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The Impacts of Protected Area Size on Land Acquisition Costs for Conservation

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The Impacts of Protected Area Size on Land Acquisition Costs for Conservation

Abstract

The size of the protected area is recognized as one of the key attributes for assessing the effectiveness of investing in protected areas. We evaluate the effectiveness of protected areas by examining economies of scale in size and the average cost of acquiring protected areas depending on the land acquisition contract types and motivations. We use recent land acquisitions (2000-2009) of the central and southern Appalachian forest ecosystems by The Nature Conservancy (TNC) as a case study. Our findings suggest that (1) the purchase of protected areas achieves economies of scale in size on average; (2) the fee simple deals achieve economies of scale in size while the easements do not, and the easement deals are more cost effective than the fee simple deals; (3) targeting the protection of mammals or birds achieves greater economies of scale than not targeting them; and (4) the deals without development pressures achieve greater economies of scale in size than the deals with the threat of development. Our findings will help TNC and other conservation organizations to design more cost effective investments in land conservation.

Key Words: Cost effectiveness, Economies of Scale, Land conservation, Protected area size.

1. Introduction

Protected areas (i.e. areas designated to prevent the degradation of ecosystems and provide positive ecological outcomes through the long-term conservation of nature) have been globally recognized as critical not only for conserving biodiversity and providing ecosystem services but also for economic benefits and social well-being (SCBD, 2008; TEEB, 2009). Protected areas already account for a significant proportion of land use type, covering around 13.9% of the terrestrial land surfaces on Earth (Coad et al, 2009; WDPA 2011), and coverage is targeted to increase at least 17% of terrestrial and inland water areas by 2020, based on the Aichi Biodiversity Target of the Convention on Biological Diversity (CBD) – Target 11 (CBD, 2011). The target also emphasizes key aspects of protected areas – effectiveness and equitability of management, representativeness and connectivity of protected areas, effectiveness of conservation measures, and integration into wider landscapes and seascapes (Woodley et al. 2012).

Taking these key aspects into account, the size of the protected area is recognized in the literature as one attribute that can influence the effectiveness of investing in protected areas for achieving their desired ecological outcomes. Correlating the size of protected areas with ecological responses suggests that small size and great isolation may limit the role of protected areas in maintaining or enriching biodiversity (Leverington et al., 2008). For example, Maioreno et al. (2008) conclude that, over the long term, small areas are not viable for biodiversity if they are isolated, surrounded by various disturbances such as development, farming practices, and fire. A number of studies have demonstrated that the size of existing protected areas is too small to support viability for biodiversity conservation (e.g. Carroll et al., 2004; Maiorano et al., 2007, Tilman et al. 2002). Worboys et al. (2010) also mentioned that increasing protected area size can ecosystem mosaics and connectivity for habitat restoration.

While most of the studies mentioned above focus primarily on examining the relationship between the size of protected areas and ecological outcomes, the cost side of the relationship is rarely addressed. Thus, the focus of this research is verifying the cost effectiveness of protected areas. We focus specifically on costs of acquiring sites for protection to begin wtih, as opposed to, say, ongoing costs associated with managing these sites. We organize our research around the question: How does the size of a protected area affect the cost of acquiring the site for protection? The relationship between the land acquisition cost and the size of the protected area is expected to differ depending on the type and motivation of the contract for land acquisition (i.e., different types of contracts, targeting to protect different ecosystems, and protecting from different threats).

We hypothesize that economies of scale in size occur for protected areas and the economies of scale in size differ according to types and motivations associated with the protected areas. We develop an empirical framework where acquisition costs are determined by the types and motivations of the contracts for land acquisition as well as other site characteristics to examine the following three sub-questions: (1) Do the economies of scale and average acquisition cost with respect to size differ across types of transactions between fee simple and easement acquisition? (2) Do the economies of scale and average acquisition cost with respect to size differ between transactions where the conservation group acquiring the site explicitly state that their intention with the acquisition is to help conserve mammals and birds and transactions where these specific objectives are not highlighted? (3) Do the economies of scale and average acquisition cost differ between transactions where the conservation group specifically highlight preventing development of the site as a goal of the acquisition and transactions where development threat is not highlighted explicitly?

The sub-question (1) is motivated by the difference in transformation of property rights between fee simple and easements. Specifically, a landowner with an easement attached often transfers conservation rights to conservation agencies (e.g., The Nature Conservancy) while allowing landowners to continue to manage the property, which can include allowing them to live on the property, to cut timber, etc.. In contrast, a landowner with fee simple title transfers complete ownership of the land with all the usual rights associated with ownership (Yuan-Farrell et al., 2005). Because of the flexible nature of easements, we hypothesize that landowners will have greater willingness to donate or sell the land at lower than fair prices with easements than with fee simple. Consequently, we expect that the average cost of acquiring protected areas with easements to be lower than with fee simple. We can also expect that the economies of scale in size is dampened by the easement if large numbers of easement deals are made with lower than the fair market prices in relatively small size areas.

The sub-question (2) is motivated by the fact that the deals targeting site protection which include mammals or birds may require relatively larger protected area size because of their mobility than the deals targeting plant and fish protection. The economies of scale in size with subgroups of different protected habitat sizes are expected to be different.

The sub-question (3) is motivated by the expectation that deals under the threat of development require relatively higher average cost per unit area due to higher expected land value. Because of the higher expected land value of the deals under threat of development, landowners are anticipated to have less willingness to donate or sell the land at lower than fair price. Accordingly, it is expected to require higher average acquisition costs than the deals without the threat of development. We also expect that the economies of scale in size are affected by the threats of development.

The rest of this paper organized as follows. Section 2 provides study area and data descriptions, Section 3 presents empirical model specifications, Section 4 describes the estimation results, and Section 5 presents a summary and the conclusion.

2. Study area and data

A regression model that evaluates sub-questions (1), (2), and (3) is developed based on 183 recent land acquisitions (2000-2009) of the central and southern Appalachian forest ecosystems[1] by the world's largest land trust, The Nature Conservancy (TNC). TNC provided data on site acquisition costs, size of land transactions, type of landowner from whom the property was acquired (i.e., private landowner, corporation, and trust), eco-region type (i.e., Cumberlands & Southern Ridge and Valley, Southern Blue Ridge and Central Appalachian Forest), transaction type (i.e., fee simple and easement), types of management responsibilities that would be incurred following acquisition (i.e., take-out partners with TNC, non-profit, state or state agency, and federal agency), priority attributes motivating the purchase (i.e., protecting mammals, birds, plants, and fishes and protecting sites from development pressures), and the year that transaction was made for each site. TNC also provides shape files of each protected site, which allows us to create variables of spatial characteristics of each protected site (i.e., average slope and elevation), various distance related variables (i.e., distances from a protected site to highway, parks, cities, golf courses, and water bodies), and neighborhood socio-economic characteristics (i.e., populations and household income at the census-block group level).

[1] The central and southern Appalachian forests cover three eco-regions (Cumberlands & Southern Ridge and Valley, Southern Blue Ridge, and Central Appalachian Forest) and 10 states (AL, GA, KY, MD, NC, PA, SC, TN, VA, and WV).

We used the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2) as a base map (NASA JPL, 2013) to generate the average elevation and slope for each protected site. For average elevation of each protected site, we averaged 30-meter postings of elevations within the parcel boundary of the protected area using ArcGIS 10 (Esri, 2013).[2] The average slope of each protected area is calculated using DEM surface Tools for ArcGIS 10 (Jenness, 2012) given the base map of the ASTER GDEM V2. The distance related variables are generated through a spatial join between parcel boundary maps for protected areas and U.S. base maps for highways, cities, golf courses, parks, and water bodies provided from ESRI Data & Maps 10 (Esri, 2011). The distances are measured between the parcel centroids of protected sites and either the centroids of the nearest city, golf course, park, or water body or the nearest point of the polylines representing a highway using spatial join in ArcGIS (ArcGIS Resource Center, 2013).

The neighborhood socioeconomic variables are collected by spatially joining the parcel boundaries for a protected area with the census-block group level shape file provided by U.S. Census Bureau (U.S. Census Bureau, 2013) using ArcGIS 10. Since census data do not cover all the years that the transactions were made, we assigned the census information to the closest census year prior to the transaction year. That is, census information for 1997 was assigned to sites protected during 2000-2001, census information for 2002 was assigned to sites protected during 2002-2006, and census information for 2007 was assigned to sites protected during 2007-2009.

To control for changes in market conditions that are not accounted for in the model, (1) the purchasing cost of the protected areas were adjusted to 2000 dollars using a state-level

[2] The ASTER GDEM V2, which was released in October 17, 2011, provides 30-meter postings and 1 x 1 degree tiles with the GeoTIFF format, (NASA JPL, 2013).

housing price index (FHFA, 2013), (2) the household income was adjusted to 2000 dollars using a consumer price index (BLS, 2013), and (3) dichotomous variables for the year of the transactions were included.

The definitions of the selected variables for the empirical econometric analyses and descriptive statistics are shown in Table 1.

3. Empirical Model Specification

We develop a translog cost function to examine the effect of size on total acquisition cost (the economies of scale in size) with respect to TNC contracts of different types and motivations. In developing the model, we address the following econometrical and modeling issues: control selection bias due to treatment of the donation of the protected areas, the potential endogeneity problem of protected area size in the translog cost function, the issue of spatial dependence between the acquisition cost in the translog cost function and its detrimental consequence, interaction terms between protected area size and land acquisition contract type and motivation, and measures of the economies of scales in size and cost effectiveness (see below for details).

3.1. Control selection bias (Heckman's selection model)

In developing the translog cost function, we need to ascertain whether any observations of protected areas occurred without monetary compensation to land owners (referred to as "donation observations") because adding these samples may distort the economies of scale in size whereas simply removing them may cause section bias. Hence, we take into account the characteristics of donations observations conducting Heckman's two-step estimator (Heckman 1979, Desvousges et al. 1987, Whitehead et al.1993, Messonnier et al. 2000, Cho et al. 2005) to correct for potential selection bias using a two-step procedure. In the first step, we run a probit model (defined as a selection equation) with the binary dependent variable corresponding to 1 for observations with a non-zero purchasing price and 0 for a zero purchasing price. In the second step, we run an OLS regression with a correction for sample selection bias using the inverse Mills ratio (*IMR*) calculated from the first step. If the parameter estimate of the *IMR* is significantly different from zero, the Heckman's two-step estimator is appropriate to apply. Therefore, our base model is specified as follows (referred to as *Model 1*)[3]:

(1) $$\ln(C_i) = \alpha_0 + \alpha_1 \ln(S_i) + \sum_{k=1}^{K} \beta_k \ln(X_{ji}) + \delta_1 N_i^F + \delta_2 N_i^G + \delta_3 N_i^D + \sum_{m=1}^{M} \gamma_m D_{mi} + \eta IMR_i + u_i.$$

where for an individual protected area i, ln$C$ is the natural log of total project cost, ln$S$ is the natural log of the size of the protected area, lnX_j is the natural log of k^{th} non-dichotomous variable including slope, elevation, and neighborhood spatial and socio-economic variables, N^F, N^G, and N^D are dichotomous variables representing contract types and motivations, i.e. N^F=1 if the deal is fee simple transaction, N^G=1 if the protection target includes mammals or birds, and N^D=1 if the deal has been made under development pressure, D_l is m^{th} dichotomous variable for other relevant attributes, α, β, δ, and γ are parameter estimates, and u is a random error term.

3.2. Endogeneity test

We suspect the endogeneity problem of protected area size in *Model 1* because the size of a protected area may be correlated with the error in the model since the real estate market partially determines acquisition cost and the size of protected areas, simultaneously. Thus, we conduct endogeneity tests (Durbin-Wu-Hausman test statistics) for the protected areas. While it is difficult to choose proper instruments for endogeneity (Ebbes 2007), we assign combinations of the three available variables – size of block group, size of nearest urban land, and county-level

[3] The translog form of cost function has been commonly used because of its flexibility since Christensen et al. (1973) and Brown et al. (1979).

housing units – as instruments for the endogeneity tests. To check the validity of the instruments, we conduct three identification tests – under-, weak-, and over-identification tests. (See Table 2.)

In the under-identification test, Anderson's (1951) Largrange Multiplier statistics, ranged from 0.04 to 9.9, suggested that five of seven sets of instruments are identified at the 5% significance level.[4] Cragg-Donald's (1993) Wald statistics for the weak identification test suggested that two of seven instruments are not weak. Sargan's (1958) statistics for the over-identification test suggested with the null hypothesis that the instruments being uncorrelated with the error term could not be rejected for all four sets with more than two instruments. Based on these three test results, we choose four valid sets of instruments for the endogeneity test. The results of endogeneity tests (Durbin-Wu-Hausman test statistics) indicate that the null hypotheses of the protected area size being an exogenous variable are failed to reject at 5% significance level. Thus we treat protected area size as an exogenous variable in the *Model 1* and the variations of the *Model 1* below.

3.3. Test for spatial autocorrelation

The spatial dependence between acquisition costs is suspected because a major factor in acquisition costs is the purchase price of land, which is highly spatially dependent. The spatial dependency in regression analysis is a concern because it may cause bias in estimates in the second step of the Heckman model. We use Moran's indices to detect the spatial dependence of acquisition costs based on thirteen spatial weight matrices (i.e., inverse distance weight matrix, contiguity-based weight matrix using county boundaries, weight matrices that capture spatial contiguity within multiple circular buffers of different radii (1, 5, 10, 30, and 50 km), and k-nearest neighbors weight matrices where k = 1, 3, 5, 10, 20, and 40). Moran's indices and the p-

[4] The significance at the 5% level is identified as significant throughout the manuscript.

value for each corresponding weight matrix are shown in Table 3. Twelve out of thirteen candidates are significant and are thus incorporated into a spatial general model which take into account both a spatially lagged dependent variable and a spatial autoregressive error term, specified as follows (referred to as *Model 2*):

$$
\begin{aligned}
(2)\qquad & \ln(C_i) = \alpha_0 + \rho\sum_{j=1}^{J} w_{i,j}\ln(C_i) + \alpha_1\ln(S_i) + \sum_{k=1}^{K}\beta_k\ln(X_{ji}) + \delta_1 N_i^F + \delta_2 N_i^G + \delta_3 N_i^D \\
& \quad + \sum_{m=1}^{M}\gamma_m D_{mi} + \eta IMR_i + u_i, \\
& u_i = \lambda\sum_{n=1}^{N} w_{i,n}u_i + \varepsilon_i
\end{aligned}
$$

where *w* is a (*i*, *j*) element of a spatial weight matrix.

3.4. Interaction terms between protected area size and land acquisition contract types and motivations

Corresponding to our three sub-questions, we evaluate the effects of protected area size on acquisition cost by three different contract natures. We add the interaction of the dichotomous variables representing contract types and motivations (N^F, N^G, and N^D) with protected areas (ln(S)) in the equations (1) and (2), which are specified in (3) (referred to as *Model 3*) and (4) (referred to as *Model 4*), respectively:

$$
\begin{aligned}
(3)\qquad & \ln(C_i) = \alpha_0 + \alpha_1\ln(S_i) + \sum_{k=1}^{K}\beta_k\ln(X_{ji}) + \delta_1 N_i^F + \delta_2 N_i^G + \delta_3 N_i^D + \sum_{m=1}^{M}\gamma_m D_{mi} \\
& \quad + \omega_1\left(N_i^F \times \ln(S_i)\right) + \omega_2\left(N_i^G \times \ln(S_i)\right) + \omega_3\left(N_i^D \times \ln(S_i)\right) + u_i,
\end{aligned}
$$

$$
\begin{aligned}
(4)\qquad & \ln(C_i) = \alpha_0 + \rho\sum_{j=1}^{J} w_{i,j}\ln(C_i) + \alpha_1\ln(S_i) + \sum_{k=1}^{K}\beta_k\ln(X_{ji}) + \delta_1 N_i^F + \delta_2 N_i^G + \delta_3 N_i^D \\
& \quad + \sum_{m=1}^{M}\gamma_m D_{mi} + \omega_1\left(N_i^F \times \ln(S_i)\right) + \omega_2\left(N_i^G \times \ln(S_i)\right) + \omega_3\left(N_i^D \times \ln(S_i)\right) + \eta IMR_i + u_i, \\
& u_i = \lambda\sum_{n=1}^{N} w_{i,n}u_i + \varepsilon_i
\end{aligned}
$$

3.5. Measures of economies of scale in size and cost effectiveness

The economies of scale in size for acquiring protected areas describe the increase in acquisition costs relevant to the increase in protected area size (Rasmussen, 2013). As one of the measures of the economies of scale with translog cost functions, we use elasticity of acquisition cost with respect to the size of protected sites, which uses average method estimates to evaluate the existence of scale economies (Noulas et al. 1990; DeBoer, 1992). From the equations (1) and (2), the cost elasticity in size is defined as:

(5) $$\text{elasiticity} = \frac{\partial \ln(\text{C})}{\partial \ln(S)} = \alpha_1 \ .$$

If the acquisition cost elasticity (α_1) is less than one, the acquisition costs of protected areas increase less than proportionately with the size, suggesting the economies of scale in size, whereas elasticity at above unity implies the diseconomies of scale in size (Latzko, 1998).

We also measure the economies of scale in size from *Models 3* and *4*, which include the interaction of the dichotomous variables representing types and motivations for contracts pertaining to protected areas. From these model specifications, we should note that the three dichotomous variables representing contract types and motivations are not mutually exclusive, and thus the economy of scale in size with respect to one particular contract nature is conditioned on the other two contract natures. For this reason, we present the expected value of the economies of scale in size (*elasticities*) based on possible combinations of the three dichotomous variables. For example, the economies of scale in size with fee simple (*F*) is calculated as the expected value of the elasticities:

(6) $$\begin{aligned} \text{E}\left(\text{elasticity} \mid N^F = 1\right) &= \left(\alpha_1 + \omega_1 + \omega_2 + \omega_3\right) \cdot Pr(N^G = 1, N^D = 1) + \left(\alpha_1 + \omega_1 + \omega_2\right) \cdot Pr(N^G = 1, N^D = 0) \\ &+ \left(\alpha_1 + \omega_1 + \omega_3\right) \cdot Pr(N^G = 0, N^D = 1) + \left(\alpha_1 + \omega_1\right) \cdot Pr(N^G = 0, N^D = 0) \end{aligned} .$$

In addition to the elasticities, we also derive the average cost function for use as a measure of economies of scale (Liu, 2003) to reaffirm the economies of scale in size. We also compare the average cost effectiveness given the protected area size between deals with fee simple and easement acquisitions, between deals for sites which do or do not target the protection of mammals or birds, and between deals subject to development pressures or not. For example, if the average acquisition cost of a fee simple transaction is greater than that of an easement transaction, the easement deal is preferred to the fee simple deal regardless of the economies of scale in size.

4. Estimation Results

Models 2 and *4* are estimated with a spatial general model incorporating the sample selection bias correction with the *IMR*. Out of the thirteen spatial weight matrices used in each model, we chose two weight matrices based on the Akaike Information Criteria (AIC) scores and R^2: a spatial contiguity weight matrix within circular buffers of a 10 km radius (referred to as a "10 km-buffer weight matrix") and a k = 20 nearest neighbors weight matrix. We report estimates of *Model 1*, estimates of *Model 2* with a 10 km-buffer weight matrix (referred to as "*Model 2-a*"), and with a k = 20 nearest neighbors weight matrix (referred to as "*Model 2-b*") in the Table 4. We report estimates of *Model 3*, estimates of the *Models 4* with a 10 km-buffer weight matrix (referred to as "*Model 4-a*"), and with a k = 20 nearest neighbors weight matrix (referred to as "*Model 4-b*") in the Table 5.

The spatially lagged dependent variable and the spatial autoregressive error term indicate that the null hypothesis of the spatial lag parameter (ρ) being equal to zero fails to reject across all the spatial general models, while the null hypothesis with the spatial error parameter (λ) equals to zero is rejected at the 5% significance level in *Models 2-b, 4-a, and 4-b*. These test results suggest that spatial structures captured in spatial lagged acquisition costs and error terms vary depending on model specifications and the spatial weight matrices used in the estimation. The parameters for the *IMR* are significantly different from zero, implying that the error terms of the selection equation and acquisition cost model are correlated.

Overall, the signs and significances of the parameter estimates are consistent across all the six models (i.e., *Models 1, 2-a, 2-b, 4-a, and 4-b*), reflecting the robustness of our models. Greater size sites for protected areas and sites with fee simple transactions are positively correlated with acquisition costs, while sites within Cumberlands & Southern Ridge and Valley eco-region, sites which take TNC as a takeout partner, and sites with protection targets including mammals or birds are negatively correlated with acquisition costs. Lower elevation and slope, closer proximity to a golf course and water body, and lower household income in neighboring sites at the census-block group level increase acquisition costs. The estimation results with respect to year dummies indicate that the parameter estimates for the years 2001, 2002, 2003, 2007, 2008, and 2009 significantly and positively affect acquisition costs compared to the base year 2000.

4.1. Overall economies of scale in size

As presented in Table 4, the elasticity in acquisition cost with respect to the size of protected area ranges between 0.854-0.859, suggesting that the purchase of a protected area achieves its economy of scale in size in average.[5] Figure 1 presents the average cost (AC) curve with respect to the size of the protected area derived based on *Model 2-a*, but those derived from other models are consistent as well. The AC curve shows that the AC decreases as the protected area size

[5] The t-statistics to test the null hypothesis that the elasticity with respect to size equals to 1 are 2.28, 1.81, and 2.71 for *Model 1*, *2-a*, and *2-b*, respectively, which indicate that the elasticities in size are significantly different from 1 at 5% significant level for *Model 1* and *2-b*, at 10% significant level for *Model 2-a*.

increases, suggesting that the greater the size, the less acquisition cost per hectare. This finding reaffirms the economies of scale in size.

4.2. Economies of scale and cost effectiveness across contract natures (corresponds to 3 sub-questions)

As presented in Table 5, the interaction terms between the size of protected areas, fee simple/easement, and the existence of development pressure are significant for all three models, while the interaction term between the size of protected areas and the targeting of the protection of mammals or birds is significant only in *Model 4-a*. Using the expected value of elasticity in equation (6), we present the economies of scale in size with respect to land acquisition contract types and motivations in Table 6, and the comparative analysis of the economies of scale in size between the contradicting types and motivations of the contracts follows below.

4.2.1. Transaction types: Fee simple vs. Easement

As presented in Table 6, the elasticities of acquisition costs with respect to the protected area size under fee simple transactions ranges from 0.884 to 0.909, indicating economies of scale in size, while those under easement transactions range from 1.153 to 1.259, indicating diseconomies of scale in size. This contradicting result confirms our premise that greater willingness to donate or sell the land at lower than fair prices for easement deals than fee simple deals means greater deviation from economies of scale for the easement deals than for the fee simple deals. There is evidence in the previous literature that landowners tend to prefer donating conservation easements to fee simple because of its flexibility of property rights (i.e., the landowner may still retain the ownership right as long as they comply with the purpose of the easement) (Merenlender et al., 2004; Green and Richmond, 2009) and financial benefits for donating conservation easements (e.g., tax deductions for the present value of easement gifts as charitable deduction from income) (Florida Forest Stewardship, 2013; Greene, 2010). Among our 183 samples, more than 80% of easement deals (54 out of 67) record zero purchasing cost with full donation, compared to 17% of fee simple deals (20 out of 116). In addition, the protected area size and dummy variable representing zero purchasing cost equals to one are negatively correlated (i.e., correlation = -0.27), which also explains why easement deals lose the economies of scale in size in contrast to fee simple. Although fee simple deals achieve the economies of scale in size while the easement does not, the average cost with respect to the size of the protected area with fee simple is much greater than that of the easement, as shown in Figure 2.

4.2.2. Site targets for the protection or not of mammals or birds

The elasticities with respect to the protected area size whose protection targets include mammals or birds range from 0.799 to 0.898, while the elasticities of protected sites which do not target mammals or birds range from 0.947 to 0.978. Acquisitions that explicitly include protection of mammals or birds in the stated objectives of the deal demonstrate greater economies of scale than acquisitions where conservation of mammals and birds was not explicitly highlighted as a motivation.

In a comparison of the average costs of targeting the protection of mammals or birds or not (Figure 3), deals including mammals or birds as protection targets require on average much less costly. Based on these elasticity results and the average cost of acquiring a protected area, we conclude that economies of scale are better achieved by targets including the protection of mammals or birds than not. These findings make sense in that protecting mammals or birds may demand a relatively greater size of protected area to support their mobility, and thus TNC may have made a greater deal of effort to acquire more cost effective deals with larger sizes of protected areas for mammals or birds than for deals for plants and fishes.

4.2.3. Threats: with or without development pressure

The elasticities with respect to the size with the pressure to develop range from 0.953 to 0.998 in Table 6, while those without the pressure to develop range from 0.660 to 0.710. This indicates that acquisitions that any economies of scale are weaker for acquisitions that explicitly include preventing development in the stated objectives of the deal than for acquisitions where this is not an explicit goal of the transaction. The average acquisition cost under the threat of development is greater than that with no threat of development, as presented in Figure 4. These results imply that the deals under development pressures might not have much opportunity for lowering the land price per unit since the development pressure causes the increase in expected land price per unit which discourages landowners from accepting lower land price per unit.

5. Summary and conclusion

In this paper, we evaluate the effectiveness of protected areas by examining economies of scale in size and the average cost of acquiring protected areas depending on the land acquisition contract types and motivations. Our findings suggest that (1) the purchase of protected areas achieves economies of scale in size on average; (2) the fee simple deals achieve economies of scale in size while the easements do not, and the easement deals are more cost effective than the fee simple deals; (3) targeting the protection of mammals or birds achieves greater economies of scale than not targeting them; and (4) the deals without development pressures achieve greater economies of scale in size than the deals with the threat of development.

Our findings will help TNC to design more cost effective investments in land conservation. For example, TNC may explore more opportunities to acquire protected sites with easements because, under the assumption of the same environmental benefits and other costs, easement deals are more cost effective than fee simple deals. By the same token, better economies of scale in size for fee simple imply better opportunities for fee simple deals of larger protected areas. Our study also suggests that TNC needs to focus on purchases of or contributing to protected areas of greater size if mammals or birds are included as protection targets and the deals are to achieve both economies of scale in size and cost effectiveness. On the other hand, if the protection candidate sites are under development pressure, a strategy to achieve economies of scale in size is challenging. In this case, TNC needs to invest more effort into lowering the land price, for example, by encouraging landowners to donate through campaigns or education or by securing extra financial benefits from other parties.

Table 1. Variable definitions and summary statistics (n = 183)

Variable	Definition	Mean	Std. Dev.
Acquisition cost	Acquisition cost of protected area (dollar)	406,032.20	969,892.90
Size	Size of protected area (hectare)	136.11	299.70
Landowners' type	Dichotomous variable for seller type (1 if private, 0 otherwise)	0.74	0.44
Cumberlands and Southern Ridge and Valley	Dichotomous variable for protected site in Cumberlands and Southern Ridge and Valley Ecoregion (1 if yes, 0 otherwise)	0.35	0.48
Central Appalachian Forests	Dichotomous variable for Protected site in Central Appalachian Forests Ecoregion (1 if yes, 0 otherwise)	0.37	0.48
Transaction type	Dichotomous variable for transaction type (1 if fee simple, 0 if easements)	0.63	0.48
Types of management responsibilities	Dichotomous variable for take-out partners (1 if TNC, 0 otherwise)	0.85	0.36
Targets to protect	Dichotomous variable for protected sites including or not including mammals and birds (1 if protection target include mammal and birds, 0 otherwise)	0.37	0.48
Protecting from different threats	Dichotomous variable for protected sites under development pressure (1 if under development pressure, 0 otherwise)	0.83	0.38
Elevation	Average elevation (unit)	567.03	308.58
Slope	Average slope (unit)	13.80	6.63
Highway	Distance to the nearest highway (kilometer)	2.46	2.38
City boundary	Distance to the nearest city boundary (kilometer)	34.35	17.85
Golf course	Distance to the nearest golf course (kilometer)	26.41	24.98
Water body	Distance to the nearest water body (kilometer)	21.98	14.18
Park	Distance to the nearest state and national park (kilometer)	8.41	9.11
Population	Population within census block-group	1,284.99	555.09
Household income	Household income within census block-group	35,237.26	8,819.45
Year 2001	Transactions occurred in 2001	0.08	0.27
Year 2002	Transactions occurred in 2002	0.11	0.32
Year 2003	Transactions occurred in 2003	0.07	0.25
Year 2004	Transactions occurred in 2004	0.05	0.23
Year 2005	Transactions occurred in 2005	0.05	0.22
Year 2006	Transactions occurred in 2006	0.10	0.31
Year 2007	Transactions occurred in 2007	0.17	0.38
Year 2008	Transactions occurred in 2008	0.14	0.35
Year 2009	Transactions occurred in 2009	0.15	0.36

Table 2. Test for instrumental variable selection and endogeneity test

	Under-identification		Weak-identification		Over-identification		Endogeneity test	
	LM stat.	p-val.	F-stat.	p-val	Sagan.	p-val	F-stat	p-val.
1	5.455	0.020	4.320	0.041	-		2.640	0.108
2	4.169	0.041	3.261	0.075	-		0.038	0.845
3	0.039	0.843	0.030	0.864	-		-	-
1, 2	9.818	0.007	4.009	0.022	1.509	0.219	1.699	0.192
1, 3	6.883	0.032	2.730	0.071	1.698	0.193	1.771	0.183
2, 3	5.208	0.074	2.032	0.138	2.143	0.143	-	-
1, 2, 3	9.943	0.019	2.677	0.053	2.161	0.340	1.472	0.225

Note: 1 = size of census block group, 2 = size of closest urban land, 3 = housing unit at county level

Table 3. Moran's indices for different types of spatial weight matrices

Spatial weight matrices		Moran's indices	Standard deviation	z-value	p-value
Inverse distance weight matrix		0.210	0.058	3.750	0.000
Contiguity within multiple circular buffers of different radii	1 km	0.904	0.118	7.712	0.000
	5 km	0.813	0.101	8.146	0.000
	10 km	0.680	0.091	7.596	0.000
	30 km	0.451	0.075	6.109	0.000
	50 km	0.334	0.061	5.622	0.000
Contiguity-based weight matrix using county boundaries		0.532	0.085	6.356	0.000
k-nearest neighbors	k=1	0.318	0.120	2.731	0.003
	k=3	0.253	0.071	3.691	0.000
	k=5	0.186	0.054	3.604	0.000
	k=10	0.101	0.038	2.943	0.002
	k=20	0.058	0.026	2.619	0.004
	k=40	-0.005	0.016	0.269	0.394

Table 4. Estimation results

Variables	Model 1	Model 2-a	Model 2-b
Size	0.854 (0.064)*	0.856 (0.080)*	0.859 (0.052)*
Landowners' type	0.089 (0.066)	0.001 (0.237)	0.038 (0.199)
Cumberlands and Southern Ridge and Valley	-1.086 (0.245)*	-1.062 (0.266)*	-1.130 (0.187)*
Central Appalachian Forests	-0.056 (0.279)	-0.067 (0.217)	0.049 (0.182)
Transaction type	1.939 (0.241)*	2.140 (0.748)*	2.105 (0.635)*
Types of management responsibilities	-0.861 (0.741)*	-0.936 (0.298)*	-0.980 (0.258)*
Targets to protect	-0.459 (0.308)*	-0.464 (0.200)*	-0.633 (0.202)*
Protecting from different threats	0.167 (0.222)	0.054 (0.241)	0.124 (0.196)
Elevation	-0.446 (0.230)*	-0.434 (0.151)*	-0.381 (0.125)*
Slope	-0.129 (0.162)*	-0.128 (0.028)*	-0.125 (0.027)*
Highway	0.001 (0.031)	-0.009 (0.024)	0.019 (0.021)
City boundary	-0.136 (0.025)	-0.076 (0.192)	-0.144 (0.153)
Golf course	-0.377 (0.199)*	-0.379 (0.12)*	-0.407 (0.09)*
Water body	-0.235 (0.123)	-0.261 (0.119)*	-0.186 (0.093)*
Park	0.016 (0.120)	0.023 (0.025)	0.022 (0.025)
Population	0.210 (0.026)	0.216 (0.220)	0.328 (0.226)
Household income	-1.366 (0.240)*	-1.255 (0.494)*	-1.639 (0.448)*
Year 2001	1.145 (0.534)*	1.049 (0.372)*	1.228 (0.363)*
Year 2002	0.944 (0.416)*	0.799 (0.387)*	0.930 (0.364)*
Year 2003	1.447 (0.418)*	1.397 (0.414)*	1.322 (0.417)*
Year 2004	0.712 (0.465)	0.671 (0.495)	0.932 (0.471)*
Year 2005	0.678 (0.568)	0.551 (0.476)	0.551 (0.483)
Year 2006	0.591 (0.539)	0.290 (0.526)	0.411 (0.398)
Year 2007	1.174 (0.493)*	1.063 (0.388)*	1.322 (0.368)*
Year 2008	1.301 (0.420)*	1.263 (0.365)*	1.198 (0.350)*
Year 2009	1.189 (0.404)*	1.020 (0.398)*	1.146 (0.373)*
IMR	1.468 (0.422)*	1.630 (0.677)*	1.650 (0.581)*
Constant	24.873 (0.673)*	23.711 (6.479)*	25.437 (5.603)*
ρ		-0.013 (0.114)	0.085 (0.157)
λ		0.204 (0.223)	-3.856 (1.130)*
Log-likelihood		-108.413	-103.353
AIC		0.732	0.766
R^2	0.832	0.829	0.821

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

Table 5. Estimation results with interaction terms

Variables	Model 1	Model 2-a	Model 2-b
Size	1.001 (0.139)*	0.997 (0.151)*	1.070 (0.120)*
Landowners' type	0.068 (0.233)	-0.109 (0.214)	0.068 (0.181)
Cumberlands and Southern Ridge and Valley	-1.261 (0.268)*	-1.210 (0.265)*	-1.402 (0.182)*
Central Appalachian Forests	-0.175 (0.232)	-0.204 (0.208)	-0.100 (0.172)
Transaction type	3.400 (0.997)*	3.862 (1.001)*	3.967 (0.864)*
Types of management responsibilities	-0.837 (0.301)*	-1.017 (0.270)*	-0.965 (0.250)*
Targets to protect	-0.057 (0.350)	0.046 (0.296)	-0.278 (0.313)
Protecting from different threats	-0.800 (0.377)*	-0.982 (0.310)*	-0.916 (0.316)*
Elevation	-0.598 (0.162)*	-0.556 (0.158)*	-0.602 (0.127)*
Slope	-0.138 (0.030)*	-0.124 (0.026)*	-0.142 (0.026)*
Highway	0.012 (0.024)	-0.010 (0.022)	0.027 (0.019)
City boundary	-0.263 (0.192)	-0.209 (0.187)	-0.293 (0.152*)
Golf course	-0.411 (0.117)*	-0.397 (0.121)*	-0.450 (0.084)*
Water body	-0.226 (0.118)	-0.291 (0.121)*	-0.163 (0.095*)
Park	0.017 (0.025)	0.033 (0.026)	0.026 (0.024)
Population	0.257 (0.231)	0.199 (0.221)	0.393 (0.212*)
Household income	-1.843 (0.520)*	-1.520 (0.491)*	-2.216 (0.430)*
Size*Transaction Type	-0.323 (0.129)*	-0.336 (0.129)*	-0.392 (0.108)*
Size*Targets to protect	-0.120 (0.084)	-0.173 (0.073)*	-0.102 (0.073)
Size*Protecting from different threats	0.285 (0.092)*	0.306 (0.078)*	0.307 (0.078)*
Year 2001	1.149 (0.392)*	1.098 (0.328)*	1.203 (0.332)*
Year 2002	0.982 (0.396)*	0.933 (0.338)*	0.926 (0.334)*
Year 2003	1.529 (0.440)*	1.607 (0.386)*	1.418 (0.383)*
Year 2004	0.719 (0.536)	0.764 (0.450)	0.863 (0.436)*
Year 2005	0.430 (0.515)	0.245 (0.408)	0.434 (0.441)
Year 2006	0.827 (0.488	0.260 (0.445)	0.630 (0.377*)
Year 2007	1.183 (0.395)*	1.100 (0.35)*	1.354 (0.339)*
Year 2008	1.328 (0.384)*	1.371 (0.337)*	1.210 (0.32)*
Year 2009	1.345 (0.404)*	1.162 (0.343)*	1.347 (0.344)*
IMR	1.411 (0.665)*	1.807 (0.654)*	1.621 (0.569)*
Constant	30.171 (6.797)*	27.179 (6.264)*	33.281 (5.519)*
ρ		-0.028 (0.095)	-0.040 (0.148)
λ		0.394 (0.140)*	-3.831 (1.036)*
Log-likelihood		-97.336	-93.066
AIC		0.686	0.697
R^2	0.857	0.849	0.846

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

Table 6. Elasticities of acquisition cost in depending on the types and motivations of the contracts

	Transaction type		Target type		Threat type	
	Fee simple	Easement	Including mammals/birds	otherwise	With development pressure	otherwise
Model3	0.884	1.165	0.850	0.947	0.963	0.691
Model4-1	0.871	1.153	0.799	0.950	0.953	0.660
Model4-2	0.909	1.259	0.898	0.973	0.998	0.710

Figure 1. Average cost with respect to the size of protected area

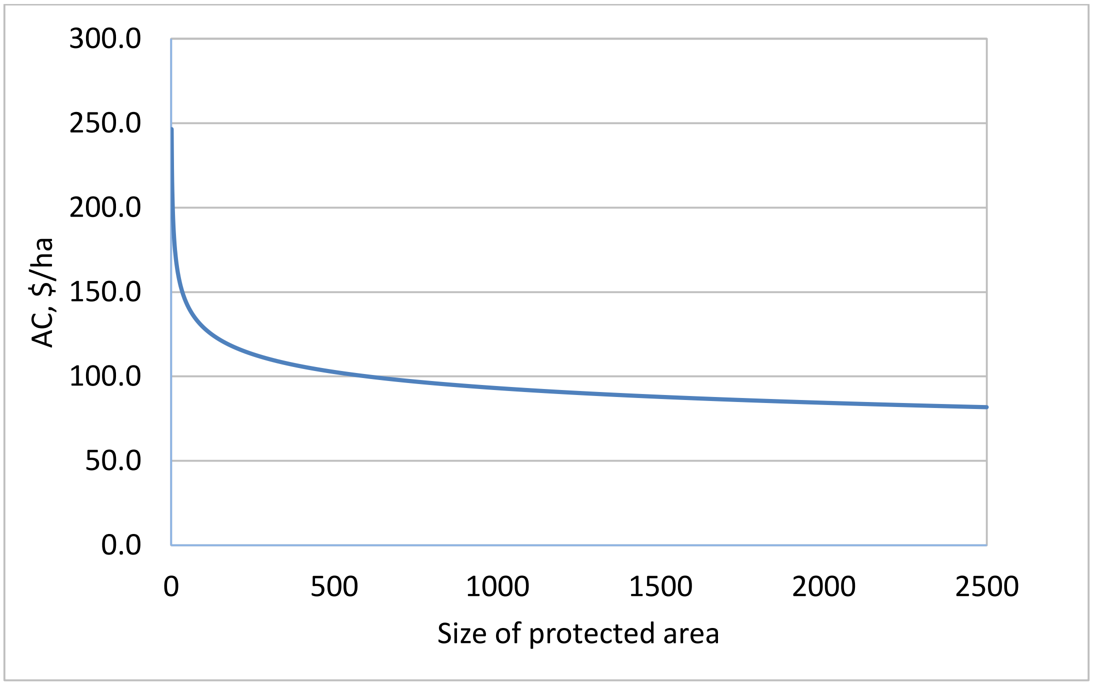


Figure 2. Average cost function with respect to size between fee simple and easement

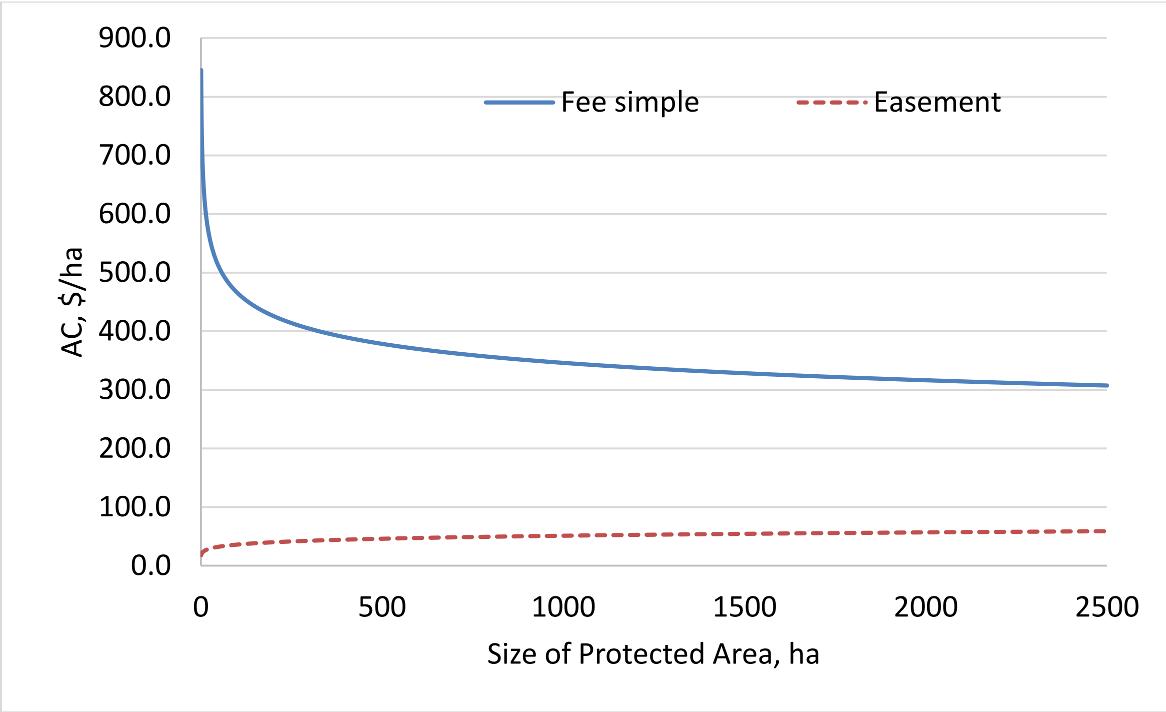


Figure 3. Average cost function with respect to size between targets

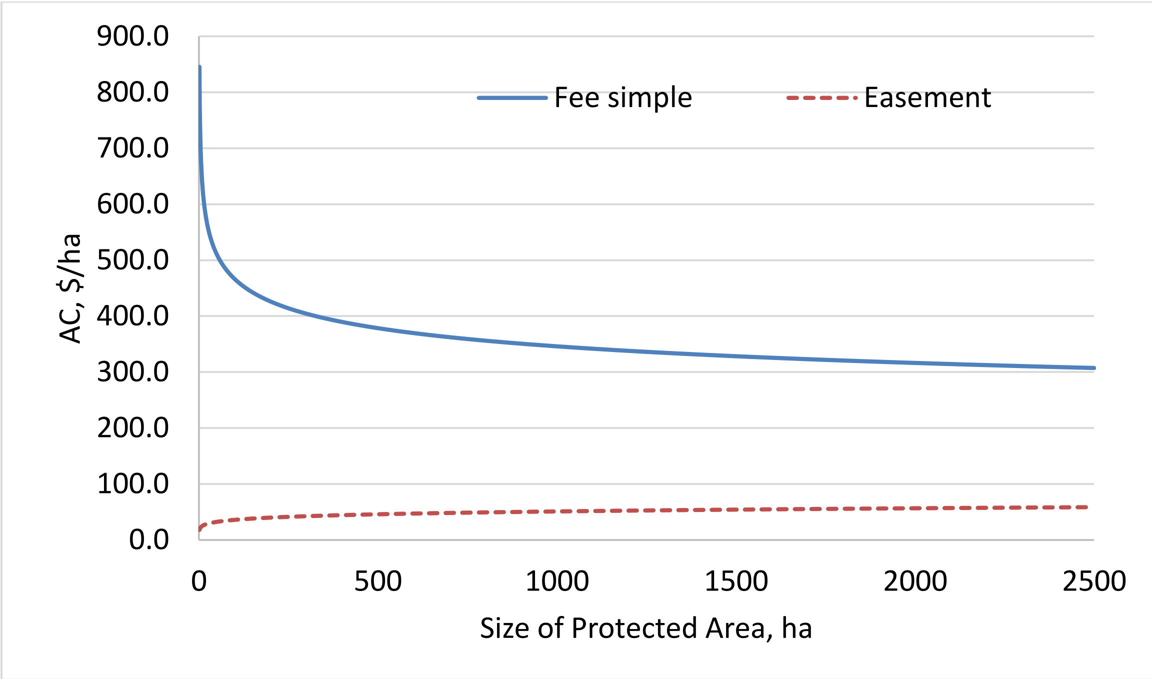
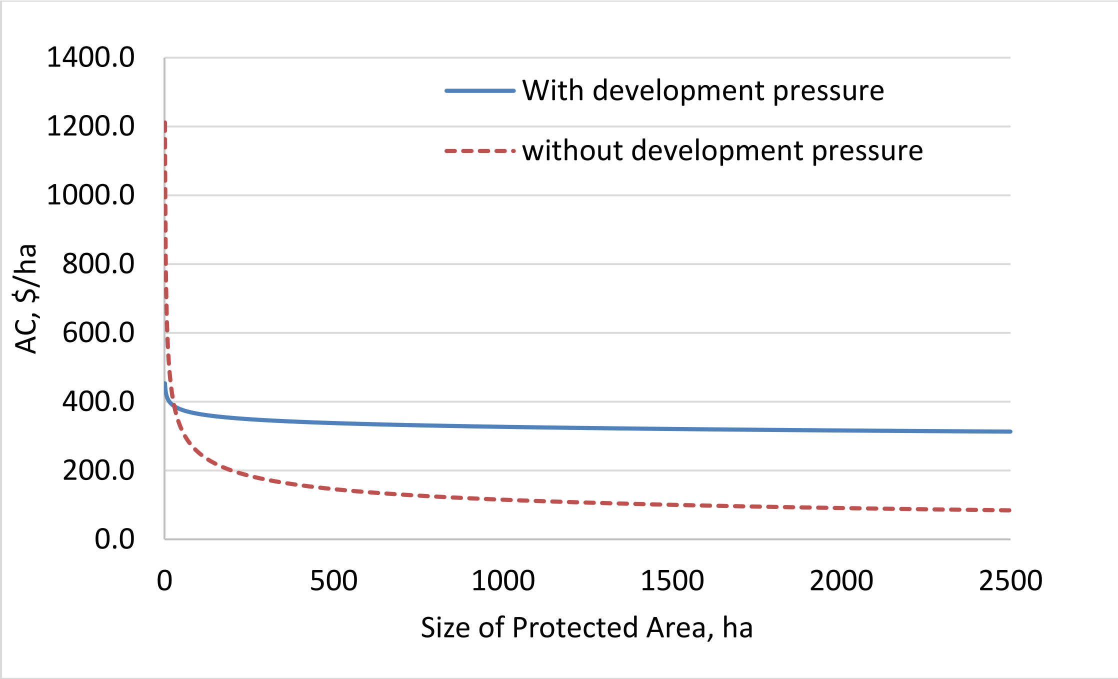


Figure 4. Average cost function with respect to size between threats



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