709)	(0.562)	(0.676)
year2005	11.181*	-1.592*	1.667*	1.943*	0.625	0.398	0.386	1.983*
	(4.997)	(0.608)	(0.605)	(0.577)	(0.550)	(0.699)	(0.739)	(0.683)
year2006	2.255	-0.797	0.905	2.142*	0.664	1.116	1.201*	1.271*
	(4.093)	(0.436)	(0.522)	(0.503)	(0.481)	(0.611)	(0.545)	(0.564)
year2007	11.054*	-0.351	0.659	1.379*	0.957*	0.302	0.538	1.178*
	(3.879)	(0.455)	(0.499)	(0.487)	(0.442)	(0.625)	(0.564)	(0.518)
year2008	6.181	0.379	1.076*	1.469*	1.338*	0.207	0.701	0.822
	(4.769)	(0.348)	(0.469)	(0.475)	(0.449)	(0.593)	(0.535)	(0.536)
year2009	9.918*	0.372	0.212	0.936*	0.646	-0.136	0.105	1.055*
	(4.100)	(0.447)	(0.473)	(0.468)	(0.453)	(0.590)	(0.552)	(0.480)
IMR	-7.957	0.676	-	-	-	-	-	-
	(4.816)	(0.455)	-	-	-	-	-	-

constant	-105.25	2.799	13.098	19.311	-0.184	0.481	1.566	-1.874
	(59.751)	(2.752)	(8.439)	(9.959)	(6.545)	(6.371)	(10.751)	(7.944)
ρ	-	0.173*	-0.742*	-0.660*	0.134	0.148	-0.163	0.191
	-	(0.067)	(0.368)	(0.310)	(0.162)	(0.105)	(0.327)	(0.113)
λ	-	-0.630*	0.632*	0.633*	-1.198*	-0.534*	0.383	-0.057
	-	(0.199)	(0.151)	(0.135)	(0.534)	(0.179)	(0.282)	(0.151)
R^2	0.584	0.878	0.455	0.549	0.584	0.477	0.467	0.442
Observation	95	87	160	149	147	164	159	160

Note: * indicates statistical significance at the 5% level, and ( ) indicates standard error.

Table 4. Elasticities in Acquisition Cost with Respect to Area and Predicted Average Cost per Hectare for Protected and Unprotected Areas

	Contract type	Protected	Unprotected					
			Mahalanobis matching			Nearest propensity score matching		
			Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Elasticities in acquisition cost with respect to size	Fee simple	0.757*	0.496*,†	0.707*	0.622*,†	0.640*,†	0.644*,†	0.525*,†
		(0.019)	(0.029)	(0.017)	(0.026)	(0.027)	(0.045)	(0.076)
	Easement	1.185*	0.619*,†	0.688*,†	0.560*,†	0.597*,†	0.650*,†	0.539*,†
		(0.018)	(0.023)	(0.019)	(0.032)	(0.035)	(0.056)	(0.098)
Predicted average cost ($/ha)	Fee simple	4958.7	8069.3†	5608.2†	6837.8†	11691.3†	15720.2†	13074.2†
		(186.5)	(462.8)	(180.6)	(353.9)	(336.2)	(1142.3)	(1111.7)
	Easement	1561.7	8549.8†	7866.6†	7101.9†	8133.1†	15435.8†	11456.6†
		(351.4)	(577.8)	(351.6)	(680.7)	(706.0)	(1278.8)	(1074.5)

Note: ( ) indicates standard error, * indicates the elasticities are significantly different from 1 at 5% significance level, where p-value is less than 0.05, and † indicates the elasticities and predicted average cost in size of unprotected deals are significantly different from those of protected area at 5% significance level.

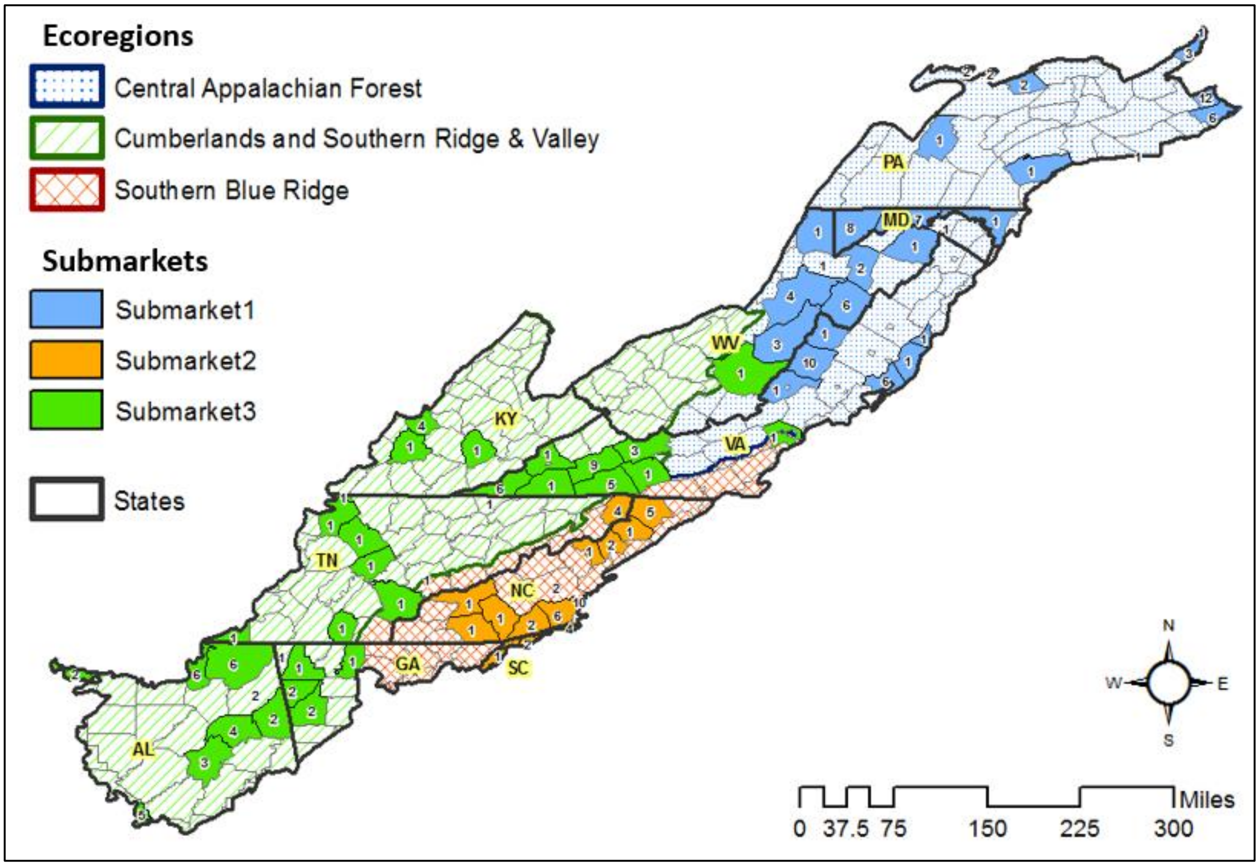

Figure 1. The study regions: eco-regions, submarket delineations, spatial distributions of each county under the submarkets, and number of protected areas in each county (given by the numbers within county boundaries; numbers are absent for counties that had no protected areas in our dataset)

Footnotes

[1] We excluded a single fee simple deal with a structure value (e.g. residence) because we knew nothing about the structure that would be amenable to estimating its value. In the case of easements, TNC reports nothing about existing residences or other structures, because in most cases the existing residences are omitted from the transacted easement.

[2] We identified the developed land use classes of the parcels using ArcGIS 10.0 by spatially joining the parcels and land use classes at the pixel level from the 2001 NLCD for the transactions during 2000-2003 and from the 2006 NLCD for the transactions during 2004-2009. Developed land uses classes included: developed open space, developed low intenisty, developed medium intensity, and developed high intensity.

Appendix

We also considered as matched unprotected areas sales comparisons provided to TNC by professional appraisers, which are used to estimate fair market values at the time specific transactions are being considered. Such sales comparisons are made by appraisers to evaluate a parcel's fair market value by comparing it to a number of recent and nearby land transactions of similar character, although in our experience (below) there is high heterogeneity in the particular parcel attributes that appraisers use to make these comparisons. Sales comparison records were provided to us from 6 of 10 TNC state chapters (i.e., Al, GA, KY, NC, PA, and WV), and yielded consistent reporting of acquisition cost and parcel size data for 145 sales comparisons provided for 23 protected area transactions (i.e., an average of 6.3 sales comparisons for each TNC protected area transaction). Limitations of the data available for sales comparisons precluded obtaining similarly detailed information on covariates for this group (e.g. precise spatial locations), necessitating an alternative statistical approach for these parcels.

Thus, we adopted the standard econometric approach of using groups of fixed effects. Once again, we regressed the acquisition costs against the size of the parcel while assuming a translog relationship between the variables. But we did not have data on all of the other control variables for the 145 sales comparisons provided by appraisers. Instead, for each individual sales comparison, we assigned values for these control variables from the TNC transaction with which the comparator deal had been matched by the professional appraiser. The fixed effects narrow the relationship between acquisition cost and size (i.e. the elasticity of acquisition cost with respect to size) from which the effects are identified so as to exclude potential confounders (Hahn and Newey, 2004; Fernández-Val, 2008; Wooldridge, 2010). Because location information for the 145 comparable deals was missing (see above), we ran the aspatial model for this fixed effect version of the trans-log cost model.

The relevant comparisons are shown in the Appendix table. The results for protected areas are the same as those shown in the relevant column of table 4. The new results for the set of sales comparisons are shown in the last column. Consistent with what we found from the comparison with statistically matched unprotected areas, we found that the average costs of protected areas were significantly less than those for unprotected areas identified as sales comparisons by professional appraisers, both for parcels protected with easements and fee simple acquisition.

Moreover, we again found that the elasticities with respect to the size of the parcel are significantly less than 1 for the appraiser's sales comparisons, indicating the presence of economies of scale in the costs of these unprotected areas. The elasticity for the unprotected areas is once again significantly less than that for areas protected using easements, but we found no significant difference in the elasticity between areas protected using fee simple transactions and the sales comparisons identified by appraisers.

As well as having implications for a conservation organization like TNC, our study also has relevance for the practice of appraising properties in this type of context (when working with land trusts and other conservation buyers in rural settings). For example, we found a great deal of heterogeneity in how different appraisers identified comparable transactions for each acquisition under consideration, as well as in how they documented that process. In some instances, we found appraisers matched proposed transactions with sales comparisons that differed greatly in their size, a practice that is at odds with our observations regarding economies of scale both within protected parcels and in the wider market.

Table A1. Elasticities in acquisition cost with respect to size and predicted average cost per hectare for protected areas and sales comparisons

	Contract type	Protected	Sales comparisons
Elasticities in acquisition cost with respect to size	Fee simple	0.757* (0.019)	0.753* (0.071)
	Easement	1.185* (0.018)	0.746*,† (0.093)
Predicted average cost per hectare ($)	Fee simple	4958.7 (186.5)	7794.5† (382.4)
	Easement	1561.7 (351.4)	3579.2† (103.5)

Note: ( ) indicates standard error, * indicates the elasticities are significantly different from 1 at 5% significance level, where p-value is less than 0.05, and † indicates the elasticities and predicted average cost in size of comparable deals are significantly different from those of protected area at 5% significance level.