



Assessing the local economic impacts of land protection

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Abstract: *Land protection, whether public or private, is often controversial at the local level because residents worry about lost economic activity. We used panel data and a quasi-experimental impact-evaluation approach to determine how key economic indicators were related to the percentage of land protected. Specifically, we estimated the impacts of public and private land protection based on local area employment and housing permits data from 5 periods spanning 1990–2015 for all major towns and cities in New England. To generate rigorous impact estimates, we modeled economic outcomes as a function of the percentage of land protected in the prior period, conditional on town fixed effects, metro-region trends, and controls for period and neighboring protection. Contrary to narratives that conservation depresses economic growth, land protection was associated with a modest increase in the number of people employed and in the labor force and did not affect new housing permits, population, or median income. Public and private protection led to different patterns of positive employment impacts at distances close to and far from cities, indicating the importance of investing in both types of land protection to increase local opportunities. The greatest magnitude of employment impacts was due to protection in more rural areas, where opportunities for both visitation and amenity-related economic growth may be greatest. Overall, we provide novel evidence that land protection can be compatible with local economic growth and illustrate a method that can be broadly applied to assess the net economic impacts of protection.*

Keywords: conservation and development, employment, land conservation, local economies, New England, private land protection, protected areas

Evaluación de los Impactos de la Protección de Terrenos sobre la Economía Local

Resumen: *La protección de terrenos públicos o privados a menudo es controversial a nivel local debido a la preocupación que tienen los residentes por la pérdida de actividades económicas. Usamos un panel de datos y una estrategia casi experimental de evaluación de impacto para determinar cómo los indicadores clave están relacionados con el porcentaje de terrenos protegidos. En específico, estimamos los impactos de la protección de terrenos privados y públicos con base en el empleo en el área local y los datos de permisos residenciales en cinco periodos que abarcaron de 1990 a 2015 para las principales ciudades y pueblos de Nueva Inglaterra. Para generar estimaciones rigurosas de impacto modelamos los resultados económicos como una función del porcentaje de suelo protegido durante el periodo previo, condicional a los efectos fijados de la ciudad o el pueblo, las tendencias de la metro-región, y los controles de protección vecina y por periodo. Contrario a las narrativas que dicen que la conservación deprime al crecimiento económico, la protección de tierras estuvo asociada con un crecimiento modesto del número de personas empleadas y en la fuerza laboral, y no*

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afectó a los permisos residenciales nuevos, a la población o al promedio de ingresos. La protección pública y la privada resultaron en diferentes patrones de impactos positivos sobre el empleo a distancias cercanas y lejanas de las ciudades, lo que indica la importancia de la investigación en ambos tipos de protección de tierras para incrementar las oportunidades locales. La mayoría de los impactos sobre el empleo se debieron a la protección en áreas rurales, en donde las oportunidades para el crecimiento económico relacionado con visitas y amenidades puede ser mayor. En general, proporcionamos evidencias novedosas de que la protección de tierras puede ser compatible con el crecimiento económico local e ilustramos un método que puede aplicarse ampliamente para evaluar los impactos económicos netos de la protección.

Palabras Clave: áreas protegidas, conservación de tierras, conservación y desarrollo, economía local, empleo, Nueva Inglaterra, protección de tierras privadas

Introduction

Land protection, both public and private, provides substantial ecological benefits by avoiding conversion of natural systems to intensive, developed uses. These benefits include carbon sequestration, watershed functioning, soil conservation, and the preservation of diverse habitat types (e.g., Daily 1997; Brauman et al. 2007; Kumar 2012; Watson et al. 2014). Land protection also solves a key market failure: private markets tend to underprovide socially beneficial land uses such as natural forests, agricultural lands, or managed timberlands. The reason for this failure is that many of the benefits of these lands go to the public in general, not individual landowners. When private values and market transactions determine land uses, less land will be devoted to socially beneficial uses than if citizens could collectively determine use on the basis of social values (e.g., Angelsen 2010; Tietenberg & Lewis 2016).

Despite these clear ecological and economic justifications for land protection, it does—by definition—limit intensive resource extraction and conversion to housing or commercial development. Opponents of land protection focus on these restrictions and the loss of possible tax revenue and have often painted protection as incompatible with economic growth, particularly for local residents and in rural areas where the number of job opportunities is limited (e.g., Lewis et al. 2003; Lorah & Southwick 2003; Rasker 2006; Baldwin et al. 2007; Lilieholm 2007; Bangor Daily News 2017, 2018; Miller 2017; New York Times 2017).

In contrast, land protection proponents highlight the ways in which it can increase local economic activity: through ecosystem services including wild pollination, flood control, watershed functioning, or forest products (Daily 1997), employment compatible with or created by protection (e.g., Dixon & Sherman 1990; Phillips 1998; Kurtz 2010; Thomas et al. 2015) and broader amenity-related growth (e.g., Wu & Plantinga 2003; Rasker et al. 2013; Chen et al. 2016). Employment-related growth effects are usually driven by recreational visitor spending in or near protected areas, which creates additional demand for locally produced goods and services. For example, visitors to U.S. national parks spend an estimated

\$15.7 billion in local gateway communities (Thomas et al. 2015). This economic activity can be multiplied as local producers purchase inputs from other local businesses or their employees spend their income locally (e.g., Thomas et al. 2015). Land protection may also drive growth by increasing an area's amenity value (Rasker et al. 2013). Although early theories of regional growth focused on how new job opportunities would be followed by immigration (e.g., Greenwood & Hunt 1984), more recent work indicates that migration can come first and be driven by the presence of attractive amenities, followed by job growth (e.g., Nelson 1999; Lorah & Southwick 2003; Rasker et al. 2013). Amenity-related growth is likely a key factor driving positive long-term impacts of land protection in the Western United States (Rasker et al. 2013; Chen et al. 2016). Prior research in northeastern states also associates county-level environmental amenities with economic growth (White & Hanink 2004).

We sought to provide a rigorous, empirical investigation of the net costs or benefits of land protection at the local level and to demonstrate a widely applicable method for use in assessing these effects. To our knowledge, we are the first to estimate the local economic impacts of both public and private land conservation based on multiple periods of panel data. Specifically, we investigated the local impacts of land protection within 1501 New England (U.S.A.) towns and cities. We constructed a unique panel data set spanning 5 intervals between 1990 and 2015 that included the percentage of land protected by the start of each interval, averages of key local economic indicators, and land-cover change for each period (sources given in Methods). We sought to show how available economic, land protection, and land-cover data can be combined fruitfully in a quasi-experimental analysis. Crucially, we used panel data from multiple periods to estimate plausibly causal impacts of land protection at the local level. Repeated observation of economic indicators from the same unit of analysis (here towns and cities) allows for comparisons that are more likely to overcome issues of bias (and thus prevent causal interpretation) because they hold constant many potentially important, unobservable characteristics of each unit (e.g., Greenstone & Gayer 2009).

Rigorous evaluations of both public and private land protection are increasingly important given concerns about the impacts of conservation on human development (e.g., Brockington & Wilkie 2015; Oldekop et al. 2016; Griffiths et al. 2018). Within the United States, prior rigorous research regarding the economic impacts of land protection has focused on public designations and areas with low population density (Duffy-Deno 1997; Lewis et al. 2002, 2003; Kim et al. 2005; Eichman et al. 2010; Rasker et al. 2013; Pugliese et al. 2015; Chen et al. 2016; Jakus & Akhundjanov 2018), whereas future conservation is likely to include more private conservation in highly populated areas (Rissman et al. 2007; Lillieholm et al. 2013; Nolte 2018). Outside of the United States, research has also focused mainly on the impacts of public protected areas (e.g., Andam et al. 2010; Sims 2010; Canavire-Bacarreza & Hanauer 2013; Ferraro & Hanauer 2014; Gurney et al. 2014; Robalino & Villalobos 2015; Oldekop et al. 2018). Only Sims and Alix-Garcia (2017) compared economic outcomes for 2 conservation types together (parks and payments for ecosystem services) based on a consistent quasi-experimental approach, but their analyses were limited to 1 period of change. Here, in addition to examining multiple conservation types, we also examined conservation impacts at a truly local scale, matching the level of actual governance structures in our study area—towns and cities—that make most land-use decisions and zoning policies, set property taxes, and provide public goods such as schools. Only Chen et al. (2016) used a similar unit of analysis, and their results pertain to a different U.S. region. Novel regional studies of local impacts are crucial for informing future policy. Although drivers of economic impacts are likely to be similar across settings, global studies are not possible due to differences in outcome data and the need to carefully account for the selection processes determining protection. Thus, policy recommendations must be based on patterns drawn from credible regional studies.

Methods

To investigate the impacts of land protection on local economic activity, we conducted panel regression analysis for 1501 units (Fig. 1). The boundaries used are for “county subdivisions” (U.S. Census Bureau 2015); in New England, county subdivisions generally align with the boundaries of established towns and cities (excepting unorganized parts of Maine and other small hamlets). Thus, we refer to these units throughout as towns and cities. Our analysis included all towns and cities with reported populations >100 in the 1990 census and no substantial boundary changes (Fig. 1), which accounted for 99.97% of the 1990 population of the area. We considered 5 equally spaced periods of data from 1990 to 2015. The percentage of land protected came from a

regionally aggregated data set of protected areas maintained by the Harvard Forest and Highstead Foundation (2018); sources of data and methods for aggregation are described in the metadata for data set HF315 on the Harvard Forest Data Archive. Data on economic indicators came from the U.S. Bureau of Labor Statistics (2017), U.S. Census Bureau, Building Permits Survey (2017), and the National Historical Geographic Information System (2017), which includes data from the American Community Survey (2006–2010 and 2011–2015) and the 1990, 2000, and 2010 Decadal Censuses.

Our main regression model was

$$\ln(Y_{ic,t}) = \beta_0 + \beta_1 \ln(\text{prot}_{ic,t-1}) + \beta_2 \ln(\text{nn10prot}_{ic,t-1}) + \alpha_i + \delta_t + \Omega'(t^* \lambda_c) + \varepsilon_{ic,t} \quad (1)$$

where i denotes each town or city, t is a 5-year period (1990–1994, 1995–1999, 2000–2004, 2005–2009, and 2010–2014); and c is the metro region (these correspond to the Census Bureau’s Core-Based Statistical Areas, plus remaining areas within states). The variable $\ln(Y_{ic,t})$ is the natural log of each local-level economic outcome, in this case the mean number of people employed, number of people in the labor force (number of people employed or actively seeking employment), unemployment rate (number of people unemployed/labor force), and number of new building permits issued by towns and cities. We used these indicators because they are consistently reported by towns and cities on an annual basis. We also used as economic outcomes total population (available in 1990, 2000, and 2010), median household income (1990, 2000, 2006–2010, and 2011–2015), and employment in resource-intensive (agriculture, forestry, fishing, hunting, and mining) and recreation-based (recreation, arts, entertainment, accommodation, and food) industries (2000, 2006–2010, and 2011–2015).

Our key explanatory variable of interest was the percentage of each town or city protected by the beginning of the 5-year period for which outcomes are measured ($\text{prot}_{ic,t-1}$). For example, if the log of average town-level employment from 2005 to 2009 is the left-hand-side variable, the corresponding right-hand-side measure is the log of the percentage of that town protected by 2005. There were substantial additions to the amount of land protected in the 4 periods preceding measurement of economic outcomes (Fig. 1).

The remaining terms in Eq. (1) reference control variables: $\text{nn10prot}_{ic,t-1}$ is the average percentage of town or city protected in the 10 nearest neighboring towns or cities. This variable was included to control for possible spatial correlation in conservation initiatives (e.g., Albers et al. 2008) or other possible spillover effects from neighboring towns. The variable α_i represents a town fixed effect, or specific intercept for each town. This controls for any fixed factors that might be correlated with both protection and economic outcomes—for instance,

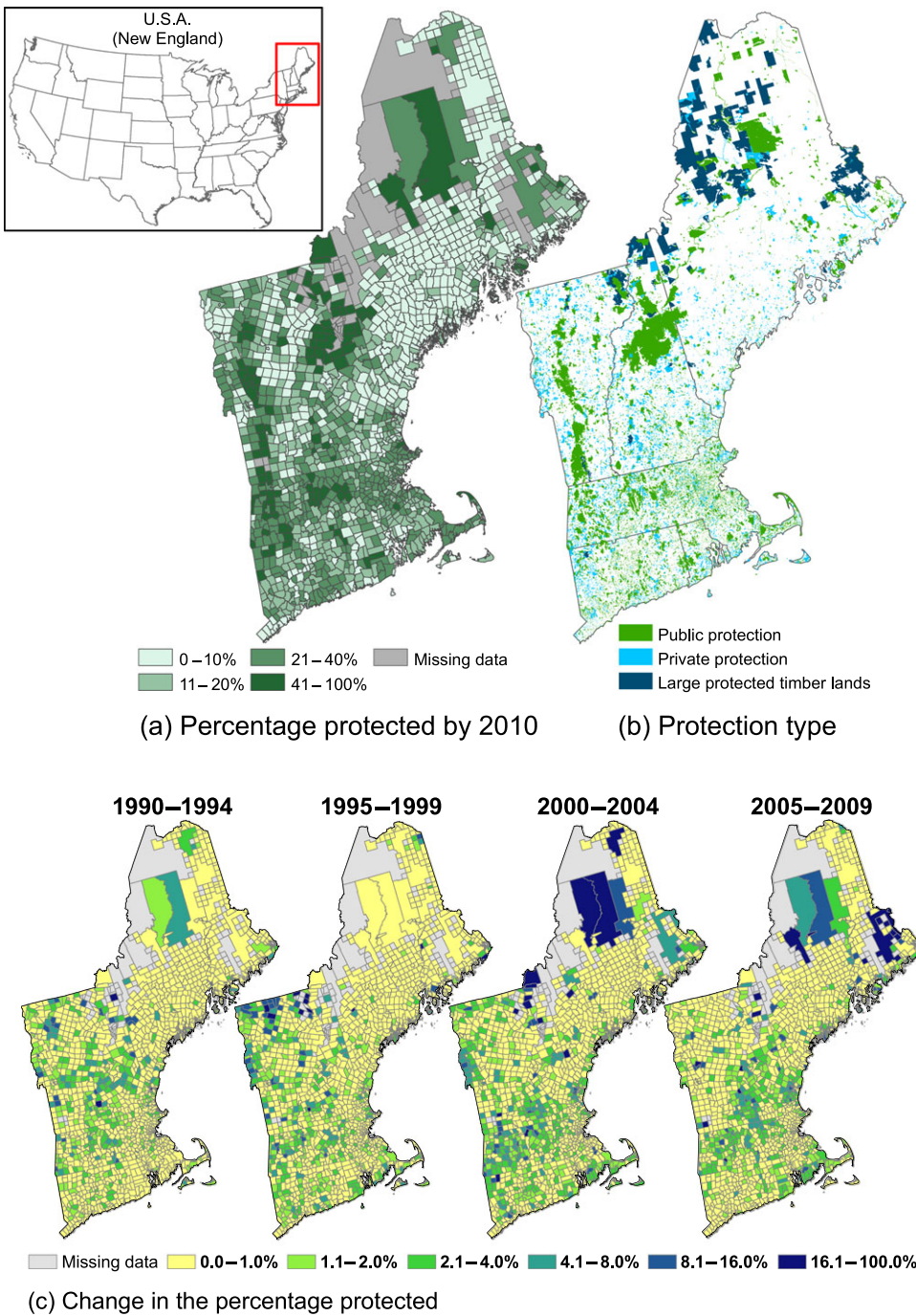


Figure 1. Protected land in the study area (New England): (a) percentage protected by 2010 within each town or city included in the analysis (1501 units where population was ≥ 100 in 1990 and there were no substantial changes in boundaries from 1990–2010), (b) types of protected land, and (c) changes in percentage of land protection within each period.

presence of spectacular natural features, long-standing cultural attitudes toward protection, or proximity to major population centers. Similarly, δ_i denotes a period fixed effect, which controls for overall economic fluctuations, such as a period of economic recession or expansion. Finally, $t * \lambda_c$ indicates a series of metro-region trend controls. This allows groups of towns and cities to grow (or decline) at different rates across time, modeling the fact that some regions of New England (e.g., the Boston metro area or Southern Connecticut) experienced more rapid economic and population growth during the study period. Models with simple associational

regression and cumulative addition of controls are compared in Supporting Information. These illustrate the importance of using panel data to control for unobservable, town- or city-specific fixed factors because coefficients change substantially when town or city controls are added. Supporting Information also contains additional checks for robustness based on dynamic panel estimation and first differences models.

We estimated all models with heteroscedasticity robust standard errors. Errors were clustered by town or city (i) to account for serial correlation within each unit. Information on spatial correlation of the raw data and residuals

and a robustness check allowing for spatial correlation within both town or city and county units are included in Supporting Information. All regressions were weighted by the log of population in each town or city.

Given the model above, the effects of protection were identified from remaining variation in the percentage of each town that was protected by the start of each period after controlling for town-specific fixed factors, time trends, protection by neighbors, and metro-region trends. The key identifying assumption that would allow for a causal interpretation is that this remaining variation was unrelated to potential economic outcomes. This is plausible, given the substantial changes in land protected over this time (Fig. 1) and the decentralized nature of new land-protection initiatives during this period. New England boasts more than 350 separate land trusts (Land Trust Alliance 2016), hundreds of other protection organizations, and dozens of conservation-focused state and federal agencies. There was no overarching conservation-planning authority or scheme; most new protection relied on the dedicated efforts of many independently acting, motivated individuals, often in response to opportunities from property transitions (e.g., Lillieholm et al. 2013; Foster et al. 2017). This created the conditions for a reasonable natural experiment or quasi-experiment—a situation where some towns ended up with more land protected than others for reasons unconnected to the potential outcomes in those towns (also see Supporting Information; a test for reverse causality based on land-cover data did not indicate that more development in prior periods led to more land protection).

In addition to our main specification (Eq. (1)), we used interaction terms to test for heterogeneous impacts by protection type, town population density, and distance to major cities. We grouped protection into 3 main types: publicly owned land protected through fee acquisition, privately owned land protected through conservation easement or fee acquisition by conservation organizations, and large protected timberlands (LPT), which are privately owned lands with working forest conservation easements that provide for, and indeed require, ongoing forest management (Fig. 1). Evaluating each protection type is important given different priorities and complex patterns of possible collocation (e.g., Albers et al. 2008). We also assessed impacts by housing density, a key urban indicator (Radeloff et al. 2005; Gianotti et al. 2016) and overall population, which separated large and small cities. Specifically, we defined city and town types as large urban (>128 housing units/km² and >30,000 people in 1990), small urban (>128 housing units/km² but <30,000 people in 1990), exurban (16–128 housing units/km²), and rural (<16 units/km²). We conducted this analysis because protection may have very different impacts depending on the underlying type of town or city. In particular, concerns about protection often focus on impacts in rural areas, where remaining resource

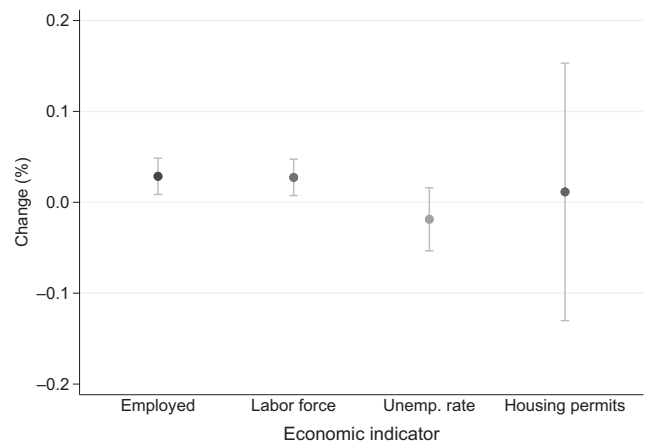


Figure 2. Estimated coefficients from panel regression models of log number of people employed, number of people in the labor force, unemployment rate, or number of new housing permits on log percentage of land protected in the prior period, controlling for town or city, period, land protection in nearby towns and cities, and metro-region trends (points, coefficients; bars, 95% CI; $n = 7505$ employed, labor force, and unemployment rate; $n = 6750$ for new housing permits).

intensive industries are located and fewer alternate employment opportunities may exist. We also allowed heterogeneity in impacts by distance to major cities (defined as population >100,000 people in 1990; specifications allowing effects to vary cubically with distance) because connections to markets or gateway communities may play an important role in the impacts of protection (e.g., Rasker & Hansen 2000; Kurtz 2010).

New England provides an ideal region of study because it has >80% forest cover, >15 million ha of forest, and >14 million people and is thus ecologically and economically important. Both public and private land protection cover substantial land areas (Fig. 1) and the more than 800,000 private land owners in the region (Butler et al. 2016) provide important opportunities to test conservation strategies incorporating private owners. After more than 150 years of forest expansion, New England is now losing forest cover to developed uses at a rate of approximately 10,000 ha/year (Olofsson et al. 2016), which has led to large-scale efforts to further increase the pace of public and private land protection (e.g., Foster et al. 2017) as well as increased questions about whether high rates of protection are compatible with economic development (McBride et al. 2019).

Results

We found a positive and statistically significant impact of land protection on the number of people employed and in the labor force (Fig. 2), indicating growth in both the

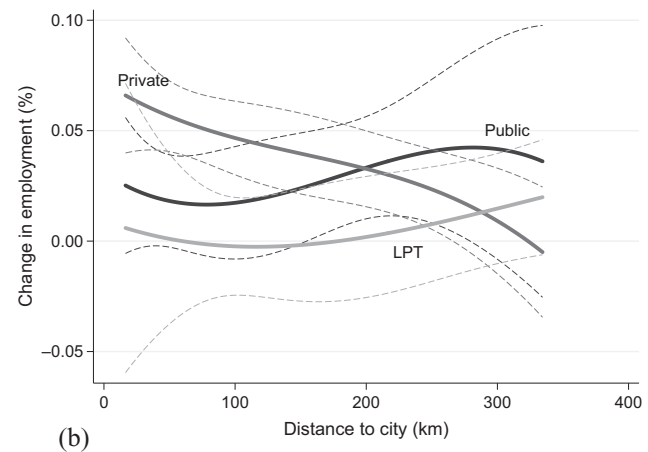
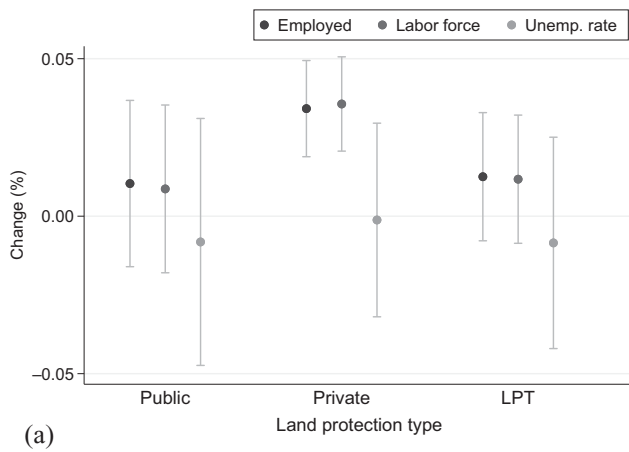


Figure 3. Estimated coefficients from panel regression models of log economic outcomes on log percentage of land protected in the prior period by (a) protection type and (b) distance to nearest city with >100,000 people in 1990, controlling for town or city, period, land protection in nearby towns and cities, and metro-region trends (points or lines, coefficients; bars or dotted lines, 95% CI; LPT, large protected timberlands; $n = 7505$).

total number of jobs and the total number of people seeking work. The estimated impact on the unemployment rate was negative but not significantly different from zero, while the estimated impact on permits for new housing units was positive but not statistically significant. The negative point estimate for the unemployment rate was consistent with a slightly larger growth in the number of jobs than growth in the labor force (which matches the magnitudes of the point estimates). The statistically significant, positive impacts of protection on employment and the labor force were robust to clustering standard errors (SEs) across both town and county and to alternate model specifications (Supporting Information).

Given the estimation model, these coefficients can be interpreted as elasticities. For the employment outcome, this means that a 1% increase in the percentage of protected land in a town or city was associated with an approximate 0.03% increase in the number of people employed. For example, for a town with 20,000 people employed, a substantial increase in protection, from 10% protected to 15% protected (or a 50% increase), would lead to an approximately 1.5% increase (0.03×50) in people employed or 300 additional people employed. By comparison, the peak-to-trough changes in employment for the economic expansion from 2003 to 2008 and recession from 2008 to 2010 were >6% nationally (Goodman & Mance 2011).

We also investigated the impacts on labor-market indicators for different types of protection: public, private, and LPT (Fig. 3). The positive point estimates indicated that all protection types likely contributed positively to employment and the labor force (although only private protection was statistically significantly different from 0). The point estimates also indicated that private protection created (or attracted) the most employment when close

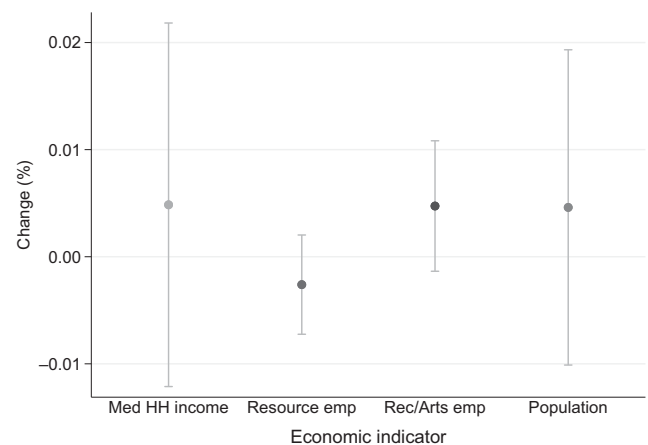


Figure 4. Estimated coefficients from panel regression models of log median household (HH) income, employment in resource-intensive (resource emp) and recreation-based industries (rec/arts emp), or population on log percentage of land protected in the prior period, controlling for town or city, period, land protection in nearby towns and cities, and metro-region trends (points, coefficients; bars, 95% CI; $n = 4502$ for median household income, $n = 4500$ for employment by industries; $n = 3002$ for population).

to major cities, whereas public protection and LPT were associated with increases in employment far from major cities (Fig. 3).

We found no statistically significant impacts of land protection on median household income or overall population, although both point estimates were positive (Fig. 4). Overall population numbers may not change as rapidly as employment or labor force numbers, because in-migration would also require changes in the housing

stock, which is likely to adjust more slowly and may be constrained by conservation efforts.

Estimates for the 2 most relevant industry employment groupings were also not significantly different from 0, but the magnitudes suggested small losses of employment (less than .005%) in resource-intensive industries and more-than-offsetting gains in recreation, hospitality, and arts employment (Fig. 4). There were no significant impacts on these indicators when we estimated models that allow for differential impacts by conservation type (Supporting Information), and the patterns of point estimates were similar.

Finally, protection had positive and statistically significant impacts in rural areas (Supporting Information), increasing employment and possibly new housing permits. This is consistent with theories of both visitation-related employment and amenity value from land protection. Impacts in exurban areas and large urban areas were not significantly different from zero. Small urban areas experienced slower growth in terms of employment, labor force, and housing permits (Supporting Information). However, the point estimate on unemployment for small cities was also negative, which is possible if the labor force grew more slowly than employment (reducing unemployment) and was consistent with the other point estimates.

Discussion

Economic theory points to both costs and benefits of protection at a local level, where the net impact depends on the magnitude of each. We found that land protection in New England led to small, statistically significant increases in employment and the size of the labor force. These results are novel because they address both public and private conservation. In direction of impact, they are consistent with prior studies within the United States. Rasker et al. (2013) found that federal land protection in the nonmetropolitan West was associated with gains in 3 out of 10 economic indicators, including per capita income. Pugliese et al. (2015) found that changes in timber sales on national lands in the U.S. West did not affect county-level employment growth, which is similar to earlier findings by Lewis et al. (2002, 2003) that changes in timber sales in the Northern Forest Region did not affect county-level net migration, employment, or wage growth. Jakus and Akhundjanov (2018) found no effect on growth trends per capita from the designation of the Grand Staircase-Escalante National Monument in Utah. An exception to these generally positive findings is Eichman et al. (2010), which found that federal restrictions on public lands under the Northwest Forest Plan decreased county-level employment growth and increased out-migration in the short term. However, in a more recent study of the plan, Chen et al. (2016) found positive,

long-term amenity benefits for small communities and no long-term effects for medium-sized communities.

Outside of the United States, increasing evidence on protected-area impacts also suggests the potential for positive local net benefits, most likely due to tourism income, with credible quasi-experimental evidence from Thailand (Sims 2010), Costa Rica (Andam et al. 2010; Robalino & Villalobos 2015), Bolivia (Canavire-Bacarreza & Hanauer 2013), Indonesia (Gurney et al. 2014), and Nepal (Oldekop et al. 2018). Still, there are also cases where protected areas have not clearly helped improve local economic indicators (e.g., in Mexico; Sims & Alix-Garcia 2017). In addition, perceptions of the motivations for and results of conservation often remain negative even when material gains are positive (Holmes 2007; Brockington & Wilkie 2015; Oldekop et al. 2016).

The positive increase in employment in the New England region due to land protection may be plausibly explained by both amenity-related growth and replacement of resource-intensive jobs with recreation-based jobs. For example, a recent study using input-output modeling found that the U.S. Department of Agriculture Forest Legacy program, which protects private working forests, contributed more than 2000 jobs in 2016 to the section of the Northern Forest region that includes northern New England. This economic activity included annual timber harvest, maple syrup production, and recreation spending on fishing, hunting, and snowmobiling (Murray et al. 2018). Overall, recreation in New England has been estimated to provide 432,000 jobs and 52 billion a year in direct spending (Outdoor Industry Association 2017). Additional studies also point to significant amenity value from protection: open spaces can result in 5–35% higher property sale prices (Thorsnes 2002; Earnhart 2006) and 13–14% greater parcel appreciation rates than regional averages (Lacy 1990).

The notion that multiple mechanisms may be at play is supported by our result that public and private protection appeared to offer complementary opportunities at different distances away from major cities. These patterns are consistent with private protection creating desirable amenity benefits close to existing employment opportunities, whereas public protection may support more recreation-based employment in more distant communities. It suggests that a mix of public and private conservation would best support economic activity across the geographic range of cities and towns.

Our results also suggest that land protection is compatible with economic growth even when it has a substantially different pattern than the large, mainly federal, public protection studied to date. Although almost half of land in the Western United States is managed by the federal government (Rasker et al. 2013), >80% of New England is privately owned, including approximately 20% corporate ownership and 60% family ownership (Butler et al. 2016). Of the land area protected since 1990, 51%

has been in large private timberlands, 29% has been privately protected by individuals and land trusts, and 20% has been protected by public agencies, mainly at the state and local level (Harvard Forest and Highstead Foundation 2018). This land has remained substantially protected from development: land-cover change analysis of our study area indicates that <0.03% of protected lands were converted to developed uses between 1990 and 2010 (Supporting Information).

Finally, our results indicate—perhaps somewhat surprisingly given negative rhetoric—that rural areas benefited in net from protection. At the same time, they suggest that more resources may be needed to support economic growth in small cities with substantial land protection. Prior research (e.g., Wu & Plantinga 2003; McDonald et al. 2007) suggests that protected space in urban areas can drive growth and in-migration, so additional case-based research is warranted to explore the relationship between small urban areas and land protection in New England.

Our analysis included key, consistently tracked major indicators of economic activity—employment indicators, new building permits, income, and population. We found overall that protection boosted, rather than depressed, local economies. However, future work should also extend analysis to additional local indicators, most importantly property values and tax revenues (e.g., King & Anderson 2004; Heintzelman 2010; Reeves et al. 2018), which are crucial for the delivery of local public goods. Future work should also combine analysis of economic and land-use change indicators to understand the interaction between development threat, conservation effectiveness, and the net economic impacts of protection.

Acknowledgments

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Supporting Information

A comparison of simple and full regression models (Appendix S1), checks regarding spatial correlation of errors (Appendix S2), tests for reverse causality (Appendix S3), alternate model specifications (Appendix S4), additional results by period, land-protection type, and town or city type (Appendix S5), and calculations of land-cover change inside and outside protected lands (Appendix S6)

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