COVID-19's impact on visitation behavior to US
national parks from communities of color - evidence
from mobile phone data

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Abstract

The widespread COVID-19 pandemic changed the fundamentals of people’s way of life. With the necessity of social distancing and lock downs across the United States, evidence shows more people engage in outdoor activities. With the utilization of location-based service data, we seek to explore how visitation patterns to national parks have changed from distinct communities of color amidst the COVID-19 pandemic. Our results show that visitation rates to national parks located closer than 353km have increased amidst the pandemic, but the converse was demonstrated amongst parks located further than 353km. More importantly, COVID-19 has adversely impacted visitation figures amongst non-white and Native American communities, with visitation volumes worsening if these communities are situated further from national parks. Our results show disproportionate representations amongst national park visitors from these communities of color. African American communities display a particularly concerning trend whereby their visitation to national parks is significantly lower amongst communities closer to national parks.

Keywords: national park visitation | COVID-19 | racial demographics | mobile phone data | Big Data

Introduction

The COVID-19 pandemic significantly impacted visitation patterns to U.S. national parks [1, 2]. While some parks experienced record visitation [1] as part of a national increase in outdoor recreation [3, 4], other national parks saw their visitation substantially decreased—in part due to safety concerns and travel restrictions [1, 2]. The pandemic also constrained broader park visitation and outdoor recreation among some groups, including—in specific settings—urban-dwellers [5], non-white individuals [6], and low-income groups [6]. The constraints include limited socioeconomic resources, a lack of cultural relevance to artifacts, landscape, or recreation activities that occurs in U.S. national parks, and discrimination of communities of color in these parks [7, 8]. Specifically, previous

research notes that the development of the National Park Service (NPS) coincided and was influenced by the rise of the U.S. eugenics movement and precipitated military-led displacement of Native Americans long-residing in many of these lands [9]. It is hypothesized that these factors contribute to the non-representatively proportionate visitation in national parks among African-, Asian-, Hispanic-, and Native Americans and present a number of related and systematic issues.

The reduced or discriminatorily constrained access to national parks among communities of color is conceptualized as a form of “environmental racism” [10]. The costs of this racially-driven discrimination are numerous. Floyd and Johnson [10] advocate to think of the distribution of health benefits from parks and outdoor recreation through an environmental justice perspective, much in the same way we might consider the distribution of health costs through hazards associated with industrial waste disposal sites or metal refineries. That is, the disproportionately low access to related health benefits among communities of color is somewhat analogous to the disproportionately frequent placement of environmental hazards near communities of color [10]. From an agency perspective, this disproportionate distribution of the benefits stemming from continued discriminatory practices in national park management also manifests in the NPS defaulting on its mission of public use for all Americans [11, 12].

While some have theorized that the pandemic may have further negatively exacerbated the relatively low level of visitation to national parks among communities of color [3], others have measured a widened racial disparity in urban park use during the pandemic [6]. Empirical data concerning the former has yet to be presented. While the NPS collects and regularly publishes data on visitation volume [13], there is no system-wide collection or reporting mechanism for visitor demographics. Thus, estimating national park visitor demographics is usually reliant on surveys distributed to a single or a few selected park units. Thus, to understand the impact of the COVID-19 pandemic on communities of color, we elected to utilize location-based service (LBS) data obtained from mobile devices. Aggregated, anonymized location data derived from national park visitors’ mobile devices is an emerging means of understanding changes in visitation patterns [2] and visitor demographics [14]. This study utilizes SafeGraph’s mobile phone dataset. SafeGraph primarily obtains GPS locational data from millions of American mobile device holders through a variety of third-party applications [15]. SafeGraph’s inclusion of the 12-digit FIPS census block group of these mobile device holders’ home locations allows us to retrieve visitor demographics using census block group information from the American Community Survey (ACS).

Despite the perceived utility provided by mobile phone location data, minimal research on park visitation [14, 16] has been published, in large part due to the relatively recent development of this data collection method [17]. One exception is a study of park visitors in Orange County, California (U.S.) where the authors found demographics gathered

through mobile phone location data to be consistent with those reported through surveys [14].

Thus, the aim of this paper is to identify the impacts of the COVID-19 pandemic on national park visitation among communities of color in the U.S. We analyzed 932 points-of-interests (POIs) across 48 national parks in the mainland U.S.

Through the utilization of racial demographics from visitors' census block groups, we are able to gain insights into COVID-19's impact on the visitation behavior towards visitors spanning communities of color. We specifically sought to determine how COVID-19 has altered the volume of visitors to national parks and how this behavior transcends across racial communities. These racial communities include non-whites, African-, Hispanics-, Asian-, and Native American communities. We achieve this by incorporating a methodological model involving a gravity model with random-effects panel data, as exemplified in Eqn 5.

Results

Fig. 1 illustrates the overall visitation to all national parks. The figure shows that total national park visitation took an initial slump after COVID-19 cases surged in the U.S. However, it was followed up by sharp increases in the subsequent months.

The visitation to each respective national park and its effects amidst the COVID-19 pandemic is illustrated in Fig. S1 of the SI appendix. Fig. S2 of the SI appendix shows that while most national parks witnessed an overall decrease in visitor volume following the COVID-19 crisis, numerous parks witnessed an increased visitation. For instance, Cuyahoga Valley, Indiana Dunes, Redwood, and Yellowstone all witnessed increased annual visitation relative to the preceding year, which are illustrated in Fig S2 of the SI appendix.

These findings partially validate the phenomenon of "revenge travel" amidst the COVID-19 crisis: the idea that individuals are eager to explore natural spaces upon being confined or restricted to their personal surroundings imposed by COVID-19 restrictions [18, 19, 20, 21, 22].

How has COVID-19 impacted visitation behavior to national parks from racially diverse communities

The results are best summarized in Table. S1 of the SI appendix.

Overall visitation to national parks

Due to significant increase to a few large national parks (Cuyahoga Valley, Indiana Dune, Redwood, and Yellowstone), the overall visitation to national parks has significantly

Figure 1: visitation to all national parks from Jan 2018 to May 2021

Figure 2: interaction plot of distance and COVID era based on results from Table S1.

increased amidst the COVID-19 pandemic as evident across the results displayed in Table S1 of the SI appendix. However, most national parks witness an decrease.

To be more precise, on average, each national park is expected to witness an average increase of 0.0971% in visitation from each census block group following the COVID-19 pandemic. However, the increase is mainly due to those few largest parks - the parks within close distance to population centers, Cuyahoga valley, Indiana Dunes, and Redwood, for example.

More specifically, our results show that visitation rates have decreased amongst visitors requiring longer travel distances following the COVID-19 pandemic. The opposite is true for visitors requiring shorter travel distances. These could be best illustrated in Interaction plots in Fig. 2. For instance, if a j^{th} park is situated within 1 kilo-meters from i^{th} census block group, the park would witness an average of 0.0927% ($0.0927 - 0.0158 * \ln(1)$) increase in visitors from census block group i as a result of the pandemic. However, beyond 353 km (or $e^{5.87}$), as evident from Fig. 2, the park would begin witness decreases in visitation rates from census block group i when compared to that of the pre-COVID era. This shows a higher distance decay rate. Distance decay rates are the amount of decrease in visitations due to a larger distance. The distance of 353 km (equivalent of 219 miles) takes around 3-4 hours' drive time. This seems to be the demarcation between a day-trip to visit a national park versus an overnight trip.

COVID-19 impact on visitation behavior from non-white communities

We have very strong evidence to suggest that COVID-19 has caused that communities with more non-white populations experience a more severe decrease in visitation to national parks. This relationship is significant, as illustrated in the interaction plot in Fig. 3.

Figure 3: interaction plot of proportion of non-whites and COVID era based on results from Table S1.

To interpret the results in the context of distance, In the top figure of Fig. 4, the values can be interpreted as the impact of diversity on visitation. Each national park would witness a $[0.00111 - 0.000186 * \ln(\text{distance}_{ij})]$ % change for every percent change of % non-whites due to the COVID-19 pandemic. The mathematical calculations could be referenced in Theorem 0.2 of the SI appendix. This impact depends on the distance between a community and a national park: within 388 km, there are actually increases in visitation during the pandemic from a more diverse community; beyond that distance, visitation rates drop with a more diverse population.

To interpret the results in the context of community composition, in the bottom figure in Fig. 4, the values represent distance decay rates. As a result of the pandemic, a particular park would observe $[-0.0165 - 0.000186 * \ln(\text{non_white}_i)]\%$ change in visitation rates for every additional percent change in distance travelled from census block i to national park j . The mathematical calculations are similar to that of Theorem 0.2 of the SI appendix. The figure shows that more diverse communities are less likely to travel further as a result of the COVID-19 pandemic, showing a higher distance decay rate.

Figure 4: Changes visitation to each national park due to COVID-19 for every 10% increase of proportion of non-whites and distance travelled respectively

COVID-19 impact on visitation behavior in African American communities

We have no evidence to suggest that COVID-19 has impacted the visitation behavior from communities with a higher percentage of African Americans.

However, our results reveal that regardless of the COVID-19 pandemic, national parks overall would witness lower visitation counts from the communities with a larger percentage of African Americans. To interpret our results in the context of distance, in Fig. 5, the values roughly represent the impact of African American majority communities. A park would witness a $[-0.000926 + 0.000108 * \ln(\text{distance}_{ij})]\%$ change in visitation from census block i for every percent increase in % African-Americans population. The mathematical computation could be referenced in Theorem 0.3 of the SI appendix.

However, as evident from Fig. 5, regardless of COVID-19, the rate of decrease in visitors from communities with a larger percentage of African Americans improves as the parks are located further away. This potentially suggests that African Americans are more likely to maintain visitation level to national parks further away than to those parks in close proximity.

Figure 5: Changes visitation to each national park for every 10% increase of proportion of African Americans

COVID-19 impact on visitation behavior from Hispanic communities

We have no evidence to suggest that COVID-19 has impacted the visitation behavior amongst visitors from Hispanic communities.

Despite yielding a positive coefficient for " $\beta_2 * \ln(\text{Hispanic}_i)$ ", we have to factor in the significance amongst the interaction terms involving Race and Distance. Thus, To interpret the results in context, regardless of COVID-19, a park would witness a $[0.000510 - 0.0000893 * \ln(\text{distance}_{ij})]\%$ change in visitation from census block i for every percent increase in Hispanic population. The mathematical computation could be referenced in Theorem 0.3 of the SI appendix.

Figure 6: Changes visitation to each national for every 10% increase of proportion of Hispanics

As per Fig. 6, regardless of COVID-19, national parks would witness higher visitation from a community with a higher percentage of Hispanic population, if they are located less than 303 km away, otherwise, visitations from those communities would decrease with an increased Hispanic population. This suggests that Hispanic communities are likely to visit national parks nearby but are less likely to travel longer distances to visit national parks. This indicates that the disparity of national park utilization for Hispanic visitors largely due to access to national parks farther away.

COVID-19 impact on visitation behavior from Asian American communities

We have no evidence to suggest that COVID-19 has impacted the visitation behavior amongst visitors from Asian American communities.

Despite yielding a positive coefficient for " $\beta_2 * \ln(Asian_American_i)$ ", we have to factor in the significance measures of the interaction terms involving Race and Distance. Thus, to interpret our results in the context of distance, regardless of COVID-19, a national park would witness a $[0.000581 - 0.0166 * \ln(distance_{ij})]\%$ change in visitation from census block i for every percent increase in its Asian American population. As best illustrated in Figure 7, unless a national park is situated extremely close (i.e. $< 1.03\text{km}$) to a census block group, the census block group would witness more reduced visitation for every percent increase in its Asian American population. The mathematical computation could be referenced in Theorem 0.3 of the SI appendix.

Figure 7: Changes in visitation to each national park for every 10% increase of proportion of Asian Americans

This suggests that Asian American are generally unincentivized from visiting national

parks but they are more likely to visit national parks in their community (within 1 km). Thus, the disparity for accessing national parks for Asian Americans are across all distances except the ones extremely close-by.

COVID-19 impact on visitation behavior from Native American communities

We have very strong evidence to suggest that visitation rates from Native American communities has decreased due to COVID-19. This can be best illustrated in the interaction plot in Fig. 8.

Figure 8: Interaction Plot of Proportion of Native Americans and COVID era based on results from Table S1.

To interpret the results in the context of distance, each national park would witness a $[0.00142 - 0.000237 * \ln(\text{distance}_{ij})]$ % change from a community for every percent change in its Native Indian population due to the COVID-19 pandemic. These changes could best illustrated in Fig. 9. The mathematical calculations could be referenced in Theorem 0.2 of the SI appendix. The value shows distance plays a role in this impact: an increase in visitation happens for a community with a larger percentage of Native Americans if the national park is within 399 km; it is a decrease otherwise. Similar to the community with a larger Hispanic population, the disparity lies largely in national parks farther away.

To interpret the results in the context of community composition, as a result of the pandemic, a particular park would observe $[-0.0257 - 0.000237 * \ln(\text{Native_American}_i)]$ % change in visitation rates for every additional percent change in distance travelled from census block i to national park j . These changes could best illustrated in Fig. 9. The mathematical calculations are similar to that of Theorem 0.2 of the SI appendix. This shows a higher distance decay effect for a community with a larger native American population.

Figure 9: Changes visitation to each national park due to COVID-19 for every 10% increase of proportion of Native Americans and distance travelled respectively

Discussion

Overall visitation behavior change due to COVID-19

While the aforementioned results reflect an overall increase in national park visitation during the first year of the pandemic—compared to the previous year, this is mainly due to a few large national parks in close proximity to population centers. In addition, the sharp increase in visitation occurring in April and May 2020 suggests that many seized the opportunity to visit in the spring and summer 2021—as parks began opening up from initial pandemic-related closures [1]. However, the fact that these increased levels of visitation only occurred amongst census block groups situated less than 353 km from the respective national park suggests that many residents visited the national parks within their respective states or regions—rather than pursuing long-distance or cross-country to visit national parks. As a point of reference, the width and length of the geographic extent of New York State are 530 km and 455 km respectively whereas the width and length of California State are 1,240 km and 400 km [23].

This finding is not surprising given distinct state-wide travel restrictions would certainly defer or hinder people from pursuing cross-country, or - in some cases - even regional, travels to visit national parks. Furthermore, limited air travels due to safety concerns likely discouraged individuals from taking long-distance trips to visit national parks [24]. In addition, this could also be the range of a day-trip instead of an overnight trip; the latter is usually perceived with higher risk of exposure to COVID-19.

COVID-19 has disproportionately impacted non-white communities

Importantly, among specific communities of color, only communities with a high percentage of Native Americans saw a significant impact on national park visitation during the COVID-19 pandemic. However, an omnibus examination of communities with a larger non-white population found that the COVID-19 pandemic significantly impacted overall minority visitation to national parks, whereas visitation to a national park from a more diversity community decreased more as the portion of non-white residents within that census block group increased. The results from non-white communities show a concerning trend: visitation from these communities was already disproportionately underrepresented prior to COVID-19, and representation has only worsened following the COVID-19 pandemic, depending on the distances to national parks. Our results align with previous research from a study of park visitation in New York City [6] showing similar results and follow the predictions of Xiao *et al.* [3]. From an environmental justice perspective, this means that the COVID-19 pandemic has led a further growth in the already lopsided portion of benefits derived from national parks going to white communities [10].

Policy implications

This finding is not alarming given numerous studies suggests COVID-19's inordinate economic impact on non-white and racially diverse communities [25, 26]. Thus, the alleviation of impacted visitor representation from non-white communities due to COVID-19 revolves around mitigating economic devastation's caused by the pandemic towards these communities.

COVID-19 has disproportionately impacted visitation from Native American communities

Native American communities were already disproportionately affected by the COVID-19 pandemic due to a relatively high frequency of underlying chronic health conditions among Native Americans, a deficient in institutional resilience, poor access to quality healthcare, and a lack of social trust [27, 28]. Further, for some Native American communities in the western U.S. reliant on the tourism economy, the COVID-19 pandemic significantly exacerbated existing economic hardships [29]. It is thus not surprising that the pandemic caused a significant decrease in national park visitation from Native American communities farther away.

Policy Implications

Communities with a large native American population actually are more likely to visit nearby national parks, but not for national parks more than 399 km away. Bridging the disproportionate impact of park visitation from farther communities with a large Native American population due to COVID-19 centers around mitigating the inordinate economic devastation of COVID-19 on Native Americans. Thus, existing literature supporting increased financial assistance towards Native American communities [30, 28, 31] could aid the circumvention of the impacted visitation from Native American communities.

Disproportionate representation and trends from other communities of color

While visitation demographics from African-American Communities remain unchanged as a result of the COVID-19 pandemic, our finding of disproportionate visitation patterns amongst African American communities are of utmost concern towards the diversity of park visitors. Further, as evident from Fig 5, we witness a distinct visitation trend amongst African American communities: the closer the park is situated to a community, the lower the likelihood of visitation. This is a somewhat unintuitive finding, but leads us to conclude that African American communities are more likely to engage in long-distance, cross-country travels to visit national parks, rather than visiting more proximate national parks. This finding follows previous findings denoting that African Americans are more likely to visit national parks that are relevant and celebrate the history of their community [8]. Therefore, they may be willing to travel further to visit these relatively few NPS units as opposed to visiting proximate NPS units that may not be culturally relevant [7].

While visitation trends from Asian American communities are more conventional (i.e., the more distant the national park, the more dramatic the decrease in representation) compared to African American communities, the fact that they experienced dramatically reduced likelihood of visitation unless the national park situated practically next to their community (i.e., $< 1.03\text{km}$) is an additional cause of concern towards the attainment of racial diversity of national park visitation. Hispanic American communities exhibit a similar trend to Asian American communities, albeit less dramatic. Unless the national park is relatively close (i.e., $< 303\text{km}$) to a census block group, the census block group would witness reduced visitation for every percent increase in proportion of Hispanic Americans.

Policy Implications

Our intuitive findings towards visitation patterns amongst African American communities could be translated to policy practices to entice more African Americans to visit National Parks. National Parks could increase efforts to celebrate the diversity amongst African American communities. Through organizing exclusive events during periods like "Black History Month", National Parks could expect to attract more visitors from predominantly African American communities. Such has been effectively demonstrated in other leisure related services, like recreational centers [32] and science museums [33].

Likewise, our findings towards Asian and Hispanic American communities suggest the preference of day trips or short inter-state travels of close proximity amongst these communities. While a myriad of factors are certainly influential towards this visitation behavior, existing literature extracting disparities amongst the benefit of paid leave amongst Asian- [34] and Hispanic American [35] employees could potentially explain this behavior. Thus, the attainment of equity in paid leave benefits could potentially entice Asian- and Hispanic Americans to spend more time on leisure activities situated within further proximity.

Furthermore, the combination of restricted mobility within Hispanic communities [36] and the lack of knowledge regarding National Parks - where only 32% of Hispanics could name a National Park [7] - could possibly explain the visitation behavior amongst Hispanics. Henceforth, the diffusion of knowledge regarding National Parks and uplift of mobility toward Hispanic communities remains a vital solution towards sustaining Hispanic representation amongst park visitors.

Materials and Methods

Materials

Data Sources

A detailed description of our data sources is summarized in Table S2 of the SI appendix.

In summary, our mobile phone data, containing Jan 2018 to Apr 2021 visitation records to each national park and the visitor's respective census block group are courtesy of SafeGraph Inc [37].

The geographical boundaries of national parks that are used to extract records only relevant to national parks are provided by NPS Land Resources Division [38].

Finally, the racial and population demographics of each census block group are provided by the 2015-2019 American Community Survey (ACS) records [39].

The utilization of each distinct dataset towards the extraction of our materials of interest are elaborated in the subsequent sections.

Selection of mainland US national parks

We adapt the official and formal definition of national parks as defined and listed by the NPS System [40].

We select national parks within the 48 states encompassing mainland USA. We chose to omit the parks that fall within the states of Alaska, Hawaii, Puerto Rico and other US minor Islands considering the fact that air travel is a necessity for out-of-state visitors to visit these parks. These separate travel behavioral patterns could result in confounding variables towards our analysis, particularly since air travel faced major disruptions amidst the COVID-19 pandemic [41, 42].

It is worth noting that New River George National Park was declared as a national park only following the COVID-19 pandemic [43]. Hence, it is excluded from our study.

Finally, we lack the data availability for White Sands National Park and Dry Tortugas National Park. The fore is due to its proximity to White Sands Missile Range and security concerns on mobile device data [44]. The latter’s lack of data availability could be attributed to the fact that the park is on an island off the coast of Key West, FL [45].

Henceforth, we include a grand total of 48 national parks in our study.

Extraction of POIs

We select our points-of-interests (POIs) based on the dataset made available by SafeGraph [37]. While SafeGraph does provide its own classification of ”national parks”, its classification methodology remains inconsistent with the National Parks Service System’s official definition and formal list of ”national parks” [16, 40].

Hence, in order to determine our relevant POIs for selection towards each distinct national park, we extracted POIs that fall within the encompassed polygon shapefiles of each respective national park. The polygon shapefiles are courtesy of the NPS OpenData [38].

We then select the POI with the highest average monthly visitation records for each distinct national park. The choice to select the POI with the highest visitation record could be attributed to the fact that a brief analysis reveals that the POIs for each national park with the top 5 POIs tends to fall within the same vicinity [16]. Thus, we only selected the POI with the highest average monthly visitation count to avoid underestimation.

Computing census block group based racial demographics

The aforementioned Safegraph [37] data provides us with the census block group of home origins of the visitors of each distinct POI. The census block group origins are identified by its 12-digit Federal Information Processing Standard (FIPS) code. We are thus able to retrieve our racial demographics of interests (% of non-whites, % of African-, % Hispanics-, % of Asian-, and % Native Americans) pertaining to each visitors census block origins.

We have decided to exclude visitors from Hawaii, Alaska, Puerto Rico and other minor US islands for their visitation patterns are expected to be abruptly disrupted following the pandemic due to restrictions put in place from air travel [41, 42]. This decision would prevent the effects of confounding variables and avoid drastically skewing our data.

Computing distance travelled by visitor to each national park

Likewise, we obtain the variables of distance in meters through the utilization of the Haversine formula [46, 47] between the POIs coordinates and the centroids of the visitors census block group. We standardize the units of distance to kilo-meters in our analysis.

Categorization of visitation records falling before and after COVID-19

We categorize classify pre-COVID era as any time-period that occurs prior to the month of March 2020. Hence, we classify the COVID era as any time period from the month of March 2020 onward. We selected March 2020 for it remains the month in which the UN declared COVID-19 a global pandemic [48]. This declaration was proceeded by numerous state and local lockdown measures which drastically impacted American commerce [49, 50, 51] and the lifestyles of many Americans [52].

Methods and Model

Issue of collinearity and high dimensionality in analysis involving racial determinants

The issue of multi-collinearity remains prevalent in past literature’s involving the analysis of vast racial determinants [53, 54, 55]. This could be attributed to the fact that the proportion of one race in a census block group are correlated towards the composition of another race in the same census block group.

Therefore, we adopt the procedures outlined by Lewis-Beck and Lewis-Beck [53], where we opt to analyze each racial composition separately. This can be best illustrated in Table. S1 of the SI appendix.

Doing so could also mitigate issues involving high dimensional data, also known as the "curse of dimensionality" [56], which could disintegrate the reliability of the model. This phenomenon occurs during the addition of multi-features into one model, resulting in unreliable results.

Offsetting visitation counts with the census block group population

Because racial demographics of the visitors census origins are measured at a census block level, we offset the visitation counts per census block population, where

$$\frac{visitation_{ijt}}{\left(\frac{population_i}{1000}\right)} = f(covid_era, race_i, distance_{ij}, interaction_terms) \quad (1)$$

This allows us to account for the fact that one would naturally expect higher visitation counts from more populated census block groups.

Gravity Model

We incorporate the gravity model into our methodology. The gravity model seeks to explore the behavior and travel patterns over distances between 2 unique points-of-interests. The gravity model has been frequented in tourism and the social sciences [57, 58, 59, 60, 61]. Thus, given that this research question seeks to explore the number of visitation from each census block group to each national park, it is appropriate to utilize this model.

Given i^{th} census block group and j^{th} national park where α_k symbolizes each respective coefficient towards the determined independent variable, the gravity model could be demonstrated as such:

$$\frac{visitation_{ijt}}{\left(\frac{population_i}{1000}\right)} \propto \frac{race_i^{\alpha_1} * interaction_terms^{\alpha_2}}{distance_{ij}^{\alpha_3}} \quad (2)$$

which can be remodelled as:

$$visitation_{ijt} \propto \frac{race_i^{\alpha_1} * interaction_terms^{\alpha_2} * \left(\frac{population_i}{1000}\right)^{\alpha_4}}{distance_{ij}^{\alpha_3}} \quad (3)$$

using natural logarithms could be transformed to:

$$\begin{aligned} \ln(visitation_{ijt}) &\propto \alpha_1 \ln(race_i) \\ &+ \alpha_2 \ln(interaction_terms) \\ &+ \alpha_3 \ln(distance_{ij}) \\ &+ \alpha_4 \ln\left(\frac{population_i}{1000}\right) \end{aligned} \quad (4)$$

Model Specification

The Gravity Model is incorporated using panel data with interaction terms to control observable individual effects while measuring the impact of COVID-19 towards our selected predictors. Specifically, the random-effects panel approach was selected in favor of the fixed-effects panel model and the pooled ordinary least squares (OLS) model as evident by the results of the F-tests [62], Hausman's Chi-Squared [63], and the Breusch-Pagan (BP) Lagrange Multiplier [64] tests displayed in Table S3 of SI appendix.

This results in Eqn. (5), given each i^{th} census block group's visitation to j^{th} national parks during t^{th} month over specified race $race_i$.

$$\begin{aligned}
\ln(visitation_{ijt}) = & \beta_0 + \beta_1(COVID_era) + \beta_2[\ln(race_i)] + \beta_3[\ln(distance_{ij})] \\
& + \beta_4 \left[\ln \left(\frac{population_i}{1000} \right) \right] + \beta_5[COVID_era \times \ln(race_i)] \\
& + \beta_6[(COVID_era \times \ln(distance_{ij}))] \\
& + \beta_7[\ln(distance_{ij}) \times \ln(race_i)] \\
& + \beta_8[(COVID_era \times \ln(distance_{ij}) \times \ln(race_i))] + V_{ijt}
\end{aligned} \tag{5}$$

References

- [1] Abraham J Miller-Rushing et al. “COVID-19 pandemic impacts on conservation research, management, and public engagement in US national parks”. In: *Biological Conservation* 257 (2021), p. 109038.
- [2] John A Kupfer et al. “Using Mobile Device Data to Track the Effects of the COVID-19 Pandemic on Spatiotemporal Patterns of National Park Visitation”. In: *Sustainability* 13.16 (2021), p. 9366.
- [3] Xiao Xiao, KangJae Jerry Lee, and Lincoln R Larson. “Who visits US national parks (and who doesn’t)? A national study of perceived constraints and vacation preferences across diverse populations”. In: *Journal of Leisure Research* (2021), pp. 1–22.
- [4] Zoe M Volenec et al. “Public parks and the pandemic: How park usage has been affected by COVID-19 policies”. In: *PloS one* 16.5 (2021), e0251799.
- [5] William L Rice et al. “Changes in recreational behaviors of outdoor enthusiasts during the COVID-19 pandemic: analysis across urban and rural communities”. In: *Journal of Urban Ecology* 6.1 (2020), juaa020.
- [6] Jennifer M Pipitone and Svetlana Jović. “Urban Green Equity and COVID-19: Effects on Park Use and Sense of Belonging in New York City”. In: *Urban Forestry & Urban Greening* (2021), p. 127338.
- [7] David Scott and Kang Jae Jerry Lee. “People of color and their constraints to national parks visitation”. In: *The George Wright Forum*. Vol. 35. 1. JSTOR. 2018, pp. 73–82.
- [8] Joe Weber and Selima Sultana. “Why do so few minority people visit National Parks? Visitation and the accessibility of “America’s Best Idea””. In: *Annals of the Association of American Geographers* 103.3 (2013), pp. 437–464.

- [9] Toby Beauchamp. “Beyond the “Pine Pig” Reimagining Protection through the US National Park Ranger”. In: *Radical History Review* 2020.137 (2020), pp. 96–118.
- [10] Myron F Floyd and Cassandra Y Johnson. “Coming to terms with environmental justice in outdoor recreation: A conceptual discussion with research implications”. In: *Leisure Sciences* 24.1 (2002), pp. 59–77.
- [11] Cassidy Jones, Nate Shipley, and Sabah Ul-Hasan. “Bringing parks back to the people: Revisiting the dual mandate and core values of the National Park Service”. In: *The George Wright Forum*. Vol. 34. 1. JSTOR. 2017, pp. 45–52.
- [12] Akiebia S Hicks et al. “When green is blue: Perspectives on inclusivity and recommendations towards reforming and demilitarizing law enforcement in US national parks”. In: *Parks Stewardship Forum*. Vol. 36. 3. 2020.
- [13] Pamela S Ziesler and David Pettebone. “Counting on visitors: A review of methods and applications for the National Park Service’s visitor use statistics program”. In: *Journal of Park and Recreation Administration* 36.1 (2018).
- [14] Christopher Monz et al. “Mobile Device Data Analysis to Determine the Demographics of Park Visitors.” In: *Journal of Park & Recreation Administration* 39.1 (2021).
- [15] SafeGraph. *SafeGraph Privacy Policy*. 2021. URL: <https://www.safegraph.com/privacy-policy>.
- [16] Yun Liang et al. “Assessing the validity of SafeGraph data for visitor monitoring in Yellowstone National Park”. In: *Collection of TTRA 2021 Research Papers and Abstracts - 51st Annual Travel and Tourism Research Association International Conference* (2021).
- [17] Kyuhyun Lee and Ipek N Sener. “Emerging data for pedestrian and bicycle monitoring: Sources and applications”. In: *Transportation research interdisciplinary perspectives* 4 (2020), p. 100095.
- [18] MNA Abdullah. “Revenge tourism: Trend or impact post-pandemic Covid-19?” In: *Promoting Creative Tourism: Current Issues in Tourism Research*. Routledge, 2021, pp. 623–627.
- [19] Desy Oktaviani and Deden Sutisna. “An Analytical Study of the Readiness of Eco-Tourism Based Transactions in the Mount Putri Bandung (Indonesia) Tourism Area”. In: *Review of International Geographical Education Online* 11.3 (2021), pp. 229–234.
- [20] Thomas Zhao et al. “Park Visitation Dashboard”. In: *Spring 2021 Learning Factory Showcase* (2021).

- [21] Philipp Wassler and Daisy XF Fan. “A tale of four futures: Tourism academia and COVID-19”. In: *Tourism Management Perspectives* 38 (2021), p. 100818.
- [22] Annisa Aulya Sudjana, Siti Nur Aini, and Hilman Khaerul Nizar. “REVENGE TOURISM: ANALISIS MINAT WISATAWAN PASCA PANDEMI COVID-19”. In: *Pringgitan* 2.01 (2021).
- [23] US-Census. “State Area Measurements and Internal Point Coordinates”. In: (2020).
- [24] Tracy L Lamb et al. “A qualitative analysis of social and emotional perspectives of airline passengers during the COVID-19 pandemic”. In: *Journal of Air Transport Management* 94 (2021), p. 102079.
- [25] Ayan Paul, Philipp Englert, and Melinda Varga. “Socio-economic disparities and COVID-19 in the USA”. In: *Journal of Physics: Complexity* 2.3 (2021), p. 035017.
- [26] Ayyoob Sharifi and Amir Reza Khavarian-Garmsir. “The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management”. In: *Science of The Total Environment* (2020), p. 142391.
- [27] DBG Tai et al. “The disproportionate impact of COVID-19 on racial and ethnic minorities in the United States [published online ahead of print]”. In: *Clin Infect Dis* (2020).
- [28] Haoying Wang. “Why the Navajo Nation was hit so hard by coronavirus: Understanding the disproportionate impact of the COVID-19 pandemic”. In: *Applied Geography* 134 (2021), p. 102526.
- [29] Jeff Wahl, Seunghoon Lee, and Tazim Jamal. “Indigenous Heritage Tourism Development in a (Post-) COVID World: Towards Social Justice at Little Bighorn Battlefield National Monument, USA”. In: *Sustainability* 12.22 (2020), p. 9484.
- [30] Neeta Kantamneni. “The impact of the COVID-19 pandemic on marginalized populations in the United States: A research agenda”. In: *Journal of Vocational Behavior* (2020).
- [31] Lisa Polen et al. “Supporting Native American girls during the COVID-19 pandemic”. In: *SOCIAL AND BEHAVIORAL SCIENCE RESEARCH (SBSR) - Gender, Poverty, and Youth* (2021).
- [32] Mariela Fernandez and Peter A Witt. “Attracting Hispanics to an African American recreation center: Examining attitudes and historical factors”. In: *Journal of Leisure Research* 45.4 (2013), pp. 423–444.
- [33] Christian Roberto Iniguez et al. “Black History Month in the Science Museum in London.” In: *The Science Museum* (2001).

- [34] Dolly A John et al. “Nativity and occupational class disparities in uninsurance and routine preventive care use among Asian Americans”. In: *Journal of immigrant and minority health* 15.6 (2013), pp. 1011–1022.
- [35] Juliana M Horowitz et al. “Americans widely support paid family and medical leave, but differ over specific policies”. In: *Washington, DC: Pew Research Center* 54 (2017).
- [36] Douglas S Massey. *Categorically unequal: The American stratification system*. Russell Sage Foundation, 2007.
- [37] SafeGraph. *Mobile phone data from SafeGraph Inc.* 2021. URL: <https://shop.safegraph.com/?countries=US&poi=ALL>.
- [38] National Park Service Land Resources Division. *National Park Service Tract and boundary data*. 2021. URL: <https://public-nps.opendata.arcgis.com/datasets/nps-boundary>.
- [39] *2019 American Community Census survey data 5 year estimate*. 2019. URL: https://www.socialexplorer.com/tables/ACS2019_5yr/R12847148.
- [40] “National Park System (U.S. National PARK SERVICE)”. In: *National Parks Service* (2021). URL: <https://www.nps.gov/aboutus/national-park-system.htm>.
- [41] SUSAN DONOFRIO et al. “Airlines Today: How to Manage COVID-19 Disruption”. In: *FTI consulting* (2021).
- [42] Megersa Abate, Panayotis Christidis, and Alloysius Joko Purwanto. “Government support to airlines in the aftermath of the COVID-19 pandemic”. In: *Journal of air transport management* 89 (2020), p. 101931.
- [43] NPS. *NEWS RELEASE: New River Gorge is Now a National Park and Preserve*. 2021. URL: <https://www.nps.gov/neri/learn/news/new-river-gorge-is-now-a-national-park-and-preserve.html>.
- [44] *White Sands National Park (U.S. National PARK SERVICE)*. 2021. URL: <https://www.nps.gov/whsa/planyourvisit/park-closures.htm>.
- [45] “Dry Tortugas National PARK (U.S. National PARK SERVICE)”. In: *National Parks Service* (2021). URL: <https://www.nps.gov/drto/index.htm>.
- [46] C Carl Robusto. “The cosine-haversine formula”. In: *The American Mathematical Monthly* 64.1 (1957), pp. 38–40.
- [47] Robert J Hijmans et al. “Package ‘geosphere’”. In: *Spherical trigonometry* 1.7 (2017).
- [48] Domenico Cucinotta and Maurizio Vanelli. “WHO declares COVID-19 a pandemic”. In: *Acta Bio Medica: Atenei Parmensis* 91.1 (2020), p. 157.

- [49] Robert W Fairlie. *The impact of Covid-19 on small business owners: Evidence of early-stage losses from the April 2020 current population survey*. Tech. rep. National Bureau of Economic Research, 2020.
- [50] Robert W Fairlie. “The impact of COVID-19 on small business owners: Continued losses and the partial rebound in May 2020”. In: *NBER working paper w27462* (2020).
- [51] Robert W Fairlie. *The impact of COVID-19 on small business owners: The first three months after social-distancing restrictions*. Tech. rep. National Bureau of Economic Research, 2020.
- [52] Sathyanarayanan Doraiswamy et al. “COVID-19 lockdown and lifestyles—A narrative review”. In: *Preprints* (2020).
- [53] Colin Lewis-Beck and Michael Lewis-Beck. *Applied regression: An introduction*. Vol. 22. Sage publications, 2015.
- [54] Luyu Liu, Harvey J Miller, and Jonathan Scheff. “The impacts of COVID-19 pandemic on public transit demand in the United States”. In: *Plos one* 15.11 (2020), e0242476.
- [55] M Katherine Hutchinson. “The influence of sexual risk communication between parents and daughters on sexual risk behaviors”. In: *Family Relations* 51.3 (2002), pp. 238–247.
- [56] Ana Maria Aguilera et al. “Assessing social interest in burnout using Google Trends data”. In: *Social Indicators Research* 156.2 (2021), pp. 587–599.
- [57] Ramesh Durbarry. “Tourism taxes: Implications for tourism demand in the UK”. In: *Review of Development Economics* 12.1 (2008), pp. 21–36.
- [58] So Young Park and Bing Pan. “Identifying the next non-stop flying market with a big data approach”. In: *Tourism Management* 66 (2018), pp. 411–421.
- [59] Clive Morley, Jaume Rosselló, and Maria Santana-Gallego. “Gravity models for tourism demand: theory and use”. In: *Annals of Tourism Research* 48 (2014), pp. 1–10.
- [60] Yang Yang and Kevin KF Wong. “A spatial econometric approach to model spillover effects in tourism flows”. In: *Journal of Travel Research* 51.6 (2012), pp. 768–778.
- [61] Faruk Balli, Hatice O Balli, and Rosmy Jean Louis. “The impacts of immigrants and institutions on bilateral tourism flows”. In: *Tourism Management* 52 (2016), pp. 221–229.
- [62] Oscar Torres-Reyna. “Getting started in fixed/random effects models using R”. In: *Data & Statistical Services. Princeton University* (2010).

- [63] Jerry A Hausman. “Specification tests in econometrics”. In: *Econometrica: Journal of the econometric society* (1978), pp. 1251–1271.
- [64] Trevor S Breusch and Adrian R Pagan. “A simple test for heteroscedasticity and random coefficient variation”. In: *Econometrica: Journal of the econometric society* (1979), pp. 1287–1294.