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# Projected impacts to the production of outdoor recreation opportunities across US state park systems due to the adoption of a domestic climate change mitigation policy

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ABSTRACT

Numerous empirical and simulation-based studies have documented or estimated variable impacts to the economic growth of nation states due to the adoption of domestic climate change mitigation policies. However, few studies have been able to empirically link projected changes in economic growth to the provision of public goods and services. In this research, we couple projected changes in economic growth to US states brought about by the adoption of a domestic climate change mitigation policy with a longitudinal panel dataset detailing the production of outdoor recreation opportunities on lands managed in the public interest. Joining empirical data and simulation-based estimates allow us to better understand how the adoption of a domestic climate change mitigation policy would affect the provision of public goods in the future. We first employ a technical efficiency model and metrics to provide decision makers with evidence of specific areas where operational efficiencies within the nation's state park systems can be improved. We then augment the empirical analysis with simulation-based changes in gross state product (GSP) to estimate changes to the states' ability to provide outdoor recreation opportunities from 2014 to 2020; the results reveal substantial variability across states. Finally, we explore two potential solutions (increasing GSP or increasing technical efficiency) for addressing the negative impacts on the states' park systems operating budgets brought about by the adoption of a domestic climate change mitigation policy; the analyses suggest increasing technical efficiency would be the most viable solution if/when the US adopts a greenhouse gas reduction policy.



## 1. Introduction

The adoption of US policies focused on reducing GHG emissions is likely to alter the provision of public goods and services. As revenues captured from existing energy markets decrease, public service agencies are likely to see operating budget reductions (Jorgenson et al., 2008; Ross et al., 2008). Impacts to the provision of public services are likely to differ by

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state. For example, in the case of outdoor recreation opportunities provided by state park systems, operating expenditures are generated by a mix of revenues and government appropriations. As a state's economic health wanes, so too will its ability to provide high quality outdoor recreation opportunities in state parks (Siderelis and Smith, 2013). As evidence of this connection, reductions in congressional appropriations in some states have already affected operating hours, reduced employment rates and created a backlog of deferred maintenance. The connection between the provision of outdoor recreation opportunities and the states' economies can subsequently impact public health benefits (Ruhm, 2000). Given GHG reduction policies may alter states' economic growth trajectories, quantifying the projected impacts of climate change mitigation policies on the provision of public goods and services is needed to identify solutions that can maintain those goods and services into the future.

The purpose of this study is to forecast changes in operating expenditures from the year 2014 to 2020 for each of the state park systems within the US under a domestic climate change mitigation policy. Our goal is to demonstrate an empirical linkage between a domestic GHG reduction policy and the provision of public goods and services, specifically outdoor recreation opportunities and its associated benefits. To our knowledge, no previous study had demonstrated a direct linkage between the adoption of a domestic GHG reduction policy and the provision of public services. Through our analyses we produce three specific outcomes highly relevant to environmental policy makers and recreation resource managers: (1) we estimate state-level technical efficiency metrics for the states' park systems, providing decision makers with empirical evidence of specific areas where operational efficiencies can be improved; (2) we estimate state-level changes to operating expenditures under a domestic climate change mitigation policy, highlighting substantial variability across the states' park systems; and (3) we explore two potential solutions (increasing gross state product (GSP) or technical efficiency) for addressing negative impacts on the states' park systems operating budgets brought about by the adoption of a climate change mitigation policy.

## 2. Study context and related literature

### 2.1. State park systems in the United States

State park systems in the US facilitate the preservation, regulation and provisioning of natural and cultural ecosystem services. The nation's state park systems are public lands and waters established for their environmental and social value (Caneday et al., 2009). Although the resources, administration type, system size and visitation levels differ among states, services provided by state park systems include both the protection of high quality or unique natural and cultural resources as well as the facilitation of outdoor recreational opportunities.

The economic and social benefits provided by the states' park systems are substantial. In 2013, over 720 million visits were recorded across the 8000 operating units in the US (Leung et al., 2014). Visitors to state parks generate an estimated economic impact of over $20 billion USD (National Association of State Park Directors, 2013). In addition to the sizable financial contribution, state park systems also provide physical and mental health benefits. A large volume of research has documented the psychological, social and physiological health benefits of outdoor recreation (Gies, 2006). Maintaining the production of these benefits requires managers understand how to best allocate operating capital among competing uses such as labor and the maintenance of capital improvements. Analyzing the effectiveness with which park system mangers make these allocations can be completed through the concept and metric of technical efficiency.

### 2.2. Technical efficiency

Technical efficiency is a simple concept. Public resource managers are responsible for allocating available financial capital to provide desired goods and services to the public. The provision of those goods and services involves discretionary decisions about how public monies can best be apportioned to specific, controllable output factors of production such as labor and the maintenance of capital improvements. Efficiency is gauged by the ability to produce maximum quantities of the output factors of production at minimal costs. Managers and administrators pursue the least costly means of achieving given ends (Simon, 1976).

Maximizing technical efficiency is a relatively straightforward and logical process when the goals and objectives of a public agency or organization are clear and measurable. Such is the case for the states' park systems, where the primary objective of managers is to provide the public with high quality outdoor recreation opportunities (Siderelis et al., 2012). We assume the states' park system managers are attempting to maximize public enjoyment of the resources they manage while minimizing costs. This assumption forms the basis of our analysis of technical efficiency.

There are several common methods for empirically estimating technical efficiency; the most common being the construction of a linear equation where controllable input factors are regressed on the output factors of production (Greene, 2008); we adopt this method for our analyses. The model we construct using this method is described in Section 3.

### 2.3. Factors of production in the provision of outdoor recreation opportunities

We gauge managers' technical efficiency by their ability to minimize costs associated with managing their state's park system (input factors = operating expenditures) in an effort to obtain the factors of production involved in producing outdoor recreation opportunities (output factors). The output factors affecting the efficiency of an individual park system are: attendance, capital expenditures, revenue, labor and the total acreage within the system. Each of these output factors affect managers' decisions regarding the magnitude and allocation of operating expenditures:

- *Attendance* refers to the total count of day and overnight visitation to both fee and non-fee areas. Attendance is directly tied to operating expenditures under the logical assumption that it costs more (less) to provide outdoor recreation opportunities to a greater (smaller) number of individuals;

- *Capital expenditures* are non-recurring expenditures used to improve the productive capacity of a state park system. Capital expenditures have a latent impact on operating expenditures as managers must pay for maintaining improvements funded as capital improvements such as upgrades to transportation infrastructure or trail system development;
- *Revenue* refers to monies generated from use fees and other associated charges. Revenues are directly tied to the operating expenditures required to maintain the states' park systems as a portion of the capital available to be spent on operating expenditures is generated through user fees and other charges;
- *Labor* refers to the total count of full-time, part-time and seasonal employees who maintain, operate and protect a state park system. Labor is directly tied to operating expenditures as more (fewer) employees will require a larger (smaller) pool of dedicated financial resources to maintain a state park system;
- Finally, *acreage* refers to the total size of a state park system. Acreage has direct impacts on operating expenditures as larger (smaller) areas are assumed to require more (less) dedicated financial resources to maintain.

The logical connections between operating expenditures and the output factors of production are important. If the financial capital committed to operating expenditures is impacted by exogenous factors, such as reductions in state appropriations due to the adoption of a new state or federal policy, the quality and composition of outdoor recreation opportunities provided by the states' park systems will be affected. If a domestic GHG reduction policy impacts the economic well-being of a state, legislative appropriations to manage that states' park system will subsequently be affected.

### 2.4. *Impacts of a climate change mitigation policy on the production of outdoor recreation*

Proactive policy-makers within the US have proposed a variety of national policies for reducing GHG emissions and curbing anthropogenic climatic change. A large majority of these policies establish a cap-and-trade system in which a regulatory agency establishes emission reduction targets and then distributes permits to states and industries that allow them to emit a certain level of $CO_2$e emissions; permits can be traded in an open marketplace between firms. The price of permits will gradually increase over time as the allowable $CO_2$e cap is reduced to target levels. Industries and organizations are believed to behave in a cost-minimizing fashion, continually evaluating the option of adopting cleaner technologies which allow them to meet their established quota, or purchasing permits via the marketplace allowing them to continue to emit GHGs beyond regulated levels.

Numerous macroeconomic studies demonstrate the adoption of a domestic cap-and-trade policy will impact the US economy. Most studies share two key findings: First, the negative economic impacts will be minimal. Decrements to GDP are generally on the order of one or two one-hundredths of a percent per year. Second, impacts on individual states' economies will vary depending upon those states' current carbon intensities and mix of emission sources. States with large proportions of their energy production portfolio devoted to emission-heavy technologies such as coal-fired power plants are likely to experience the largest regulatory burden (Backus et al., 2013). States' economies will be differentially impacted by the adoption of a national climate change mitigation policy.

Most formal analyses of the economic impacts of emission reduction strategies make direct connections to GSP, the market value of all officially recognized final goods and services produced within a state in a single year. Logically, it follows that public goods and services tied to the health of the states' economies will be indirectly affected by policy change. The provision of nearly all public goods and services is dependent, at least partially, on state legislative appropriations generated through property, income and sales tax. When a state's economy slows, state tax receipts are reduced and government officials are faced with the difficulty of providing public services with reduced resources. State park systems and the managers responsible for producing outdoor recreation opportunities are not exempt from this linkage. Landrum, in his historical review of US state park systems (2004), details the long-standing connection between states' economic activity and their ability to provide outdoor recreation at state parks. He describes how this connection extends back to the 1940s, when the post-WWII economic boom led to the rapid expansion of state highway systems, driving up demand for state parks as regional tourism destinations. Recent empirical work has illustrated the direct and significant connection between states' economies and the production of outdoor recreation opportunities at state park systems. Siderelis and Smith (2013) demonstrated a significant and positive relationship between a state's economic health and operating expenditures used to maintain the states' park systems.

## 3. Method

To analyze the potential impact of a GHG reduction policy on the provision of outdoor recreation through the states' park systems we utilize a longitudinal panel dataset extending from the years 1984–2013 that details the 50 states' park systems. We join these data with simulation results projecting changes to the states' economies from 2014 to 2020 as a result of the adoption of a domestic cap-and-trade policy. We then dynamically forecast changes to operating expenditures under the hypothetical adoption of the policy. Joining empirical data and simulation-based estimates allow us to better understand how the adoption of a domestic climate change mitigation policy would affect the provision of public goods and services in the future.

### 3.1. *Data*

#### 3.1.1. *The AIX archive*

We utilize data collected from the Annual Information Exchange (AIX), a data collection and reporting system in which individual state park system managers annually report on their system's assets, usage and finances. We generated a longitudinal panel data set of key data collected through the AIX. Each of these variables is reported annually for the 50 state park systems between the years 1984 and 2013. All variables used in our analysis are expressed relative to the total acreage within their respective state park system; summary statistics for all variables are provided in Table 1.

#### 3.1.2. *Adjustments for missing data and inflation*

Due to poor data collection standards or limited resources available to those responsible for the AIX archive in the past, not all state park systems reported data for each year. Consequently, the longitudinal panel data set has several missing data points. Given only a small proportion of the data were missing (≤3.5% for any one variable used in our analysis), we used linear interpolation to fill missing values. For each panel (state), we interpolated missing values as a function of time (year). We also adjusted all monetary variables (operating expenditures, capital expenditures and revenue) to a 2013 base rate to compensate for inflation. The adjustments were made using the Consumer Price Index for all Urban Households (www.bls.gov).

### 3.2. *Analysis*

#### 3.2.1. *Technical efficiency model development*

We assume the states' park system managers are attempting to maximize public enjoyment of the resources they manage while minimizing costs associated with providing and managing those opportunities (i.e., minimizing operating expenditures). This allows us to fit a technical efficiency model by regressing annual operating expenditures on the output factors affecting the production (Aigner et al., 1977). The estimation process is grounded in the premise that a frontier production function exists which represents the maximum outputs that can be obtained given a controllable set of inputs (Greene, 2008). This theoretical maximum, the frontier, calculated by summing the estimated coefficients across the output factors of production after estimation, represents a theoretical measure of optimal efficiency. When observational units can be organized into a discrete classification scheme, such as states, comparisons regarding efficiency can be made across those classifications.

**Table 1 – Summary statistics for data in the longitudinal panel data set (1984–2013) for all 50 state park systems.**

| Variable | Mean | SD | Skewness |
|---|---|---|---|
| Attendance/acre[a] | 119.31 | 136.59 | 2.64 |
| Attendance (visitor-hours)/acre[a] | 359.01 | 410.87 | 2.65 |
| Operating expenditures/acre[b] | 379.96 | 410.69 | 2.79 |
| Capital expenditures/acre[b] | 159.90 | 328.03 | 7.81 |
| Revenue/acre[b] | 184.14 | 252.27 | 3.58 |
| Labor (personnel)/acre | 0.0093 | 0.0113 | 2.91 |
| Labor (person-hours)/acre[c] | 19.32 | 23.51 | 2.91 |

[a] Using the assumption each visit is 3.010 h long; this value was derived by taking the estimated 2.2 billion hours of outdoor recreation provided by the states' park systems (Siikamäki, 2011) and dividing it by the average annual attendance rates for all the states' park systems over the past 30 years (731,000,000).
[b] Operating expenditures, capital expenditures and revenue are adjusted to a 2013 base rate.
[c] Using the assumption each employee works 2080 h per year.

#### 3.2.2. *Technical efficiency model specification*

Our technical efficiency model is expressed as:

$$y_{jt} = \beta_1 a_{jt} + \beta_2 cx_{jt} + \beta_3 r_{jt} + \beta_4 l_{jt} + u_j + \epsilon_{jt} \quad (1)$$

The dependent variable y refers to the operating expenditures per acre for the $j$th = 1,. . .,50 park system in year $t$ = 1,. . .,30. The independent variables are $a$ (visitor-hours per acre), $cx$ (capital expenditures per acre), $r$ (revenue per acre) and $l$ (person-hours per acre); these are also indexed to each park system and each year. The individual regression coefficients are expressed as $\beta$s. Within-panel (state) correlation is handled through the inclusion of the fixed effect $u$; this coefficient is time-invariant. Finally, $\varepsilon$ refers to random error. All variables are transformed to their natural log (*ln*) before estimation. We fit the model using the *xtreg* command in the Stata statistical software package.

#### 3.2.3. *Modified technical efficiency model specification*

In previous analyses of data within the AIX archive, we found the health of the states' economies was significantly related to the production (operating expenditures) of outdoor recreation opportunities provided through the nation's state park systems (Siderelis and Smith, 2013). In our previous work, states' economic health was measured by taking an average of the monthly state coincident index, a composite measure published by the Philadelphia Federal Reserve Bank (Crone and Clayton-Matthews, 2005). While the coincident index is a good measure of the states' economic health, its composite nature limits its ability to be linked to more commonly used metrics used to evaluate impacts of hypothetical policy implementation. Consequently, here we use GSP as a measure of the states' economic health. GSP is a widely used metric used to forecast and simulate the consequences of both federal and regional climate change mitigation policies (Ruth et al., 2007). We obtained GSP data for the years 1983–2012 from the US Bureau of Economic Analysis (www.bea.gov).

The modified technical efficiency model, with the inclusion of GSP measures, is expressed as:

$$y_{jt} = \beta_1 a_{jt} + \beta_2 cx_{jt} + \beta_3 r_{jt} + \beta_4 l_{jt} + \beta_5 gsp_{jt} + u_j + \epsilon_{jt} \quad (2)$$

With the exception of *gsp* (GSP per acre), all notations remain the same. All of the independent variables are indexed to individual park systems and years. However, given states' legislative appropriations are to a large extent based on tax revenues from the previous year, we lag the GSP data one year in our analysis (e.g., the GSP for 2003 are used to predict the 2004 operating expenditures). All variables were transformed to their natural log (*ln*) before estimation.

#### 3.2.4. *The applied dynamic analysis of the global economy (ADAGE) model*

The latter half of our analyses utilizes simulation results generated from a GHG reduction policy simulated with a CGE model of the US economy (Ross et al., 2008). CGE models combine economic theory with empirical data to estimate how the effects of policies with no historical precedent will affect all interactions among businesses and consumers within an economy. CGE models are common in the analysis of climate change mitigation policy, having been used to examine impacts associated with The Kyoto Protocol (Böhringer, 2000; Weyant et al., 1996), other international carbon abatement policies (Ross et al., 2009) and failed domestic policies such as the *American Power Act*, the *American Clean Energy and Security Act* and the *Climate Stewardship and Innovation Act* (US Environmental Protection Agency, 2007, 2010a, 2010b).

The specific CGE model used here is ADAGE (Ross, 2009), a dynamic intertemporally optimizing model designed specifically to estimate macroeconomic effects of climate change mitigation policies. The ADAGE model combines a classical general equilibrium framework to describe economic interactions with historical economic data (see Ross (2009) for detailed model documentation). ADAGE is one of two CGE models used by the Environmental Protection Agency to analyze the economic impacts of GHG reduction bills and has been extensively vetted via peer-review (Kolstad et al., 2010). The ADAGE simulations used in our analysis are fully described by Ross and his colleagues (2008). The simulations are not specific to a real national mitigation policy, rather they were specified using commonly proposed policy provisions, these were:

- A US GHG emissions target established at year 2000 emissions levels, beginning in 2010;
- Emission regulation on $CO_2$ and the five most important types of non-$CO_2$ GHGs;
- A nationwide cap-and-trade system (with some exemptions for households, agriculture and small businesses). The system gives affected organizations/firms the option to reduce their emissions, purchase allowances (i.e., credits) giving them the right to emit GHGs or sell allowances if they have low-cost opportunities to reduce emissions below the number of allowances they receive under the policy scenario; and
- Several 'flexibility mechanisms' such as the flexibility to over-comply and save allowances for use in the future and the ability to acquire allowance 'offsets' equivalent to 15% of the target through emissions reductions made by sources outside the trading system.

The economic impacts incurred to individual organizations, firms and households are determined by the availability and costs of allowance offsets generated by emission reductions options available outside the cap-and-trade system. For example, private firms can purchase and/or trade allowances on international GHG markets or fund carbon sequestration projects. Consequently, financial costs have a theoretical lower bound of $0 if an organization/firm engages in options outside the domestic regulatory system.

Ross and his colleagues (2008) used the ADAGE model to explore the impact of two hypothetical policy scenarios on state economies. The first scenario (free offsets) assumes the full 15% of the offsets allowed under the hypothetical policy are available at no cost. This lower-bound approximation represents what would occur if allowances could be made from international GHG markets at a marginal costs or large quantities of inexpensive carbon sequestrations options were available. The second scenario (market offsets) is a more restrictive case where offsets are assumed to be available from emissions reductions made by non-covered domestic entities at market costs estimated within the model (i.e., it assumes international markets do not exist and no allowance offsets can be generated through carbon sequestration activities). Together, the free and market offsets scenarios provide a lower and upper bounds to impacts on state economies under a GHG reduction policy.

The two scenarios used by Ross and his colleagues (2008) hold all other model parameters constant, which allows for an unambiguous connection between the offset costs and state-level economic impacts. While beyond the scope of this paper, future research could examine shifts in state-level economic impacts, and subsequently the provision of quasi-public goods and services such as outdoor recreation opportunities at state parks, relative to controlled manipulation of other ADAGE model parameters. Parameters such as state-specific energy production and consumption levels, state-specific improvements to energy efficiency and the adoption of multi-state emission reduction policies may influence shifts in GSP (Ross et al., 2009).

## 4. Results

### 4.1. *Technical efficiency for all the states' park systems*

Results of applying the technical efficiency model described in Eq. (1) to the longitudinal panel data are shown in Table 2. The model fit the data exceptionally well; the $R^2$ was 0.90 suggesting the output factors associated with producing outdoor recreation opportunities explain 90% of the variance in reported operating expenditures.[1] A large proportion of the model's explanatory power comes from explicitly modeling the correlation within states (panels) through the $u_j$ term. This is evident through the high $\rho$ coefficient. Our model yielded a $\rho$ value of 0.592, suggesting nearly 60% of the variance in reported operating expenditures over the past 30 years can be explained by observed correlation within states.

All of the output factors were highly significant ($p \leq 0.001$). The $\beta$ coefficients can be interpreted as point elasticities, meaning they indicate the percentage change in operating expenditures given a 1% increase (decrease) in the independent variable. The $\beta$ coefficients are also used to calculate the average marginal effect, the monetary change in operating expenditures corresponding to a 1% increase in a $\beta$ coefficient's respective variable.

[1] The model also performed well when applied to each state individually. Table S1 reports $R^2$ values from 50 independently run models.

**Table 2 – Results of the technical efficiency model fit to the longitudinal panel data set (1984–2013).**

| Independent variable | $\beta$[a] | Std. error | $t$ | $p$ | 95% C.I. | | Average marginal effect ($)[b] |
|---|---|---|---|---|---|---|---|
| | | | | | U.B. | L.B. | |
| *ln* Attendance (visitor-hours)/acre | 0.245 | 0.017 | 14.30 | ≤0.001 | 0.211 | 0.279 | 24.87 |
| *ln* Capital expenditures/acre | 0.053 | 0.006 | 8.49 | ≤0.001 | 0.041 | 0.066 | 6.64 |
| *ln* Revenue/acre | 0.259 | 0.016 | 16.72 | ≤0.001 | 0.229 | 0.290 | 20.14 |
| *ln* Labor (person-hours)/acre[c] | 0.292 | 0.019 | 15.63 | ≤0.001 | 0.255 | 0.329 | 7.03 |
| Constant | 2.056 | 0.080 | 25.61 | ≤0.001 | | | |
| $\rho$[c] | 0.592 | | | | | | |
| $R^2$ | 0.900 | | | | | | |

*Notes.* N = 1500 (50 states × 30 years).

[a] The $\beta$ coefficients can be interpreted as point elasticities, meaning they indicate the percentage change in operating expenditures given a 1% increase (decrease) in the independent variable.

[b] Average marginal effects are the monetary change in operating expenditures corresponding to a 1% increase in a $\beta$ coefficient's respective variable; they are calculated as $\bar{x}^{\beta} \times \ln(\bar{x})$ where $\bar{x}$ is the variable mean.

[c] The proportion of the variance in the dependent measure explained solely by within-panel (within-state) effects.

On average, a 1% increase in attendance (visitor-hours) is associated with a 0.245% or $24.87 increase in operating expenditures. More intuitively, we can say that it costs nearly $25 for a state park system manager to produce an additional 3.59 h of outdoor recreation within their state's park system. Similarly, the model revealed that a 1% increase in capital expenditures is associated with a 0.053% increase in operating expenditures. Every $1.60 spent on capital improvements is associated with a concomitant $6.64 increase in costs associated with maintaining existing opportunities for outdoor recreation. Our analysis also suggests a 1% increase in revenue corresponds to a 0.259% increase in capital expenditures. Every $1.84 generated by the states' park systems corresponds to $20.14 in operating expenditures; this is logical given the states' park systems are quasi-public goods whose operating expenditures are only partially funded by generated revenues (state appropriations, dedicated funds and federal funds are also used to pay for operating expenditures). Finally, our model revealed a 1% increase in labor (person-hours) is associated with a 0.292% increase in operating expenditures. Every 11.59 min ($M_{\text{Labor (person-hours)/acre}}$ = 19.32 × 1% × 60 min/h) worked by employees of the states' park systems corresponded to $7.03 in operating expenditures. This finding is intuitive, state park systems with larger labor pools also have larger costs associated with maintaining opportunities within their system.

### 4.2. *How technically efficient is each state park system?*

Analyses of technical efficiency are designed to produce a single ratio between input and output factors (Chambers, 1988). The input factor provides the reference for the technical efficiency ratio given it is both singular and the dependent variable in the analysis. The output factor measure, also referred to as the production frontier (Greene, 2008), is generated by summing the $\beta$ coefficients for all of the individual output factors. Values of 1.0 indicate optimal technical efficiency; each additional input factor yields a 100% return across the output factors. Summing the $\beta$ coefficients generated by our model (Table 2) yields an output factor measure of 0.849, which suggests the states' park operators are highly efficient at developing and maintaining outdoor recreation opportunities within their systems.

Individual technical efficiency scores are computed through the following equation:

$$\text{Technical efficiency}_j = \frac{1}{\exp(u_j)} \tag{3}$$

Here, $u_j$ is simply the estimated fixed effect from Eq. (1); it is unique for each of the $j$ = 1,...,50 park systems. Because $u_j$ estimates are derived through the technical efficiency model for all 50 park systems, they are expressed relative to a theoretical maximum ratio of 1.0 between input and output factors. States whose park systems yield technical efficiency scores greater than 1.0 are operating above the theoretical maximum. States with technical efficiency scores less than 1.0 are operating below the theoretical maximum. We calculated the state-level technical efficiency scores using Eq. (3) and report the results in Table 3. To ease interpretation, we also rank individual states' park systems by their scores. The Alaska State Park System is the most efficient at jointly producing the output factors of visitation, capital expenditures, revenue and labor with minimal operating costs. The South Dakota, Nebraska, New Hampshire and Colorado state park systems round out the top five systems that have most efficiently produced outdoor recreation opportunities over the past 30 years.

### 4.3. *Linking empirical data to simulation estimates*

If an analyst is able to demonstrate an empirical, long-term and significant linkage between the health of a state's economy and any singular public good, they can forecast variable changes to the production of that public good into the future under variable rates of economic growth. This is precisely what we accomplish here through the following 4-step process:

1. We re-estimate our technical efficiency model using the longitudinal panel data for the past 30 years, only this time we include measures of the states' overall economic well-being, GSP.

**Table 3 – Individual state park systems' technical efficiency scores and rankings.**

| State | Technical efficiency score[a] | 2014 Rank | State | Technical efficiency score[a] | 2014 Rank |
|---|---|---|---|---|---|
| Alabama | 0.707 | 44 | Montana | 1.070 | 16 |
| Alaska | 1.766 | 1 | Nebraska | 1.642 | 3 |
| Arizona | 0.661 | 48 | Nevada | 1.040 | 17 |
| Arkansas | 0.767 | 41 | New Hampshire | 1.563 | 4 |
| California | 0.669 | 47 | New Jersey | 1.016 | 20 |
| Colorado | 1.507 | 5 | New Mexico | 0.763 | 42 |
| Connecticut | 1.458 | 7 | New York | 0.944 | 32 |
| Delaware | 0.865 | 37 | North Carolina | 0.949 | 30 |
| Florida | 0.987 | 25 | North Dakota | 1.266 | 10 |
| Georgia | 0.716 | 43 | Ohio | 0.995 | 24 |
| Hawaii | 0.944 | 31 | Oklahoma | 0.844 | 38 |
| Idaho | 0.930 | 34 | Oregon | 0.928 | 35 |
| Illinois | 0.843 | 39 | Pennsylvania | 0.796 | 40 |
| Indiana | 1.372 | 9 | Rhode Island | 1.165 | 15 |
| Iowa | 1.231 | 12 | South Carolina | 1.034 | 18 |
| Kansas | 1.237 | 11 | South Dakota | 1.669 | 2 |
| Kentucky | 0.604 | 49 | Tennessee | 0.956 | 29 |
| Louisiana | 0.557 | 50 | Texas | 1.015 | 21 |
| Maine | 1.172 | 14 | Utah | 0.682 | 46 |
| Maryland | 1.016 | 19 | Vermont | 1.182 | 13 |
| Massachusetts | 0.971 | 27 | Virginia | 0.975 | 26 |
| Michigan | 1.394 | 8 | Washington | 1.013 | 22 |
| Minnesota | 0.930 | 33 | West Virginia | 1.011 | 23 |
| Mississippi | 0.707 | 45 | Wisconsin | 1.506 | 6 |
| Missouri | 0.962 | 28 | Wyoming | 0.901 | 36 |

[a] A score of 1.0 is the theoretical maximum.

2. We utilize forecasted changes to states' GSP under a national emission reduction strategy generated by the ADAGE CGE model (Jorgenson et al., 2008; Ross et al., 2008).
3. We perform three dynamic forecasts with our technical efficiency model fitted to an extended longitudinal panel data set that includes the variable changes to GSP derived from the CGE model; all other covariates are held constant at 2013 levels.[2] The dynamic forecasting data extend to the year 2020.
4. Finally, we calculate point estimates generated from each of the dynamic forecasting models at their final time-step, 2020. These point estimates are compared against each other to determine if, and to what extent, the adoption of a GHG reduction policy impacts the ability of the states' park managers to produce outdoor recreation opportunities. *Simply put, we are determining whether changes to GSP over the next six years attributable solely to a climate change mitigation policy affect forecasted operating expenditures over the same time period.*

### 4.4. *Re-estimation of technical efficiency model*

Re-estimation of the technical efficiency model including the annual GSP covariate revealed very similar results to the initial model. The independent variables (output factors of production and GSP) explained a substantial proportion of observed variance in state park systems' operating expenditures ($R^2 = 0.89$). The vast majority of explained variance is attributable to within-panel (state) effects ($\rho = 0.69$).

Results, shown in Table 4, reveal all of the output factors of production retained relative effect size measures and were highly significant. The model also suggests states' GSP has a significant effect on state park systems' annual operating expenditures. States with larger GSP, on average, have larger annual operating expenditures; this finding is consistent with previous analysis utilizing the alternative coincidence index to gauge state-level economic well-being (Siderelis and Leung, 2013; Siderelis and Smith, 2013).

## 5. Dynamic forecasting

Given substantial heterogeneity in GSP measures, we generated state-specific forecasts for the years 2014–2020. Forecasted GSP measures were created through state-specific time-trend regression models fit to all 30 years of the data.[3] Given these data represent GSP forecasts using only observed measures, we use them to define our 'business as usual scenario'.

Changes to GSP under the 'free offsets scenario' and the 'market offsets scenario' for the years 2014–2020 were derived by using annual estimates generated by the ADAGE CGE model

[2] This assumes visitation, capital expenditures, revenue and labor do not change in response to new equilibrium of the economy. Given the high level of within-state correlation across these measures, this assumption is not tenuous. However, slight shifts would likely be expected as state park management systems adapt to reduced GSP levels.

[3] The regression of each states' lagged GSP on year is specified as: $gsp_{t-1} = t + \varepsilon_t$.

**Table 4 – Results of the technical efficiency model including the annual state GDP data.**

| Independent variable | $\beta$ | Std. error | $t$ | $p$ | 95% C.I. | |
|---|---|---|---|---|---|---|
| | | | | | U.B. | L.B. |
| *ln* Attendance (visitor-hours)/acre | 0.156 | 0.016 | 9.63 | $\leq$0.001 | 0.124 | 0.187 |
| *ln* Capital expenditures/acre | 0.032 | 0.006 | 5.58 | $\leq$0.001 | 0.021 | 0.043 |
| *ln* Revenue/acre | 0.123 | 0.016 | 7.83 | $\leq$0.001 | 0.093 | 0.154 |
| *ln* Labor (person-hours)/acre | 0.200 | 0.018 | 11.43 | $\leq$0.001 | 0.166 | 0.235 |
| *ln* Gross state product$_{t-1}$/acre | 0.476 | 0.018 | 18.48 | $\leq$0.001 | 0.425 | 0.527 |
| Constant | 3.287 | 0.026 | 33.45 | $\leq$0.001 | 3.094 | 3.479 |
| $\rho$[a] | 0.690 | | | | | |
| $R^2$ | 0.890 | | | | | |

$N$ = 1500 (50 states × 30 years).
[a] The proportion of the variance in the dependent measure explained solely by within-panel (within-state) effects.

(Ross et al., 2008). We multiplied these annual change estimates (reported in Table S2) by forecasted GSP values for their corresponding year. The resulting raw GSP forecasts under both scenarios were lagged, converted to their per acre unit of measurement[4] and transformed to their natural logarithms. This transformation enables us to proceed with the formal dynamic forecasting process.

Dynamic forecasting involves generating out-of-sample estimates for a regression equation where all but one 'dynamic' variable is allowed to change, all other covariates are held constant. This process allows the analyst to explicitly gauge how change in the dynamic independent variable influences projected estimates of the dependent variable. In our case, we are able to see how CGE-derived changes in GSP affect each of the state park systems' operating expenditures over the next six years.

We ran three dynamic forecasting models with our longitudinal panel data set that, with the inclusion of the estimated changes to GSP, now spans the years 1984–2020. The first model includes GSP projections derived from the state-specific time-trend regression; model specification is identical to Eq. (2). The second model includes historical GSP rates for years 1984 to 2013 and projected GSP rates under the free offsets scenario for the years 2014–2020. The third and final model substitutes in projected GSP rates under the market offsets scenario for the years 2014–2020. After estimation of each model, point estimates of each state park system's operating expenditures for the year's 2014–2020 were generated from the linear predictions; estimates were transformed into 2013 dollars through exponentiation. Table 5 reports the last year, 2013, of observed operating expenditures per acre along with transformed estimates generated by each of the forecasting models.

## 5.1. *Comparison of operating expenditures point estimates*

The business as usual scenario (Column 4 of Table 5) illustrates the vast majority of states will experience increases in operating expenditures if their economies continue on the trajectories defined by the previous 30 years. On average, the states' park systems will see an increase in annual operating expenditures per acre of $67. Rhode Island's state park system is likely to experience the largest increase in operating expenditures per acre (+$460). Oklahoma (+$305), Georgia (+$284) and Mississippi (+$254) are also likely to experience substantial increases in operating costs per acre over the coming years. Some states however, will experience declines in operating expenditures. Minnesota's state park system's operating expenditures will decline by $87 dollars per acre by the end of the decade. Similarly, Indiana's state park system is projected to see a drop in operating expenditures by $40 per acre over the same time period.

Results from the free offsets scenario forecast reveal similar trends when looking at expected changes by 2020 (Column 6 of Table 5). On average, the states' park systems will see an increase in annual operating expenditures per acre of $49 under a domestic GHG reduction strategy. This result reveals the real costs of a domestic climate change policy on the operations of the states' park systems. Relative to the business as usual scenario, the free offsets scenario will, on average, result in an $18 per acre reduction in operating expenditures for the states' park systems. The free offsets scenario's marginal negative impacts on GSP are likely to 'trickle down' and be felt by the states' park systems. State park managers, on average, will be faced with the burden of maintaining current outdoor recreation opportunities with smaller pools of money to allocate to operating costs.

Results from the market offsets scenario are similar. On average, the state park systems' operating expenditures per acre are projected to increase $40 by 2020 (Column 9 of Table 5). Relative to the business as usual scenario, operating expenditures per acre are expected to be $27 per acre less by the end of the decade (Column 10 of Table 5). Again, these findings reveal the real, indirect effects on the decisions of state park operators as a result of domestic GHG reduction efforts. It is important to note however, that projected changes in operating expenditures are far from homogeneous; states like Kentucky (−$98 $\Delta_{\text{BAU-FOS}}$, −$128 $\Delta_{\text{BAU-MOS}}$), Rhode Island (−$71 $\Delta_{\text{BAU-FOS}}$, −$92 $\Delta_{\text{BAU-MOS}}$) and Delaware (−$56 $\Delta_{\text{BAU-FOS}}$, −$74 $\Delta_{\text{BAU-MOS}}$) are expected to see the most significant changes to their operating costs. States like Alaska (−$0.14 $\Delta_{\text{BAU-FOS}}$, −$0.19 $\Delta_{\text{BAU-MOS}}$), Colorado (−$2 $\Delta_{\text{BAU-FOS}}$, −$2 $\Delta_{\text{BAU-MOS}}$) and New Hampshire (−$3 $\Delta_{\text{BAU-FOS}}$, −$4 $\Delta_{\text{BAU-MOS}}$) however, are expected to see very little change. This variation

[4] This assumes the states' park systems will remain at their 2013 acreage until the end of our forecasting period, 2020.

**Table 5 – Forecasted changes to the states' park systems operating expenditures per acre under climate change mitigation policies.**

| State | Business as usual (BAU) scenario | | | Free offsets scenario | | | Market offsets scenario | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2020 | Δ | 2020 | $\Delta_{2013\text{–}2020}$ | $\Delta_{BAU}$ | 2020 | $\Delta_{2013\text{–}2020}$ | $\Delta_{BAU}$ |
| Alabama | 902.33 | 1027.97 | 125.64 | 976.66 | 74.33 | −51.32 | 960.99 | 58.66 | −66.98 |
| Alaska | 4.04 | 2.90 | −1.13 | 2.76 | −1.28 | −0.14 | 2.71 | −1.32 | −0.19 |
| Arizona | 278.28 | 375.76 | 97.47 | 357.00 | 78.72 | −18.76 | 351.27 | 72.99 | −24.48 |
| Arkansas | 1017.14 | 1040.20 | 23.06 | 988.27 | −28.87 | −51.93 | 972.42 | −44.72 | −67.78 |
| California | 240.88 | 276.18 | 35.30 | 262.40 | 21.52 | −13.79 | 258.19 | 17.31 | −18.00 |
| Colorado | 41.70 | 34.74 | −6.96 | 33.01 | −8.69 | −1.73 | 32.48 | −9.22 | −2.26 |
| Connecticut | 81.54 | 86.06 | 4.53 | 81.77 | 0.23 | −4.30 | 80.46 | −1.08 | −5.61 |
| Delaware | 896.01 | 1127.32 | 231.31 | 1071.04 | 175.04 | −56.27 | 1053.86 | 157.85 | −73.46 |
| Florida | 97.80 | 145.92 | 48.11 | 138.63 | 40.83 | −7.28 | 136.41 | 38.61 | −9.51 |
| Georgia | 483.34 | 766.92 | 283.57 | 728.63 | 245.29 | −38.28 | 716.94 | 233.60 | −49.97 |
| Hawaii | 250.38 | 320.47 | 70.08 | 304.47 | 54.08 | −16.00 | 299.58 | 49.20 | −20.88 |
| Idaho | 275.15 | 327.10 | 51.95 | 310.78 | 35.63 | −16.33 | 305.79 | 30.64 | −21.31 |
| Illinois | 147.98 | 148.52 | 0.54 | 141.10 | −6.88 | −7.41 | 138.84 | −9.14 | −9.68 |
| Indiana | 334.89 | 294.72 | −40.17 | 280.01 | −54.88 | −14.71 | 275.52 | −59.37 | −19.20 |
| Iowa | 215.26 | 256.26 | 40.99 | 243.47 | 28.20 | −12.79 | 239.56 | 24.29 | −16.70 |
| Kansas | 71.61 | 85.06 | 13.45 | 80.81 | 9.20 | −4.25 | 79.52 | 7.91 | −5.54 |
| Kentucky | 1803.20 | 1966.83 | 163.63 | 1868.65 | 65.45 | −98.18 | 1838.67 | 35.47 | −128.16 |
| Louisiana | 657.54 | 629.38 | −28.16 | 597.97 | −59.58 | −31.42 | 588.37 | −69.17 | −41.01 |
| Maine | 76.13 | 107.75 | 31.62 | 102.37 | 26.24 | −5.38 | 100.73 | 24.60 | −7.02 |
| Maryland | 254.06 | 378.79 | 124.74 | 359.89 | 105.83 | −18.91 | 354.11 | 100.06 | −24.68 |
| Massachusetts | 180.75 | 200.56 | 19.81 | 190.55 | 9.80 | −10.01 | 187.49 | 6.74 | −13.07 |
| Michigan | 197.90 | 220.96 | 23.06 | 209.93 | 12.03 | −11.03 | 206.57 | 8.66 | −14.40 |
| Minnesota | 268.89 | 182.10 | −86.79 | 173.01 | −95.88 | −9.09 | 170.24 | −98.65 | −11.87 |
| Mississippi | 520.53 | 774.45 | 253.92 | 735.79 | 215.26 | −38.66 | 723.99 | 203.46 | −50.46 |
| Missouri | 225.33 | 201.13 | −24.20 | 191.09 | −34.24 | −10.04 | 188.02 | −37.30 | −13.11 |
| Montana | 174.96 | 194.46 | 19.50 | 184.75 | 9.79 | −9.71 | 181.79 | 6.83 | −12.67 |
| Nebraska | 175.08 | 198.83 | 23.76 | 188.91 | 13.83 | −9.93 | 185.88 | 10.80 | −12.96 |
| Nevada | 72.34 | 102.89 | 30.55 | 97.75 | 25.41 | −5.14 | 96.18 | 23.85 | −6.70 |
| New Hampshire | 85.85 | 67.51 | −18.34 | 64.14 | −21.71 | −3.37 | 63.11 | −22.74 | −4.40 |
| New Jersey | 77.47 | 120.45 | 42.98 | 114.43 | 36.96 | −6.01 | 112.60 | 35.13 | −7.85 |
| New Mexico | 87.10 | 117.86 | 30.76 | 111.98 | 24.88 | −5.88 | 110.18 | 23.08 | −7.68 |
| New York | 165.86 | 193.99 | 28.13 | 184.31 | 18.45 | −9.68 | 181.35 | 15.49 | −12.64 |
| North Carolina | 166.96 | 201.61 | 34.65 | 191.55 | 24.58 | −10.06 | 188.47 | 21.51 | −13.14 |
| North Dakota | 154.44 | 136.51 | −17.92 | 129.70 | −24.74 | −6.81 | 127.62 | −26.82 | −8.90 |
| Ohio | 354.66 | 518.89 | 164.22 | 492.98 | 138.32 | −25.90 | 485.07 | 130.41 | −33.81 |
| Oklahoma | 413.70 | 718.80 | 305.10 | 682.92 | 269.21 | −35.88 | 671.96 | 258.26 | −46.84 |
| Oregon | 511.03 | 645.82 | 134.79 | 613.59 | 102.55 | −32.24 | 603.74 | 92.71 | −42.08 |
| Pennsylvania | 279.17 | 359.08 | 79.91 | 341.15 | 61.98 | −17.93 | 335.68 | 56.51 | −23.40 |
| Rhode Island | 958.51 | 1418.39 | 459.87 | 1347.58 | 389.07 | −70.81 | 1325.96 | 367.45 | −92.42 |
| South Carolina | 289.31 | 360.30 | 70.99 | 342.31 | 53.00 | −17.99 | 336.82 | 47.51 | −23.48 |
| South Dakota | 170.86 | 201.16 | 30.30 | 191.12 | 20.26 | −10.04 | 188.05 | 17.20 | −13.11 |
| Tennessee | 411.49 | 515.54 | 104.04 | 489.80 | 78.31 | −25.74 | 481.94 | 70.45 | −33.59 |
| Texas | 118.66 | 133.33 | 14.67 | 126.68 | 8.01 | −6.66 | 124.65 | 5.98 | −8.69 |
| Utah | 103.63 | 252.88 | 149.25 | 240.26 | 136.63 | −12.62 | 236.40 | 132.77 | −16.48 |
| Vermont | 121.46 | 153.27 | 31.81 | 145.62 | 24.16 | −7.65 | 143.28 | 21.83 | −9.99 |
| Virginia | 488.91 | 515.83 | 26.92 | 490.08 | 1.17 | −25.75 | 482.22 | −6.69 | −33.61 |
| Washington | 516.91 | 570.00 | 53.09 | 541.55 | 24.64 | −28.45 | 532.86 | 15.95 | −37.14 |
| West Virginia | 235.45 | 262.07 | 26.63 | 248.99 | 13.55 | −13.08 | 245.00 | 9.55 | −17.08 |
| Wisconsin | 150.82 | 179.45 | 28.63 | 150.82 | 0.00 | −28.63 | 70.05 | −80.77 | −109.40 |
| Wyoming | 70.05 | 92.40 | 22.35 | 170.49 | 100.44 | 78.09 | 87.79 | 17.74 | −4.62 |
| Average | 317.55 | 384.19 | 66.64 | 366.27 | 48.72 | −17.92 | 357.23 | 39.68 | −26.96 |

*Note.* All values are 2013 US dollars.

is wholly driven by different GSP growth trajectories and historical trends in operating expenditures per acre. States with technically efficient state park systems like those in Alaska and Colorado, and states with strong GSP growth, like New Hampshire, are less likely to experience substantial reductions in operating costs.

### 5.2. *Exploration of possible solutions*

Our forecasting revealed the adoption of a domestic cap-and-trade policy would reduce the operating budgets of the states' park systems by an average of $18 (free offsets scenario) to $27 (market offsets scenario) per acre by the year 2020. This effect may seem marginal when viewed in the aggregate, however there is considerable heterogeneity across the states (Table 5). States with rapidly growing economies (i.e., greater year over year increases in GSP) and high technical efficiency scores (Table 3) are expected to experience only minor declines if a GHG reduction policy were implemented. Colorado (−\$2 $\Delta_{BAU\text{-}FOS}$, −\$2 $\Delta_{BAU\text{-}MOS}$), Connecticut (−\$4 $\Delta_{BAU\text{-}FOS}$, −\$6 $\Delta_{BAU\text{-}MOS}$) and New Hampshire's (−\$3 $\Delta_{BAU\text{-}FOS}$, −\$4 $\Delta_{BAU\text{-}MOS}$) state park systems are exemplars of high technical efficiency and marginal impacts to operating expenditures under a national GHG reduction policy.

So what are the best strategies for states to cope with the probability of increasingly restricted operating budgets once a national GHG reduction strategy is implemented? Our analysis can point to two possible solutions: first, encourage rapid economic growth and increases in GSP. This strategy is logical. Increases in GSP will lead to increased appropriations in the states' operating budgets and subsequent increases in allocations to operating expenditure by managers. The data for some states suggests this may be a good strategy. For example, Nevada experienced the highest annual GSP growth rate from 1980 to 2012 (10.877%) and is estimated to only see marginal impacts to their state park system's operating costs over the next six years under either of the GHG reduction scenarios (−\$5 $\Delta_{BAU\text{-}FOS}$, −\$7 $\Delta_{BAU\text{-}MOS}$). The data from Florida reveals a similar trend; the state has experienced the fifth largest increase in annual GSP growth over the past thirty years and is expected to incur relatively minor impacts to their state park system's operating budget as a direct result of the adoption of a domestic GHG reduction policy (−\$7 $\Delta_{BAU\text{-}FOS}$, −\$10 $\Delta_{BAU\text{-}MOS}$).

An alternative solution is to increase technical efficiency—that is, become more efficient in the use of operating costs to produce and/or manage visitation, capital improvements, revenue and labor. Mathematically, more technically efficient state park systems will have more 'leeway' to become more inefficient relative to other states as they can produce and/or manage more visitation, capital improvements, revenue and labor with less operating costs. Again we see several states that highlight this logic. Alaska's state park system is the most technically efficient in the country and is expected to incur a very minor impact to operating expenditures under the adoption of a GHG reduction policy (−\$2 $\Delta_{BAU\text{-}FOS}$, −\$4 $\Delta_{BAU\text{-}MOS}$).

To explore possible policy recommendations for the states' park systems, we calculated simple rank-order correlations between the inflation adjusted annual growth rate between 1980 and 2012, our previously computed technical efficiency score (Table 3) and the decrement in operating expenditures under a national GHG reduction policy; Table S3 provides the full set of rank orders. Comparing historic GSP growth rates to projected shifts in operating expenditures under a climate mitigation policy allows us to explore whether the strength of a state's past economic performance is related to how well their state park systems' operating budget will fare under the hypothetical policy change.

The correlation analysis revealed only a negligible correlation between a state's annual historic GSP growth rate and the projected impact to that state's park system operating costs (free offsets scenario: $r = 0.013$; market offsets scenario: $r = 0.026$). However, the analysis revealed a substantial correlation between a state park system's technical efficiency and the projected impact to that state park system's operating costs (free offsets scenario: $r = 0.499$; market offsets scenario: $r = 0.478$). This exploratory analysis suggests even states with higher GSP growth rates may not be able to escape the indirect impacts of a domestic climate change mitigation policy. Rather, the data suggest a much more viable solution lies in improving the efficiency by which state park system managers produce or maintain visitation, capital improvements, revenue and labor with given operating outlays. In summation, our modeling reveal more technically efficient state park systems will be more resilient to exogenous economic changes, such as those brought about through the adoption of federal climate change mitigation policies.

## 6. Discussion

The results of our dynamic forecasting model applied to the longitudinal panel dataset reveal the real, indirect effects on the decisions of state park operators as a result of domestic GHG reduction efforts. As GSP levels are impacted by the transition to renewable energy sources and more sustainable land use practices, appropriations to the states' park systems will see reciprocal decreases. In turn, capital available to maintain high-quality outdoor recreation opportunities will be reduced. This finding, while logical and fairly intuitive given a fundamental understanding of how public services are supported in the US, highlights the need for state park operators to not only prepare for environmental impacts shaped by anthropogenic climate change, but to also prepare for potentially unforeseen economic impacts brought about by the adoption of domestic climate change mitigation policies. If a domestic GHG reduction policy is adopted in the US, public administrators are likely to face a double bind of needing to adapt to various climate-related impacts that will become increasingly severe over time while financial resources simultaneously dwindle. Proactive park operators should not only be thinking about how their park systems can adapt to increasingly variable environmental stressors, they should also be thinking about how their park systems can financially adapt to policy decisions at larger spatial scales. The philosophy of needing to do more with less will become even more of a reality for US state park system managers if a national GHG reduction policy is enacted.

Our analyses also revealed substantial variability across the states' park systems in forecasted changes to operating costs under the implementation of a hypothetical GHG reduction policy. Some states like Alaska, Colorado and New Hampshire are likely to experience only marginal changes to operating costs. However, other states like Kentucky, Rhode Island and Delaware will face more dramatic changes to their operating costs by the end of the decade. These variable changes are driven jointly by the states' past trends in operating costs and forecasted changes in GSP (all other covariates are held constant in our dynamic forecasting model). This finding highlights the very real likelihood that the indirect impacts of a domestic climate change mitigation policy vary substantially at the state level. Previous studies that have attempted to discern why climate change mitigation policy has repeatedly failed at the federal level point to an inability to equitably distribute costs and benefits across sub-national governance units such as regions and states (Backus et al., 2013). Our data illustrate that at least for the states' park systems there will be an inequitable burden to continue to supply public services at current levels of quality. If this inequity is consistent across other public services such as state-run hospitals and universities, then those individual states likely to experience disproportionately large costs relative to marginal gains will be strong advocates against a unified domestic GHG reduction policy. Elected officials and decision-makers developing potential climate change mitigation frameworks and policy solutions should earnestly consider mechanisms for equitably distributing costs and benefits. Otherwise, policies are likely to continue to fail due to political blockage from disproportionately affected states.

Finally, our concluding exploratory analysis suggests improving technical efficiency, rather than growing GSP, is the most viable solution to addressing the negative impacts on the states' park systems operating budgets brought about by the adoption of a domestic climate change mitigation policy. Further research that incorporates the diversity, quantity and quality of recreation opportunities is needed to better understand the public service impacts of reduced state appropriation and subsequent operating costs. The growing phenomenon of public–private partnerships for recreation service provision (e.g., Seekamp et al., 2013) will likely increase within the states' parks systems as the need for technical efficiency increases.

While the scope of this analysis focused on the U.S. state park systems, our methodology and results also have several international implications. First, other park systems can utilize similar technical efficiency analysis to identify areas where operational efficiencies can be enhanced. Second, for countries that are pursuing more progressive GHG reduction policies, the negative impacts on their national and provincial/state park budgets would likely be more severe. Similar analysis is encouraged to generate more country-specific estimates for policy makers, enabling them to identify potential solutions for anticipated shortfalls in funding. Third, this study offered two alternative solutions, encouraging more rapid economic growth or increasing technical efficiency. Some countries, however, may find themselves in a position with other viable solutions, such as charging use fees, privatization, attracting development aid and donations/sponsorships, that are more appropriate for their finance models, the nature of their recreation resource base and their unique visitor profiles (Emerton et al., 2005). Finally, this study demonstrates the utility of long-term park operation data sets like AIX in affording empirical evaluation of technical efficiencies in a complex nationwide park system while projecting impacts in the face of policy change.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2014.12.013.

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