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The effect of spatial interdependencies on prioritization and payments for environmental services

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ABSTRACT

Empirical studies and on-the-ground policies assessing optimal selection of projects in the context of payments for environmental services programs rarely consider spatial proximity of one project to other projects. This occurs despite evidence from theoretical and ecological studies that benefits are often spatially interdependent. This paper develops a flexible construct of "spatial synergy benefits" using the principles of Newtonian gravity similar to efforts in other application areas. This approach is novel to the literature on environmental preservation and, as a systematic method, can account for a wide variety of spatial interdependencies. The empirical setting for the application is farm and forest preservation in Delaware, with a quadratic knapsack algorithm used to select the optimal set of parcels. Application results show that the specific level of the spatial synergy benefit measure does not significantly alter the number of parcels and acreage preserved, but that the composition of the optimal set changes as agglomeration preferences increase. These changes in the optimal targeted set indicate a potential bias in past research on PES selection. Policy makers informed by methods that do not explicitly account for spatial agglomeration preferences often make incorrect investment choices from a cost-effectiveness perspective.

1. Introduction

Public investment in payments for environmental services (PES), such as those provided by land preservation, increasingly draws public funds from across the globe. Valuable amenity streams are often external to markets and are hence typically undersupplied by profit-maximizing management decisions (Gardner, 1977). Because of the difficulty of quantifying and valuing site-specific environmental service provision, PES programs often target observable activities associated with service provision rather than the services themselves (Kroeger and Casey, 2007). Examples include payments for conservation easements (PACE) on agricultural or undeveloped land, agricultural best management practices, and other land conservation activities. A large literature has developed to improve PES selection (i.e., how to optimally target or select environmental service investments). Among the central aspects of these decisions is spatial targeting, and a growing literature investigates these aspects of PES decisions. As noted by Bergstrom and Ready (2009), Bateman (2009), and Duke et al. (2014), incorporating spatial complexities into PES selection is an area in need of continuing research and innovation. Observations from this literature often parallel those in work devoted to the targeting of conservation activity, with both the PES and conservation targeting literature emphasizing the relevance of spatial considerations for optimal decisions (e.g., Ando et al., 1998; Knight et al., 2009; Pfaff and Sanchez-Azofeifa, 2004; Polasky et al., 2008). The specific focus of this paper is to evaluate a new spatial targeting approach for PES that optimizes over benefits subject to agglomeration effects. The application area involves land preservation, a longstanding and common example of PES.

Optimal targeting requires benefit and cost measures. Revealed and stated preference valuation are common tools used in PES selection studies because nonmarket valuation is required to estimate many of the benefits and some of the costs associated with individual PES projects. Stated preference techniques (or survey-based valuation techniques) are used when amenities have significant nonuse components and policies to enhance amenity provision trigger marginal changes in amenity supply. Studies of marginal and nonmarginal changes in environmental

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quality and ecosystem service supply show that spatial considerations frequently affect willingness to pay (WTP) (Bateman et al., 2006; Campbell et al., 2009; Hanley et al., 2003; Johnston and Ramachandran, 2014; Jørgensen et al., 2013; Johnston et al., 2002a; Schaafsma et al., 2012).[1] For example, in the marginal case, a substantial literature has emerged to evaluate continuous and noncontinuous spatial patterns in nonmarket WTP for numerous types of environmental commodities and services. This literature frequently shows statistically significant and policy-relevant impacts of spatial factors. In the nonmarginal case, the sorting literature has shown that consumers adjust their locational preferences and willingness to pay in response to large changes in environmental amenities (Sieg et al., 2004) and that different welfare estimates can result from spending a budget for procuring a public good in different locations (Walsh, 2007).

The present model and application assess spatial synergies using data from an application of marginal land preservation decisions, with benefit and cost data derived from stated and revealed preference studies. In agricultural land preservation programs, parcel prioritization necessitates locating specific parcels in space and determining that parcel i is more valuable preserved in its current state than parcel j. Studies that value average parcels at an average spatial location are likely inadequate, because parcel i and parcel j have parcel-specific spatial attributes that influence their benefit to society in often predictable ways. For example, as soon as any one specific parcel of land i is targeted for potential preservation, the fact that targeted parcel i has a distance to another parcel j creates a potential interaction that can influence the benefits of preserving both parcels. This interaction can be positive or negative, and implies that the benefits of jointly preserving i and j may exceed (benefit synergy) or be exceeded by (cost synergy) the summation of the independent benefits of preserving i and j. Furthermore, the interaction raises the possibility that the joint benefits of preserving i and j are less than the joint benefits of preserving i and k. Spatial synergies introduce considerable complications to optimal selection. If the synergies exist but are ignored, then project selection will suffer from a systematic bias. This bias occurs because spatial independence is (incorrectly) assumed, when a spatially interdependent process determines benefits or costs. This bias will reduce the net benefits and/or cost-effectiveness of independent optimal selection strategies (excepting the remote possibility that the interdependent and independent optimal selection sets overlap by chance because of a fortuitous benefit and cost ordering that matched distance synergies).

Numerous approaches have been used to investigate spatial aspects of PES and other environmental programs. The spatial nature of benefits[2] and the implications for cost-effective parcel selection has been assessed using stated preference data in the context of targeting location-specific single parcels (Breffle et al., 1998; Duke et al., 2012), benefit aggregation and transfer (Campbell et al., 2009 Hynes et al., 2010), distance decay of benefits (Hanley et al., 2003; Bateman et al., 2006), spatial availability of substitutes (Jørgensen et al., 2013), heterogeneity of pre-intervention environmental quality (Tait et al., 2012), and the potential for part-whole bias (Hanley et al., 2003; Brouwer et al., 2010). There also are studies examining optimal targeting in spatially explicit contexts, focusing on the probability of conversion and correlated land costs (Newburn et al., 2006, 2005; Stoms et al., 2011) and econometric simulations (Lewis et al., 2009). An examination of spatial land preservation in practice found little contiguous-block formation and that an optimization method would protect different lands (Stoms et al., 2009). Davis et al. (2006) examined prioritization and clustering in a spatially explicit biodiversity conservation study in California. There are also many studies that use revealed preference data to estimate the capitalized effect of quasi-use values for locational-specific amenity provision from land uses and preservation (Bolitzer and Netusil, 2000; Geoghegan, 2002; Geoghegan et al., 2003; Neumann et al., 2009; Borchers and Duke, 2012).

The most relevant works in this literature for the present analysis are those that employ spatial stated preference benefit estimates. Campbell et al. (2009), for example, highlight a potential improvement for benefit transfer by accounting for spatial autocorrelation of WTP estimates of households for rural landscape improvements. Similarly, Hynes et al. (2010) use synthetic estimates of WTP for small-area populations from a combination of survey and demographic data to improve benefit aggregation across space. The Hanley et al. (2003) examination of distance decay functions demonstrates the spatial extent for use and nonuse values in water quality improvements. This result implies that defining the extent of the geographic area where benefits accrue is an important consideration for optimal PES selection. Both Hanley et al. (2003) and Brouwer et al. (2010) find WTP for water quality improvements differ across the same river basins, with households willing to pay more for improvements in their own sub-basin than the river basin as a whole (i.e., part-whole bias). Taken together, the literature suggests that a household's utility for preservation or environmental improvement often depends on the household's relative proximity to the PES intervention.[3] Although these results are not universal (cf. Rolfe and Windle, 2012) and the specific influence of spatial relationships on economic value varies across different types of resources (Bateman et al., 2006; Hanley et al., 2003), the literature finds broad similarities in the types of spatial patterns found across different types of environmental service values (Schaafsma et al., 2012).

While demonstrating the important role of spatial factors for preservation value, the vast majority of this literature emphasizes the effect of distance between a potential beneficiary and an environmental improvement, the variable provision of environmental services that may occur over geographical areas,[4] or potential differences in preferences over these areas. Less attention is given to agglomeration effects or to the fact that the spatial proximity of multiple environmental improvements (e.g., parcels chosen for preservation) may influence the benefit of each individual improvement. For example, the combined net benefit of two parcels preserved in close proximity may be greater (or perhaps smaller) than otherwise identical parcels preserved at a greater distance, simply due to the proximity effect.

[1] Willingness to pay, or WTP, is a commonly used measure of economic value in benefit-cost analysis. It is defined conceptually as the maximum amount of money (or another good) that a person or group would voluntarily sacrifice in exchange for a specified quantity of a good or service. Marginal changes refer to incremental or very small changes in a variable from a baseline, for which effects on broader markets or conditions (e.g., prices for other goods and services) are generally assumed to be trivial. Nonmarginal changes refer to larger changes in a variable, which may lead to non-trivial effects on broader markets or conditions.

[2] This paper abstracts from spatial cost dynamics, where coordination strategies and incentives to induce agglomeration have received the bulk to the research attention. Experimental (Parkhurst et al., 2002; Parkhurst and Shogren, 2007; Banerjee et al., 2012, 2013; Fooks et al., forthcoming), and empirical (Drechsler et al., 2010) research has focused on the development of payment schemes (i.e., agglomeration bonuses) to incentivize landowners to overcome cooperation difficulties and spatially coordinate preservation decisions.

[3] This is a common but not universal finding. Other evaluations fail to find statistically significant distance decay in values, particularly for cases involving WTP motivated largely by nonuse values (e.g., Johnston and Ramachandran, 2014; Rolfe and Windle, 2012).

[4] For example, flood attenuation benefits of a riparian buffer are often greater for buffers located upstream, compared to similar buffers located downstream. This is because larger areas are affected by the upstream services compared to downstream ones, ceteris paribus.