

Reservation policies and equity in national park access

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 Check for updatesJonathan E. Hughes ^{1,2} 

National parks are experiencing unprecedented demand. High use strains infrastructure, damages ecosystems and reduces visitor enjoyment. To sustainably manage visitation, many parks now require reservations, raising concerns about equity. We quantify the effects of two reservation system features, advance purchase windows and competition for permits, on visitor income at seven national parks. Both effects disproportionately favor higher-income users. In the most competitive day-ahead and advance markets, reservation holders come from zip codes with 3–5% higher median household income. Extending the advance purchase window to six months shifts reservations toward users residing in zip codes with 5% higher income. Robustness checks imply individual effects of the same direction. This underscores a key challenge for park managers: designing reservation systems that protect resources while ensuring broad access. Without attention to distributional impacts, efforts to control crowding risk exacerbating income-based disparities in who can visit and enjoy the nation's public lands.

National parks play a crucial role in preserving biodiversity, natural landscapes, historical and cultural heritage. However, the sustainability of the parks themselves is under threat from overuse. In 2024, U.S. national parks saw record use, 331.9 million visits, including 38 parks that experienced levels above their 10-year averages¹. Many park campgrounds are routinely filled to capacity². Such high use is costly, taxing park resources³, negatively affecting plants and wildlife⁴, and causing congestion that diminishes visitors' experiences^{5,6}.

In response to these concerns, scholars, users and park managers have, for over 50 years, argued for rationing use to avoid a tragedy of the commons in parks and protected areas^{7,8}. Unlike market goods, price increases are seldom used to ration demand on public lands. This leaves non-market allocation methods such as reservation systems, lotteries, queues (first-come, first-served systems) and merit systems as potential rationing methods⁹. Of these alternatives, reservation systems are the most common, receiving support from users across a range of settings^{10–13}.

While reservations for campsites and river trips date back to at least the 1970s, several national parks have recently adopted policies to more broadly manage visitation. These systems, implemented nearly entirely online, include vehicle reservation systems (regulating

parking at popular destinations or travel on popular corridors), and timed-entry systems (permitting park entry during specific time windows). Initial evidence suggests these systems have helped improve sustainability and are generally supported by the public^{14,15}. However, many have expressed concern that these systems may unintentionally reduce access for lower-income users^{8,13,16}. These concerns echo evidence that lower income individuals have poorer access to urban green spaces¹⁷ and that terrestrial and marine protected areas are located closer to wealthier neighborhoods¹⁸. More recently, there is growing concern that technology limitations and congestion in online reservation systems such as Recreation.gov, may disadvantage lower income or less technologically-savvy users¹⁹. This highlights a tension in the dual mission of park managers, to protect natural resources, historical and recreational sites while, at the same time, promoting equitable access—two objectives that can be at odds with one another.

Unfortunately, empirical evidence on the equity effects of reservation systems for public lands is limited¹³. Miller et al.¹⁴ document a positive shift in the income distribution of timed-entry permit holders in Zion National Park but ultimately conclude reservations produce no exclusionary effects. Rice et al.²⁰ use mobile phone data to study demographics of national park campers who reserve in advance versus

¹Department of Economics, University of Colorado Boulder, Boulder, CO, USA. ²Renewable and Sustainable Energy Institute, University of Colorado Boulder, Boulder, CO, USA. ✉e-mail: jonathan.e.hughes@colorado.edu

those who camp in first-come, first-served sites. Advance reservations may favor users who can plan vacations weeks or months in advance and who may also have higher paying, and more flexible employment¹³. Rice et al. find those who reserve in advance do reside in higher income areas compared to those who camp first-come-first-served. However, they are not able to distinguish between the effects of reserving in advance and the effects of the online reservation system itself. Hughes²¹ studies the exclusionary effects of competition in congested online reservation systems by comparing river permits allocated by lottery with those obtained during online “buying frenzies.” Competition may be exclusionary if higher-income users are better able to navigate online congestion, for example, due to greater digital literacy, faster internet access, or more flexible work schedules that allow participation in weekday on-sale events²¹. He finds users who obtained their permit during a buying frenzy are from higher income zip codes than those selected at random. This suggests congestion in the online reservation system itself is an important factor in determining the types of users who receive a permit. However, since both lottery and frenzy reservations are made far in advance of the actual trips, we learn little about the effects of advance purchase.

In this paper, we examine how advance purchase periods and competition for reservations affect the income distribution of visitors, a measure of inequality, at seven national parks. We ask two questions. First, is greater competition for online reservations associated with higher income among users who successfully obtain a permit? Second,

is a longer (or shorter) advance reservation window associated with higher (or lower) income among reservation holders? Whereas prior work has studied demographic effects in a single park^{14,16}, we exploit variation in advance purchase periods and permit competition within and across parks to separately identify the effects of each factor on visitor income. Findings of substantial equity effects may motivate park managers to implement random lotteries to avoid competition effects or to implement additional phasing of on-sales to avoid advance-purchase effects. Therefore, understanding these relationships could improve equity in sustainable management of the national parks.

Results

The analysis focuses on eleven reservation systems at seven national parks from 2021 through 2024. This period captures the post-pandemic recreational demand surge and increased interest in reservation systems. These seven national parks represent the universe of general reservation systems operating during the period, but exclude four systems targeting more specialized recreational activities within parks (as described in the Methodology). Figure 1 shows the location of each park, which span the U.S., and include a variety of landscapes, regional economies and gateway communities. The extent to which users from a park’s home state dominate reservations varies substantially across parks. Table 1A summarizes the main features of each park’s system. Advance reservation periods range from 30 to 120 days

National Park Reservation State Shares

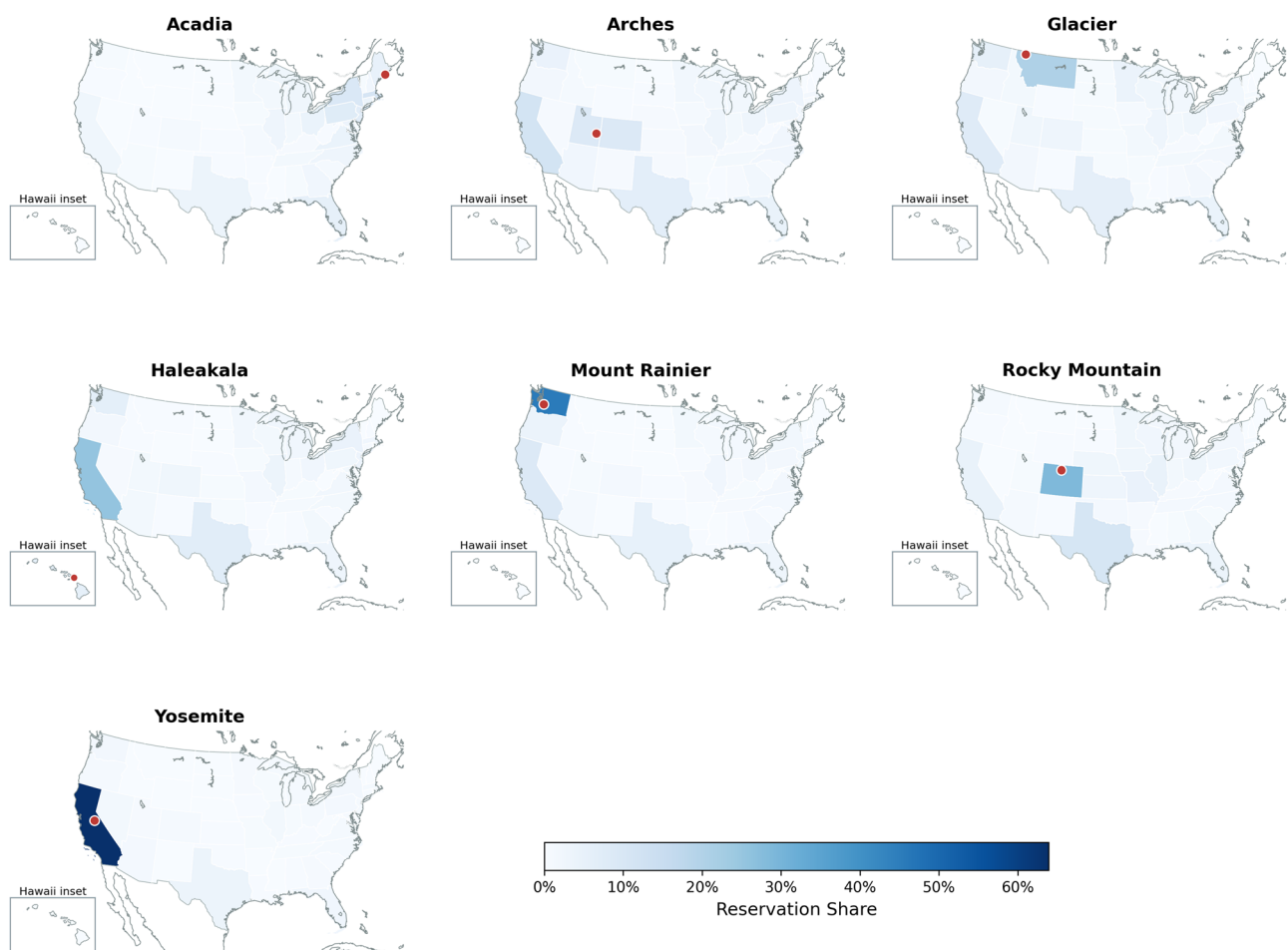


Fig. 1 | Share of reservations by user state for parks operating reservation systems from 2021 through 2024. Some parks, such as Yosemite are dominated

by in-state users. Others, such as Acadia, Arches, and Haleakalā, attract visitors more uniformly from across the country.

Table 1 | Design parameters of timed entry reservation systems, 2021–2024

Panel A: Advance reservation windows (days in advance)					
Park (State)	2021	2022	2023	2024	
Rocky Mountain (CO)—Bear Lake Rd.	30–60 (block), 1 (day-ahead)	30–60 (block), 1 (day-ahead)	30–60 (block), 1 (day-ahead)	30–60 (block), 1 (day-ahead)	
Rocky Mountain (CO)—Rest of Park	30–60 (block), 1 (day-ahead)	30–60 (block), 1 (day-ahead)	30–60 (block), 1 (day-ahead)	30–60 (block), 1 (day-ahead)	
Arches (UT)	–	90–120 (block), 1 (day-ahead)	90–120 (block), 1 (day-ahead)	90–120 (block), 1 (day-ahead)	
Glacier (MT)—Sun Rd.	60 (rolling), 1 (day-ahead)	120 (rolling), 1 (day-ahead)	120–150 (block), 1 (day-ahead)	120 (rolling), 1 (day-ahead)	
Glacier (MT)—Many Glacier	–	–	120–150 (block), 1 (day-ahead)	120 (rolling), 1 (day-ahead)	
Mount Rainier (WA)—Sunrise	–	–	–	90–120 (block), 2 (day-ahead)	
Mount Rainier (WA)—Paradise	–	–	–	90–120 (block), 2 (day-ahead)	
Haleakalā (HI)—Summit Sunrise	60 (rolling), 2 (day-ahead)	60 (rolling), 2 (day-ahead)	60 (rolling), 2 (day-ahead)	60 (rolling), 2 (day-ahead)	
Acadia (ME)—Cadillac Sunrise	90 (rolling), 2 (day-ahead)	90 (rolling), 2 (day-ahead)	90 (rolling), 2 (day-ahead)	90 (rolling), 2 (day-ahead)	
Acadia (ME)—Rest of Day	90 (rolling), 2 (day-ahead)	90 (rolling), 2 (day-ahead)	90 (rolling), 2 (day-ahead)	90 (rolling), 2 (day-ahead)	
Yosemite (CA)	30–60 (5-blocks), 7 (day-ahead)	60–120 (1-block), 7 (day-ahead)	–	90–240 (block, Apr–Oct), 7 (day-ahead)	
Panel B: Reservation periods and release times					
Park (State)	2021	2022	2023	2024	Release time (Adv. Day-Ahead)
Rocky Mountain (CO)—Bear Lake Rd.	5/28–10/11	5/27–10/10	5/26–10/22	5/24–10/20	8 a.m., 10 a.m. MDT 5 p.m./7 p.m. MDT
Rocky Mountain (CO)—Rest of Park	5/28–10/11	5/27–10/10	5/26–10/22	5/24–10/20	8 a.m., 10 a.m. MDT 5 p.m./7 p.m. MDT
Arches (UT)	4/3–10/3	4/1–10/31	4/1–10/31	4/1–10/31	8 a.m. MDT 6 p.m./7 p.m. MDT
Glacier (MT)—Sun Rd.	5/28–9/6	5/27–9/11	5/26–9/10	5/24–9/8	8 a.m. MDT 8 a.m./7 p.m. MDT
Glacier (MT)—Many Glacier	–	–	7/1–9/10	7/1–9/8	8 a.m. MDT 8 a.m./7 p.m. MDT
Mount Rainier (WA)—Sunrise	–	–	–	5/24–9/2	8 a.m. PT 7 p.m. PST
Mount Rainier (WA)—Paradise	–	–	–	5/24–9/2	8 a.m. PT 7 p.m. PST
Haleakalā (HI)—Summit Sunrise	Year-round	Year-round	Year-round	Year-round	7 a.m. HST
Acadia (ME)—Cadillac Sunrise	5/26–10/19	5/25–10/22	5/24–10/22	5/22–10/27	10 a.m. ET
Acadia (ME)—Rest of Day	5/26–10/19	5/25–10/22	5/24–10/22	5/22–10/27	10 a.m. ET
Yosemite (CA)	5/21–9/30	5/20–9/30	–	4/13–10/27	8 a.m. PST

“–” indicates year without operating reservation system.

and vary both across parks and within a given park over time. For instance, Yosemite National Park has experimented with advance periods of different lengths while Acadia has maintained a 90-day period throughout. Advance allocations can be block format, whereby reservations for all dates within a period are available at one time (e.g., the entire month of July becomes available on March 1), or rolling (e.g., a single date 90 days in the future is reservable). Each park also makes a portion of its permits available shortly in advance of the desired visit date to accommodate users who either cannot or prefer not to reserve in advance. In most cases these are day-ahead reservations, but can also be two-day (Acadia and Haleakala) or seven-day ahead (Yosemite).

Table 1B summarizes each park’s reservation period from 2021 through 2024. Visitation patterns vary throughout the year and across parks. Reservation systems are typically designed to operate during peak demand periods, which is reflected in the range of system dates. The final column of Table 1B reports the advance and day-ahead permit release times. Parks such as Glacier experimented with both morning and evening release times, while parks such as Rocky Mountain (RMNP) shifted release times from late afternoon (5 p.m.) to early evening (7 p.m.). Finally, while permit allocations are not reported, parks set different allocation levels and, in some cases, appear to have adjusted those allocations over time. These differences likely reflect the fact that some systems are capacity constrained, for example, due to parking lot capacity, while others set allocations more flexibly to

meet management goals. These system characteristics create rich variation in competition and lead time that we exploit in the regression analysis below. However, to the extent that design choices reflect unobserved demand preferences, the empirical approach must account for potential park-specific, time-varying demand shifters that could be correlated with income.

Reservation markets in Rocky Mountain and Acadia

Figure 2 illustrates differences in reservation activity, competition and permit allocations for two representative systems, Rocky Mountain National Park (RMNP)—Bear Lake Road permits and sunrise at the summit of Cadillac Mountain in Acadia National Park. Figure 2a shows reservations by order (purchase) date in RMNP. The four spikes in each calendar year correspond to the on-sale dates of the block allocations. This rush to reserve is consistent with reservations for national park campgrounds and is an indicator of the popularity of these permits². Lower levels of advanced purchase continue between each block allocation. Day ahead reservations begin on Memorial Day weekend each year, contributing to reservation totals during the remainder of the year. Figure 2b shows reservations for Acadia, which has a rolling allocation of advance reservations each spring. Reservations increase substantially around Memorial Day weekend when day-ahead allocations begin. Reservation activity drops mid-summer when advance purchases end, leaving only day-ahead reservations for the remainder of the season.

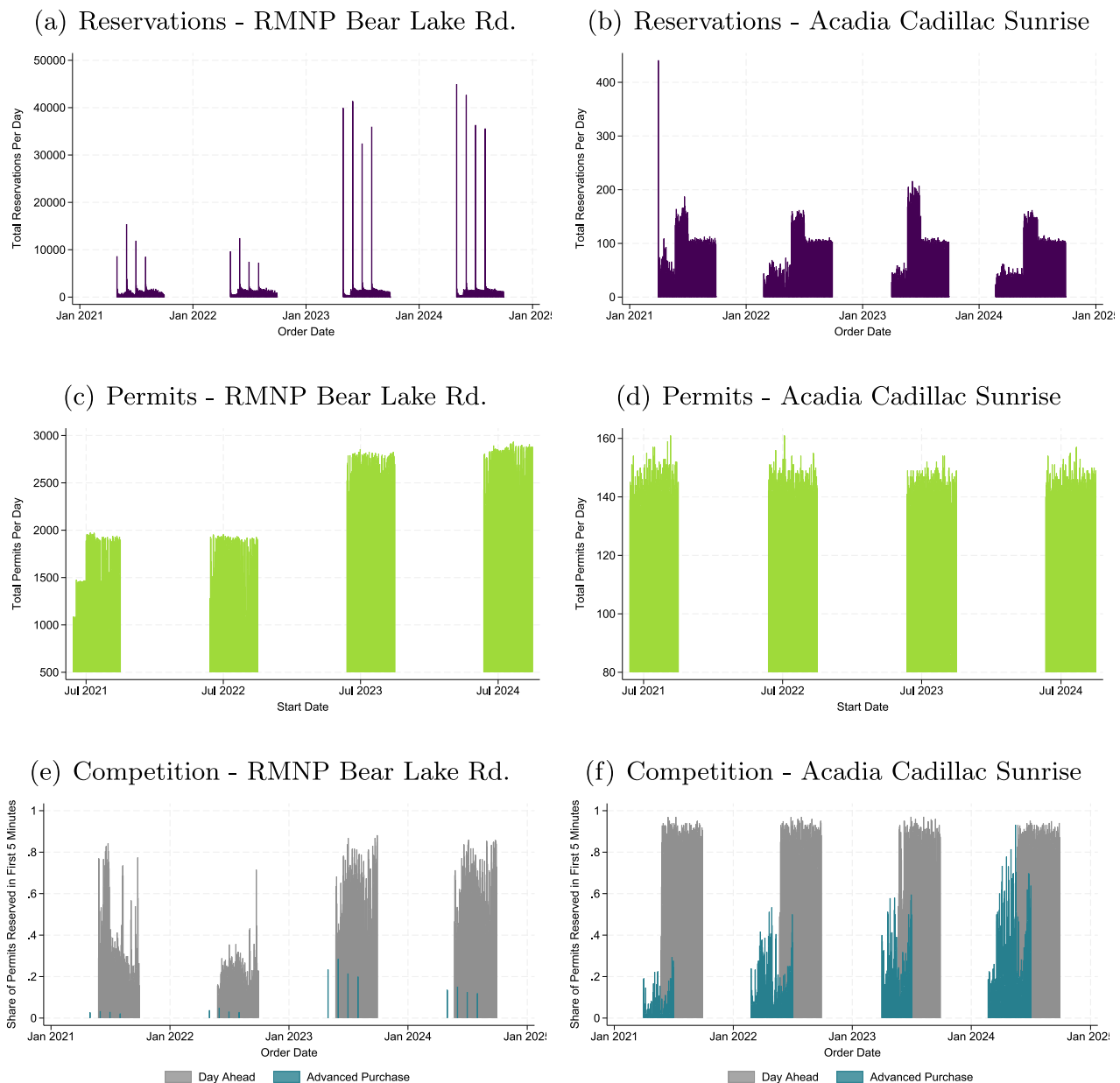


Fig. 2 | Reservations, competition and permit allocations for Rocky Mountain National Park (Bear Lake Road) and Acadia National Park (Cadillac Mountain Sunrise). Reservations are the total number of reservations made per day. Competition is the share of total day-ahead permits reserved during the first 5 min permits are available. Permits are the total number of permits available by travel date. **a** Spikes in reservations at Rocky Mountain National Park at the beginning of

the advanced block distribution period. **b** Acadia reservations reflect the sum of advance purchase and two-day-ahead market. **c** Total permits allocated by Rocky Mountain National Park managers vary over the period. **d** The allocation is constant in Acadia, about 150 per day. Competition for day-ahead reservations is intense in both Rocky Mountain National Park (**e**) and Acadia (**f**). In Acadia, over 90% of day-ahead permits are reserved during the first 5 min.

Figure 2c, d plot total permits reserved for each day of the permit season. While the data are noisy, we can infer an (approximately) binding permit cap in RMNP during the 2021 through 2024 season. The cap appears to increase from approximately 1000 permits per day early in the 2021 season, to approximately 1500, then approximately 2000 permits per day later in the season. The cap is approximately the same throughout the entire 2022 season but increases to somewhat under 3000 permits per day during the 2023 and 2024 seasons. For sunrise permits to Cadillac Mountain in Acadia, daily permits fluctuate around 150 each year, suggesting an allocation (target) of around 150 per day consistent with anecdotal reports²². Supplementary Fig. 1 through 3 present summary statistics for all eleven permit systems.

Figure 2e, f plot competition for day-ahead and advance purchases in the two systems. We define competition as the share of total permits allocated (for a start date or block) that are reserved during the first 5 min permits are available. During 2021 and 2022, competition for advance purchase permits in RMNP is low, approximately five percent of permits are reserved during the first 5 min of each on-sale event. Competition is moderately higher during the 2023 and 2024 seasons, with between 10 and 20 percent of available permits reserved during the first 5 min. In contrast, day ahead permits are generally more competitive. In 2023 and 2024, 60–80 percent of available permits are reserved during the first 5 min. For Acadia, both advance and day ahead reservations are competitive. Advance reservations during the first 5 min increase from approximately 10–20

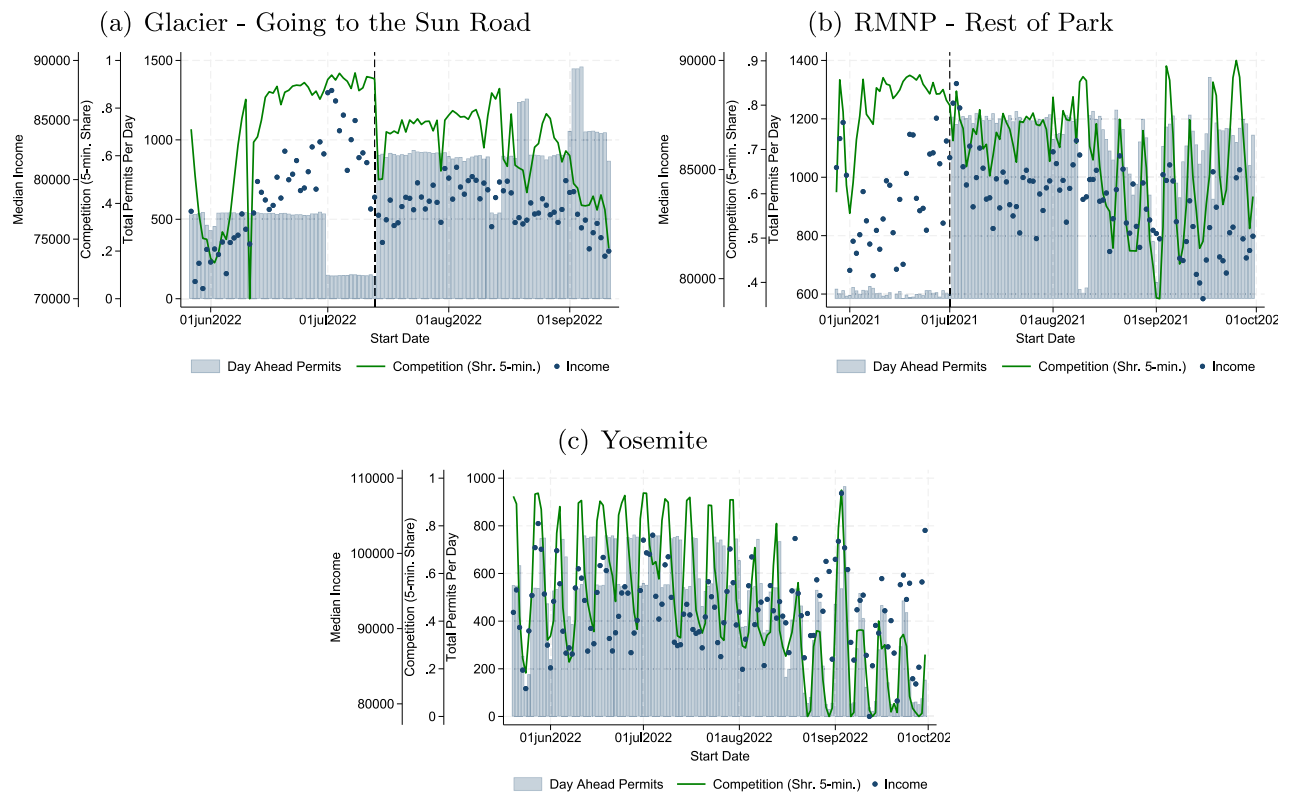


Fig. 3 | Reservation competition and income of park users. Correlations between day-ahead reservations, competition and visitor income in three reservation systems: **a** Glacier National Park (2022); **b** Rocky Mountain National Park - Rest of Park (2021); and **c** Yosemite (2022). Day-ahead permits are the total number of day

ahead permits allocated each period. Competition is the share of total day-ahead permits reserved during the first 5 min permits are available. Income is zip-code level median household income of park visitors, averaged by reservation date.

percent in 2021 to over 60 percent on many days during the 2024 season. Over 90 percent of day-ahead permits are reserved during the first 5 min. The Supplementary Information show similar periods of intense competition for day-ahead permits in each of the other parks.

Permits and competition in Glacier and Rocky Mountain

Differences in reservation system design parameter create variation in competition for permits that we exploit in the regression analysis below. When demand for permits exceeds supply, the permit allocation affects competition for reservations, all else equal. To see this, Fig. 3 plots day ahead permit reservations for the Going to the Sun Road in Glacier National Park during the 2022 season (panel a) and RMNP (No Bear Lake Road/rest of park) during the 2021 season (panel b). In Glacier, 500 permits per day were awarded in June 2022. Early season permits are limited to lower elevations as the summit over Logan Pass has not yet been cleared of snow. However, each year additional permits are allocated once the entire road opens. The exact date varies from year to year depending on snowpack and the spring thaw. In 2021, this occurred on July 13th as indicated by the vertical dotted line in Fig. 3a, amounting to an (essentially) exogenous increase in the permit allocation on that date. The green line in Fig. 3 plots the 5 min competition measure. We see competition rises throughout June, presumably due to increasing summer travel during the period, peaking at approximately 90 percent in early July. Competition falls to about 70 percent when additional permits are allocated on July 13th – travelers have already arrived at the park having made plans weeks or months in advance and so, the exogenous increase in permits decreases competition without increasing permit demand, at least in the short-run. Thus, park managers' decisions about the number of permits to award can determine the level of permit competition.

Further, we see similar patterns in the average income of permit holders. Income, approximated as the median household income in the zip code where a user resides, increases throughout June. However, immediately after July 13th, both competition and income fall sharply. Income decreases from about \$85,000 in early July, to between \$75,000 and \$80,000 after permits are released. This result is consistent with Hughes²¹ who finds income is positively correlated with competition for river permits in the western United States.

Figure 3b shows similar trends for RMNP. During the 2021 season, park managers realized approximately one third of reservation holders “no-show,” resulting in un-used capacity²³. As a result, on July 1, 2021 RMNP increased Bear Lake road permits from 600 to 1200 per day. This reduced the competition measure from approximately 85 percent to approximately 70 percent. Income, which had been increasing throughout the spring, decreases after the shock such that the average reservation holder resides in a zip code with about \$2000 lower median income.

Figure 3c plots day ahead permits, competition and income for Yosemite in 2022. During the peak summer season, permits and competition follow an inverse relationship. It appears that more permits are allocated Sunday through Wednesday each week and fewer on Thursday through Saturday. This pattern could be due to higher weekend camping demand since camp reservations substitute for an entry permit. Nevertheless, on days with fewer day-ahead permits there is intense competition for reservations and income increases. However, behavior is different during the early and late season when permits, competition and income all move together. Here, it appears that competition and potentially income, are driven by recreational demand shocks. This highlights the need to control for time-varying demand shifters that could be correlated with income in the regressions below.

Table 2 | The dependent variable in each regression is median household income by customer zip code

	(1) Base	(2) Weekend effects	(3) Seasonality	(4) Park seasonality	(5) Non parametric
Advance Comp. (0, 0.25)	520.4 [*] (288.6)	519.7 [*] (296.7)	479.2 (300.1)	343.4 (273.4)	595.2 ^{**} (271.8)
Advance Comp. [0.25, 0.50)	730.2 (497.6)	693.4 (497.0)	403.8 (499.2)	115.6 (483.1)	1069.0 ^{***} (466.7)
Advance Comp. [0.50, 0.75)	2614.8 ^{***} (509.4)	2529.8 ^{***} (584.0)	2506.1 ^{***} (522.6)	1814.8 ^{***} (515.5)	1976.2 ^{**} (736.3)
Advance Comp. [0.75, 1.00)	4135.1 ^{***} (786.9)	3968.8 ^{***} (754.1)	4047.7 ^{***} (701.5)	3747.7 ^{***} (716.2)	3158.8 ^{***} (890.8)
Day-Ahead Comp. (0, 0.25)	-351.0 (556.3)	-271.9 (554.2)	-197.7 (530.5)	-120.8 (476.9)	1866.5 ^{***} (558.5)
Day-Ahead Comp. [0.25, 0.50)	54.57 (495.1)	36.37 (460.0)	59.43 (469.0)	-73.73 (472.3)	2279.2 ^{***} (385.8)
Day-Ahead Comp. [0.75, 1.00)	965.5 ^{**} (440.2)	957.1 ^{**} (402.3)	658.2 (441.9)	615.4 (418.5)	3232.0 ^{***} (436.3)
Day-Ahead Comp. [0.75, 1.00)	3203.8 ^{***} (549.8)	2815.2 ^{***} (551.1)	2771.2 ^{***} (575.4)	2690.4 ^{***} (554.5)	5029.8 ^{***} (502.6)
Lead-Time Days (0, 30)	3702.0 ^{***} (336.2)	3631.8 ^{***} (335.0)	3456.8 ^{***} (332.5)	3313.2 ^{***} (333.4)	
Lead-Time Days [30, 60)	3641.6 ^{***} (396.8)	3533.6 ^{***} (410.8)	3333.4 ^{***} (403.0)	3254.3 ^{***} (361.3)	
Lead-Time Days [60, 90)	3830.1 ^{***} (415.8)	3722.9 ^{***} (435.8)	3378.4 ^{***} (425.2)	3256.4 ^{***} (376.3)	
Lead-Time Days [90, 120)	2586.0 ^{***} (643.8)	2480.7 ^{***} (672.0)	2455.1 ^{***} (704.7)	2466.2 ^{***} (661.2)	
Lead-Time Days [120, 180)	2022.3 [*] (784.5)	1922.1 [*] (798.6)	1707.3 [*] (786.1)	1614.7 [*] (777.3)	
Lead-Time Days [180, ∞)	2098.5 ^{***} (577.8)	1880.5 ^{***} (595.6)	1681.1 ^{***} (495.9)	2060.3 ^{***} (541.7)	
Federal Holiday		1952.8 ^{***} (308.9)	1722.0 ^{***} (249.5)	1655.2 ^{***} (229.7)	1621.5 ^{***} (330.2)
Weekend		1520.5 ^{***} (279.2)	1539.8 ^{***} (274.5)	1527.7 ^{***} (269.9)	1506.3 ^{***} (301.3)
Permit Effects	Yes	Yes	Yes	Yes	Yes
Week Effects	No	No	Yes	Yes	No
Permit*Week Effects	No	No	No	Yes	No
Observations	5,279,457	5,279,457	5,279,457	5,279,457	527,512

Federal Holiday is a set of indicator variables equal to one if the trip start date is a federal holiday. Weekend is a set of indicator variables equal to one if the trip start date is a Saturday or Sunday. Standard errors clustered at the permit-by-year level.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Competition for reservations and income

We perform a regression analysis relating average income to competition in the advance and day-ahead permit markets and to advance reservation lead time. Competition in advanced and day-ahead permit markets is flexibly modeled with sets of indicator variables corresponding to four regular interval bins of the 5-min competition measure. The length of advance purchase is captured by a set of indicator variables corresponding to the number of days before the trip start date permit reservations are first accepted. Lead time of zero days, i.e., same day purchase, is the omitted category. Therefore, comparisons are between a given category and reservations made when there is sufficient capacity for same-day entry. These results are presented in Table 2. Column 1 presents results from a base specification that controls for permit fixed-effects. Columns 2–4 add controls for demand shifters based on: whether the permit falls on a weekend or federal holiday (column 2); week of year (column 3); and permit-specific week-effects (column 4).

Higher competition, in both the advanced and day-ahead permit markets, is associated with higher average income. During the least competitive advance purchase on-sales, where 5 min sales percentages are between zero and 25 percent, reservation holders come from zip codes with median income between \$343 and \$520 higher than users who reserve same day. However, in the most competitive advance on-sales, with 5 min sales percentages between 75 and 100 percent, the average reservation holder resides in a zip code with \$3748–\$4135 higher median income. Effects are similar for day-ahead reservations. In the most competitive day-ahead on-sales, successful reservation holders come from zip codes where median income is between \$2690 and \$3204 higher compared to those who purchased same day. In all cases, permits falling on federal holidays or weekends are associated with higher incomes. Controlling for holiday, weekend and seasonal effects reduces the estimated effects of competition on income, suggesting controlling for demand related factors is important.

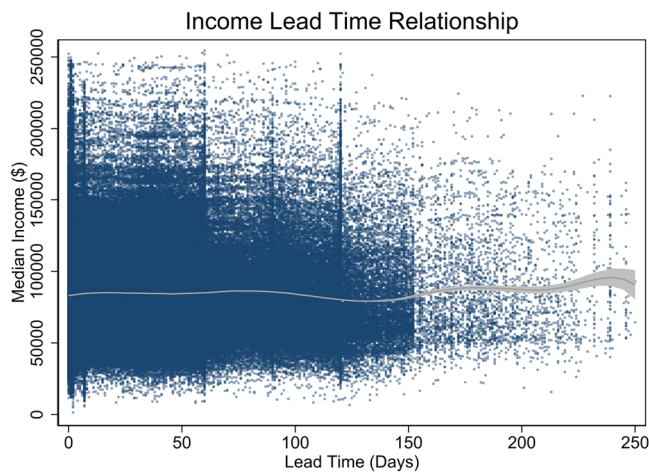


Fig. 4 | Relationship between advance purchase reservation lead time and visitor income. Non-parametric relationship estimated using Robinson's square of root N-consistent semi-parametric regression. Data are a 10 percent sample of all reservations. Model specification includes permit-specific mean effects.

While it is tempting to interpret the estimated effects on zip-code level income as individual effects, this characterization would be misleading due to the “ecological fallacy”^{24,25}. Aggregation introduces both zip-code-level selection and within-zip sorting arising from heterogeneous individual treatment effects. We model these effects as selection on unobservables^{25,26} and adapt the approach of Oster²⁷ to demonstrate that, under plausible bounds on residual within-group sorting, the aggregate and average individual-level effects have the same sign. In other words, higher income individuals are more likely to reserve during more competitive day-ahead and advance on-sales. These results are presented in Supplementary Tables 2 and 3. Supplementary Table 2 also provides evidence the observed effects are not driven by travel costs or affinity for outdoor recreation, factors that may be correlated with both income and success in obtaining a reservation.

Advance purchase period length and income

Advance purchase reservations are also associated with higher incomes, consistent with results in Rice et. al.²⁰ for camping reservations. Relative to same-day reservations, advance reservations made up to 30, 30–60, and 60–90 days in advance are associated with median zip-code incomes that are \$3254 to \$3830 higher. Longer advance purchases are associated with somewhat smaller income differences, between \$2455 and \$2586 for 90–120 days, \$1615 and \$2022 for 120–180 days and between \$1681 and \$2099 for greater than 180 days. The pattern of non-linearity of the advanced purchase parameters, suggests a more flexible specification for lead time may be important. Column 5 presents results using Robinson's square of root N-consistent semi-parametric regression²⁸ that allows for a general functional relationship between advance purchase lead time and income $\lambda(l_i)$. We estimate the model on a random ten percent sample of transactions and without week-effects for computational tractability. The estimated effects of competition in the advance and day-ahead reservation markets are comparable to estimates in columns 1–4. In the most competitive advance purchase on-sales, reservation holders come from zip codes with \$3159 higher median income. The most competitive day-ahead on-sales are associated with \$5030 higher median income.

The relationship between advance purchase lead time and income is plotted in Fig. 4. Median income shows a generally upward trend, increasing with advance purchase lead time. Users who reserve 180 days in advance come from zip codes where median income is

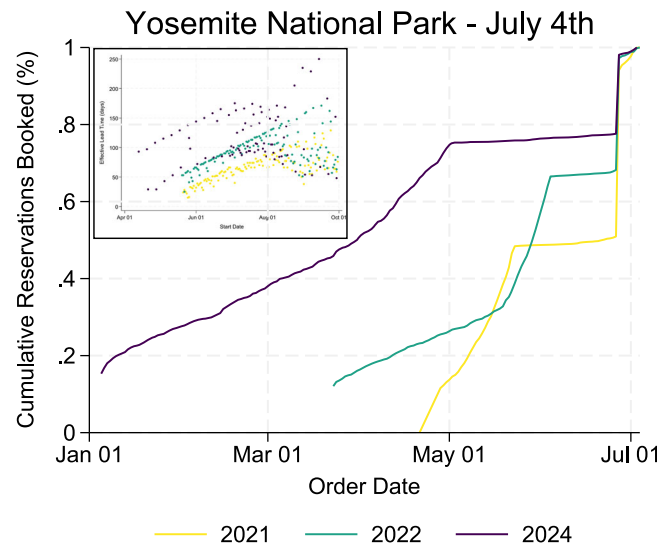


Fig. 5 | Booking curves for Yosemite National Park ticketed entry permits for July 4 in 2021, 2022 and 2024. Changes in the duration of the reservation period and total permit allocation each year lead to different effective lead times (inset), defined as the date advanced reservations are sold-out.

approximately \$10,000 higher than those who reserve same-day, all else equal. However, while visitors from lower income zip-codes appear to prefer short advance purchase windows or day-ahead reservations, congested buying frenzies in the day-ahead markets disadvantage lower income users. Therefore, moving to a day-ahead-only model would not necessarily alleviate the equity problem.

When interpreting the results in Table 2 and Fig. 4 it is important to note while higher income users prefer to reserve in advance, this preference only impacts equity if their reservations prevent lower income users from reserving later. Therefore, a better test of the advanced reservation effect would focus on the effective lead time when advanced reservations are sold-out, potentially excluding lower income users.

Advance purchase period in Yosemite

Because parks' advance purchase period may reflect differences in demand and tend not to vary during this period, it is difficult to separate out the effect of the effective lead time from differences in park characteristics that may be correlated with user incomes. However Yosemite, did experiment with different advance reservation periods. In 2021, the park operated five advanced purchase block allocations approximately 30–60 days in advance of trip start dates. In 2022, the separate periods were eliminated in favor of a single block allocation (March 23, 2022) with lead time between 60 and 120 days depending on trip date. Finally, in 2024 the single block allocation was moved back 3 months (January 5, 2024) increasing lead time to between 90 and 240 days. These changes altered the effective date of the advanced purchase.

Figure 5 plots the booking curves for Yosemite permits for July 4 in 2021, 2022 and 2024. Cumulative reservations are the share of total permits booked by any given order date. The plateau in each curve occurs when advance reservations are completely booked, i.e., the effective lead time for making an advance reservation. The jump in each curve in late June marks the seven day-ahead on-sale. For 2024, we see that opening reservations earlier extends the reservation period and shifts the effective lead time from the end of May in 2021 to the beginning of May in 2024. In 2022, the larger allocation to advanced reservations, about 70% versus 50% in 2021, shifts lead time to early June. However in 2024, the longer advance reservation period extends

lead time back to May 1. Figure 5 (inset) shows these changes in the Yosemite reservation system affect reservation lead time throughout the season, increasing average times from 2021 to 2022 and from 2022 to 2024.

Regression results using this variation in effective lead time are presented in Supplementary Table 5. In Yosemite, increasing lead time is correlated with a shift toward reservation holders residing in higher-income areas. Each additional day of lead time corresponds to \$21–\$24 higher median zip-code income; thus, extending the lead time from 30 to 180 days implies a difference of approximately \$3150–\$3600 in median zip-code income. This result is broadly consistent with results for all seven parks above, and suggests exclusionary effects and not simply differences in preferences, explain the observed advanced purchase effects.

Discussion

While evidence suggests reservation systems can be effective at protecting national park resources and visitor experience, we show these systems can also have equity effects. In the most competitive advance reservation on-sales, reservation holders reside in zip codes with median incomes between \$3200 and \$4200 (4–5 percent) higher. In the most competitive day-ahead on-sales, reservation holders come from zip codes with incomes \$2700–\$5000 (3–6 percent) higher. Longer advance reservation periods also favor higher-income users: increasing the effective lead time from 30 to 180 days is associated with \$1500–\$3500 higher zip-code income. These competition and advance purchase effects are comparable to other estimates of the exclusionary effects of reservation systems^{20,21}. In the only other study on the relationships between park reservation systems and user characteristics, Miller et al.¹⁴ find Arches National Park visitors planned further in advance during the 2022 timed-entry pilot period. They provide some evidence of higher user incomes, particularly in the right tail of the income distribution during the reservation period, though they ultimately conclude the Arches timed-entry system had no significant impact on household income. Looking beyond a single park in a single year, we provide evidence of exclusionary effects associated with both advance purchase requirements and competition for reservations. Although these effects appear modest, both park managers and users are highly sensitive to management strategies perceived as unfair.

So what is a park manager to do if equitable access is a concern? Because reservation systems are designed to ration use, some level of competition is unavoidable. However, adjusting the share of permits offered in advance versus day-ahead could reduce competition and potentially mitigate its effects. Future experimentation, where parks vary permit allocations while tracking competition and user income, would be invaluable for identifying these relationships. Admittedly, such experimentation may not always be feasible. For instance, limited vehicle parking means that sunrise permits for Acadia and Haleakalā are very competitive in both the day-ahead and advance markets (see Supplementary Fig. 2). However, other parks may have greater flexibility to experiment with permit levels.

With respect to advance reservation periods, the evidence presented here suggests that higher-income users are more likely to reserve permits in advance, consistent with findings from related markets²⁰. This pattern can lead to equity concerns when permits are fully reserved months in advance. One potential response is to experiment with additional phasing of permit on-sales to better understand, and potentially mitigate, these advance reservation effects. This approach has already been adopted by several public campgrounds. While shorter lead times may give users with scheduling constraints more opportunity to compete for permits, competition effects may still favor higher-income users, even under staggered allocations. Moreover, these competition effects could intensify if the total permit allocation is further subdivided into sequential releases,

highlighting a potential equity trade-off that warrants further study. Finally, in some cases, random allocation mechanisms, such as lotteries used in many river systems and popular hiking destinations, may be necessary to ensure more equitable access to permits.

Methods

Data

Transaction-level data on reservations (permits) are from the Recreation Information Database (RIDB)²⁹. The sample runs from 2021 through 2024, covering the first post-COVID year of reservation systems through the most recent year data are available. Median household income data are from the American Community Survey (ACS)³⁰. We match zip-code-level income with each user's zip code as reported in RIDB. We exclude international visitors (about 2 percent of the raw sample) from the analysis because their incomes are unobserved. Supplementary Table 1 describes mean zip code-level income for reservation holders who live within 50 miles of each park (Gateway) and those who reside further away (Travelers). While Travelers reside in fairly uniform, high-income areas, the sample includes a broad cross-section of gateway community incomes. As a result, the findings are likely to generalize to a wide range of parks and gateway settings.

We collect data on eleven permits at the seven national parks employing general reservation systems from 2021 to 2024: Acadia, Arches, Glacier, Haleakala, Mount Rainier, Rocky Mountain and Yosemite. Reservations may permit access to specific locations, e.g., Cadillac Mountain (Acadia) or the Bear Lake Road corridor (RMNP), or to large areas of the park such as in Arches or Yosemite. Permits may also pertain to a specific time of day, e.g., sunrise (Acadia or Haleakala) or hourly blocks when park entry is permitted (RMNP). These eleven systems are general in the sense they do not pertain to a specific activity and can encompass hiking, car touring, wildlife viewing, etcetera. We exclude reservation systems at two parks for activities requiring advanced or technical skills (Old Rag in Shenandoah and Angels Landing, the Subway and the Narrows in Zion). We compile historical information on the design of each park's permit system from the corresponding product pages on Recreation.gov and use the Internet Archive Wayback Machine³¹ to access prior years' data.

The RIDB data record the exact time and date of each transaction. We calculate reservation lead times as trip start-date minus order-date. From historical product pages we note the on-sale date as the first day permits are available for each period. We then classify individual transactions as “advance-purchase” or “day-ahead” reservation if the transaction falls on the on-sale date, for either type, and record whether the purchase occurred during the first 5 min of the on-sale period.

Regression model

The empirical model separately estimates the effects of advanced reservation lead time and competition for permits on the average incomes of permit holders. To do this requires controlling for factors related to the time-varying demand for particular permits that could also be correlated with the incomes of permit holders. The main specification is:

$$\text{Income}_{it} = \alpha A_{pt} + \delta D_{pt} + \lambda L_{ipt} + \epsilon_p + \epsilon_t + \epsilon_{it}, \quad (1)$$

where Income_{it} is the average median household income (zip-code level) of user holding individual permit i purchased at time t . Competition for advanced purchase permits is flexibly modeled as a vector of indicator variables A_{pt} , defined by the ranges for the share of available permits that are purchased during the first 5 min permits are for sale. The specification uses four intervals: (0, 0.25); [0.25, 0.50]; [0.50, 0.75]; and [0.75, 1.00]. Similarly, D_{pt} is a vector of indicator variables defined by analogous intervals of competition during day-ahead on-sale events. To flexibly capture advance purchase, L_{ipt} is a vector of indicator variables corresponding to different lead time

intervals. Specifically, we use six bins: (0, 30); [30, 60); [60, 90); [90, 120); [120, 180); and [180, ∞). Day-of purchase, i.e., zero lead time, are the omitted category serving both as the reference for advanced and day-ahead on-sales, but also purchases at other times during the season captured by the lead time categorical variables.

We control for permit-specific factors using mean-effects ϵ_p . Here, we distinguish between permit types for parks that have multiple timed-entry permits, for example Bear Lake Road and the rest of the park in RMNP. We control for time-varying demand factors that may be correlated with user characteristics with ϵ_t , a set of time or time-by-permit fixed-effects and ϵ_{it} is the error term. Finally, education and race could serve as alternate measures of inequality. Supplementary Table 4 presents results showing education is positively correlated with competition for permits and advance purchase. The percent of a zip code identifying as white is positively associated with advance purchase.

Signs of individual-level effects

The results above rely on zip-code-level proxies for individual incomes. In general, results from aggregate regressions cannot be interpreted as individual effects, a result broadly known as the ecological fallacy^{24,25}. Here, we develop robustness checks to determine the likely sign of individual effects based on the aggregate results. The use of zip-code-level income data creates two potential problems. First, aggregation can lead to omitted variable bias due to zip-code-level selection into different reservation types (e.g., more versus less competitive parks or periods). Second, when individual treatment effects are heterogeneous, aggregation induces compositional bias whenever the distribution of individuals (or their potential outcomes) co-varies with group composition.

We model these concerns as selection on unobservables and estimate two auxiliary regressions. First, we estimate a specification that accounts for baseline compositional differences across zip-codes that could drive reservation selection²⁶. Specifically, we include zip-code-level proxies for income distribution (Gini coefficient), travel costs (the distance between each zip code centroid and each national park) and affinity for outdoor recreation (purchases on Recreation.gov per capita). These additional controls are intended to proxy for unobserved factors that could be both correlated with income and lottery success probability. Second, to account the possibility of slope heterogeneity, we create proxies for missing cross-moments by interacting the zip code controls with the reservation system competition and lead time dummies²⁵. In the latter, we calculate the marginal effects of the main effects at the means of distance, Gini coefficient and Recreation.gov purchases. While it is impossible to identify individual-level treatment effects using aggregate zip-code data, we use the approach developed by Oster²⁷ to construct bounds on the average individual-level effects at typical zip compositions, which allows me to determine the likely sign of those effects under reasonable assumptions about residual within-zip sorting.

These results are presented in Supplementary Table 2. We choose the specification with permit and week effects to account for park-specific preferences and seasonality (column 3 in Table 2) but not the fully interacted model (column 4 in Table 2) to simplify calculation of the marginal effects when the seasonal categorical variables are unbalanced across parks. Because the zip code controls are not available for all observations, column 1 presents results for the base model estimated on the restricted sample. Column 2 adds controls for income distribution, travel costs and affinity for outdoor recreation. Column 3 adds interaction terms proxying for the missing cross-moments and reports marginal effects evaluated at the means of zip-code Gini, travel distance and recreation.gov activity. The coefficient stability tests outlined in Oster²⁷ assess robustness to omitted variable bias by comparing changes in coefficient estimates and *r*-squared

values between regressions with and without control variables that account for selection on observables.

Comparing columns 1 and 2, adding zip-code characteristics generally increases the magnitudes of the estimated effects of lead-time and competition in advance and day-ahead reservations. *R*-squared increases from approximately 0.0244 to 0.0456. Column 2 of Supplementary Table 2 reports the proportional selection parameter necessary to reduce the estimated effect to zero (δ_0)²⁷. Values are all either much larger than one or negative, indicating the selection on unobservables would have to be either substantially stronger than selection on observables or act in the opposite direction to eliminate the estimated effects, or change their sign.

Comparing columns 1 and 2 with column 3, adding proxies for missing treatment heterogeneity, we see the estimated marginal effect for the most competitive advance on-sales is smaller in magnitude compared to the parameter estimates in columns 1 and 2. The estimated marginal effect for the most competitive day-ahead on-sales are larger in magnitude. The marginal effects of lead time are generally smaller in magnitude and the *r*-squared value increases slightly to 0.0503. While the δ_0 values reported in Supplementary Table 2 are generally smaller in magnitude than those in column 1, they all exceed the threshold of $\delta = 1$ or are negative. Therefore, while the individual-level average treatment effect cannot be identified from aggregate data, the results above suggest the individual level effects are unlikely to have a different sign than the estimates presented in Table 2. In other words, individuals who obtain their permit in a competitive advanced or day-ahead on-sale or those who reserve weeks or months in advance are likely higher income than other users.

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Transaction level reservation data are available from the Recreation Information Database (<https://ridb.recreation.gov/>). Zip-code level income data are available from the American Community Survey (<https://www.census.gov/programs-surveys/acs.html>). Replication data for this paper are available via Zenodo at (<https://zenodo.org/records/17186257>)³².

Code availability

Replication code for the analysis is available at <https://github.com/jonathan-e-hughes/Park-Reservations> and <https://zenodo.org/records/20816749>.

References

1. National Park Service Visitor Use Statistics Dashboard. Accessed 21 July 2025. <https://www.nps.gov/subjects/socialscience/visitor-use-statistics-dashboard.htm> (2024).
2. Walls, M., Wichman, C. & Ankney, K. Nature-based recreation: Understanding campsite reservations in national parks. *Washington, DC: Resources for the Future*. 1–24, https://media.rff.org/archive/files/document/file/CampsiteReservations_Report_Final.pdf (2018).
3. Rice, W. L., Spivey, O., Newman, P. & Taff, B. D. “On the staff of the Grand Canyon”: assessing manager and stakeholder perspectives on sustainable wilderness visitor use management. *Int. J. Wilderness* **27**, 54 (2021).
4. Dertien, J. S., Larson, C. L. & Reed, S. E. Recreation effects on wildlife: a review of potential quantitative thresholds. *Nat. Conserv.* **44**, 51–68 (2021).
5. Freeman III, A. M. & Haveman, R. M. Congestion, quality deterioration, and heterogeneous tastes. *J. Public Econ.* **8**, 225–232 (1977).

6. Cole, D. N., Hoff, R. J. & Bunting, S. C. *Managing Wilderness Recreation Use: Common Problems and Potential Solutions* 230–232 (US Department of Agriculture, Forest Service, Intermountain Research Station, 1987).
7. Hardin, G. The tragedy of the commons: the population problem has no technical solution; it requires a fundamental extension in morality. *Science* **162**, 1243–1248 (1968).
8. Stankey, G. H. & Baden, J. *Rationing Wilderness Use: Methods, Problems, and Guidelines* Vol. 192 (Intermountain Forest and Range Experiment Station, U.S. Forest Service, 1977).
9. Manning, R. E. et al. *Studies in Outdoor Recreation: Search and Research for Satisfaction* (Oregon State University Press, 2022).
10. Fleming, C. M. & Manning, M. Rationing access to protected natural areas: an Australian case study. *Tour. Econ.* **21**, 995–1014 (2015).
11. Carter, D. P. & Katz, J. Land management policy tools and institutionally contingent types of goods: Understanding rock climbers' resistance to and desire for public lands fees and quotas. *J. Environ. Policy Plan.* **26**, 264–278 (2024).
12. Rice, W. L. et al. Explorations of preferred and maximum booking windows among US national park campers: implications for improved fairness. *Tour. Hosp. Res.* **25**, 526–534 (2025).
13. Rice, W. L. et al. A systematic review of visitor preferences concerning recreation allocation. *Socio-Ecol. Prac. Res.* **7**, 253–265 (2025).
14. Miller, Z. D. et al. Comparing visitor perceptions, characteristics, and support for management actions before and during a pilot timed entry system at Arches National Park. *Sustainability* **15**, 10035 (2023).
15. Creany, N., Monz, C. A. & Esser, S. M. Understanding visitor attitudes towards the timed-entry reservation system in Rocky Mountain National Park: contemporary managed access as a social-ecological system. *J. Outdoor Recreat. Tour.* **45**, 100736 (2024).
16. Schwartz, Z., Stewart, W. & Backlund, E. A. Visitation at capacity-constrained tourism destinations: exploring revenue management at a national park. *Tour. Manag.* **33**, 500–508 (2012).
17. Spotswood, E. N. et al. Nature inequity and higher COVID-19 case rates in less-green neighbourhoods in the United States. *Nat. Sustain.* **4**, 1092–1098 (2021).
18. Abatayo, A. L., van Adrichem, M. & Lynham, J. Comparing access to US marine and terrestrial protected areas. *Nat. Sustain.* **7**, 255–259 (2024).
19. Phillips, K. E. & Rice, W. L. Visitor sentiment concerning changes in backcountry permit allocation at Glacier National Park, Montana, USA. *J. Prot. Mt. Areas Res. Manag.* **16**, 30–37 (2024).
20. Rice, W. L., Rushing, J. R., Thomsen, J. M. & Whitney, P. Exclusionary effects of campsite allocation through reservations in US National Parks: evidence from mobile device location data. *J. Park Recreat. Adm.* **40**, 45 (2022).
21. Hughes, J. E. Are “buying frenzies” equitable? Distributional effects of congested online markets. *Land Economics, forthcoming* 103 (2025).
22. Average Wild Experience. Cadillac Mountain sunrise reservations 2025: everything you need to know. Accessed 9 July 2025. <https://averagewildexperience.com/cadillac-mountain-sunrise-2025/> (2024).
23. Golden, A. Reservation system will return to Rocky Mountain National Park in 2022. Accessed 21 July 2025. <https://www.skyhnews.com/news/reservation-system-will-return-to-rocky-national-park-in-2022/> (2021).
24. Robinson, W. S. Ecological correlations and the behavior of individuals. *Am. Sociol. Rev.* **15**, 351–357 (1950).
25. Goodman, L. A. Some alternatives to ecological correlation. *Am. J. Sociol.* **64**, 610–625 (1959).
26. Mundlak, Y. On the pooling of time series and cross section data. *Econometrica* **46**, 69–85 (1978).
27. Oster, E. Unobservable selection and coefficient stability: theory and evidence. *J. Bus. Econ. Stat.* **37**, 187–204 (2019).
28. Robinson, P. M. Root-n-consistent semiparametric regression. *Econometrica* **56**, 931–954 (1988).
29. Recreation.gov. *Recreation Information Database*. Accessed 10 June 2025. <https://ridb.recreation.gov/download> (2025).
30. U.S. Census Bureau. American Community Survey. Accessed 8 November 2021. <https://www.census.gov/programs-surveys/acs> (2021).
31. Internet Archive. Internet archive: Wayback machine. Accessed 9 July 2025. <https://web.archive.org/> (2024).
32. Hughes, J. E. Code and Data Repository for “Reservation Policies and Equity in National Park Access”. <https://zenodo.org/records/20816749> (2026).

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Competing interests

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Additional information

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Correspondence and requests for materials should be addressed to Jonathan E. Hughes.

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