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LETTER

# The effect of temperature on outdoor recreation activities: evidence from visits to federal recreation sites

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**Keywords:** temperature, outdoor recreation, climate change

## Abstract

This paper uses over 30 million individual-level trips in federal recreation locations to investigate the impact of short-term temperature shocks on outdoor recreation activities. Our results show that in the short term, a 1 °C temperature increase during the last six months increases the total trip duration by 1.197 d (or a 4.12% increase) and the total number of trips by 0.472 (or a 5.44% increase) at the zipcode-month level. The positive effect is primarily driven by the increased number of trips and more in-state travel. We find that the impact of temperature on the number of recreation trips generally increases under a higher temperature. When the monthly temperature is below 5 °C, the temperature increase will reduce the number of trips as individuals in low-temperature regions are likely to reduce travel when the temperature gets warmer.

## 1. Introduction

Outdoor recreation activities contribute positively to both physical and mental health [1–3]. Outdoor recreation helps maintain lower body fat percentages and lead to lower blood pressure and cholesterol level [4, 5] while also helping stress management and reducing anxiety or depression [6–9]. Nearly half of Americans aged six and older participate in various types of outdoor recreation activities such as hiking, camping, and fishing, among many others [10]. In addition to personal benefits, outdoor recreation activities can also stimulate the destination economy as visitors spend on items such as food and lodgings as well as contributing to the overall economics by buying specialized equipment and paying for travel costs [11, 12]. Outdoor recreation is one of the largest economic sectors in the U.S. and lead to about $887 billion in consumer spending in 2017, which is substantially higher than several other prominent economic sectors such as education ($278 billion), gasoline and fuels ($304 billion), and pharmaceuticals ($468 billion) [10]. Outdoor recreation is a critical component of everyday life but relatively understudied.

Outdoor recreation activities are directly impacted by climate change [13, 14]. An increase in greenhouse gas concentration will lead to changes in the temperature and other climate factors [15–17], thus impacting the individuals' decisions on outdoor recreations. While it is easy to agree that climate change will impact outdoor recreations, current research provides mostly qualitative evidence and speculates about the relationship or limits to specific types of recreation activities such as bicycling or fishing [18–24]. This paper advances the literature by providing the first comprehensive quantitative analyses on the relationship between temperature and outdoor recreation activities based on more than 30 million individual-level trip data obtained from Recreation.gov, a portal for outside recreation activities at federal sites collaborated by 12 federal agencies such as the National Park Service. We aggregated individual trip data at a zipcode-by-month level to match with high resolution (on a 4 km grid) temperature data obtained from PRISM. Our methods explicitly control for the location differences to isolate the impact of short-term temperature shocks on outdoor recreation activities based on flexible fixed effects models.

## 2. Method

### 2.1. Data sources

Temperature data at the zipcode level is constructed from the PRISM Climate Group at Oregon State University [25]. The PRISM climate data has been used widely in academic journals and has extensive geographic and time coverage as well as high resolution [26–29]. We use the monthly long-term temperature data from January 2007 to December 2019. The PRISM temperature is stored in the raster format and we use ArcGIS to first convert the raster to polygon format, which is then used to intersect with the U.S. zipcode boundary file to calculate the average monthly temperature at the zipcode level. The outdoor recreation data is obtained from Recreation.gov, which provides individual-level trip data for over 4200 facilities and 113 000 individual sites across the country from 2016 to present, including a rich set of variables such as the location of the visitor, visiting length, visiting destination, and many others. There are currently over 21 million users of the website. The types of outdoor recreational activities cover camping, hiking, horseback riding, wildlife viewing, monument tours, and many others. The website is a collaborative effort by 12 federal agencies including the Bureau of Land Management, National Oceanic & Atmospheric Administration, National Park Service, Fish and Wildlife Service, US Forest Service, and others. We excluded the year 2006 due to a small number of observations and excluded the data after 2020 due to the influence of the pandemic. The dataset includes information on 31 150 985 individual-level trips. We dropped trip information without origination location (i.e. zipcode) and then aggregated the individual data at the zipcode-by-month level. Our data sample used for regression analysis contains 2 350 802 observations at the zipcode-by-month level.

### 2.2. The effect of temperature on trip decisions

We use a fixed effects model to investigate the average impact of temperature on outdoor regression decisions. The empirical model is specified as follows:

$$y_{zmy} = \beta T_{zmy} + \tau T^{d}_{zmy} + \theta_m + \gamma_{zy} + \epsilon_{pym}, \quad (1)$$

where $z$ indexes zipcode, $m$ indexes month of the year, and $y$ indexes year. The dependent $y_{zmy}$ represents the total trip duration or the number of trips at zipcode $z$ in month m of year $y$, the $T_{zmy}$ represents the average monthly temperature at zipcode $z$ in month m of year $y$ at the origin location, and $T^{d}_{zmy}$ is the average monthly temperature at zipcode $z$ in month m of year $y$ at the traveling destination. $\beta$ is the coefficient of interest and indicates the effect of the average temperature on the trip decisions. $\theta_m$ controls for the month of the year fixed effects and absorbs all time-invariant, month-specific variations. $\gamma_{zy}$ captures the zipcode-by-year fixed effects and controls for differential yearly trends at the zipcode level. In some specifications, we control for the yearly and zipcode level fixed effects, which control for the time-invariant factors across zipcodes and years. Our set of fixed effects effectively controls for the potential confounding factors that change across years and allow such changes to differ across different zipcodes when we control for the zipcode-by-year fixed effects. $\varepsilon_{pym}$ is the idiosyncratic error term. The estimated standard errors are clustered at the zipcode level when controlling the zipcode fixed effects and yearly fixed effects, and clustered at the zipcode-by-year level when controlling for the zipcode-by-year fixed effects. In addition, we also specify a selection model where we first estimate the impact of temperature on the probability of the outdoor recreation trips and then estimate the impact of temperature on the trip duration conditional on making the trip decision based on the outcome equation (heckman1979sample).

To investigate the heterogenous effects of temperature on the trip decisions, we use a binned approach and specify the following model:

$$y_{zmy} = f(T_{zmy}; \mathcal{B}) + \tau T^{d}_{zmy} + \theta_m + \gamma_{zy} + \epsilon_{pym}, \quad (2)$$

where $z$ indexes zipcode, $m$ indexes month of the year, and $y$ indexes year. $y_{zmy}$, $T^{d}_{zmy}$, $\theta_m$, $\gamma_{zy}$, and $\varepsilon_{pym}$ follow the same definitions as in the equation above. The $f(T_{zmy}; \mathcal{B})$ can be specified as a flexible function to capture the nonlinear, heterogeneous effects of temperature on trip decisions. Specifically, we use

$$f(T_{zmy}; \mathcal{B}) = \sum_{s \in \mathcal{S}} \beta_s T_{zmy} I(T_{zmy} \in s) \quad (3)$$

where $I(\cdot)$ is an indicator function and equals 1 if $T_{zmy} \in s$ and zero otherwise. The $\mathcal{S}$ is the set of temperature within the data range and $s$ stands for the different temperature bins. In our context, $s$ indexes eight temperature bins including <0 °C, 0 °C–5 °C, 5 °C–10 °C, 10 °C–15 °C, 15 °C–20 °C, 20 °C–25 °C, 25 °C–30 °C, and >30 °C. The nonlinear, heterogenous relationship is thus captured by the set of coefficients $\beta_s$.

## 3. Results

### 3.1. Total trip duration and temperature

To investigate the impact of temperature changes on trip durations, we first aggregate the individual trip duration data (measured in days) at the zipcode-by-month level and then match it with the temperature data. Figure A1 in the appendix presents the distribution of trip duration in our sample. The mean duration is 29.02 d per month at the zipcode level. We use the monthly average temperature (in Celsius) at the visitors' origination location (also at the zipcode level) and use fixed effects estimation strategies. To examine the potential response to the current temperature and recent temperature changes, we compile the monthly average temperature for the current month as well as the average temperature for the past 1 to 12 months at the visitors' origination zipcodes. We used a couple of alternative specifications with the detailed models discussed in the Methods section. Our data used for statistical analyses ranges from January 2007

**Table 1.** Recreation activities based on the temperature in the current and previous month.

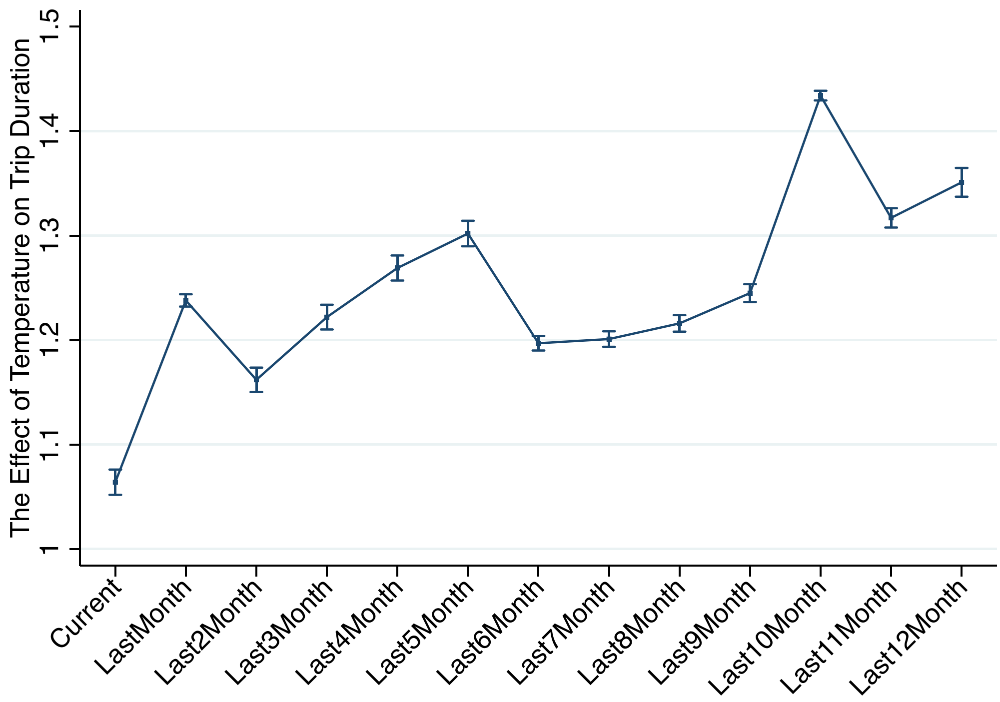
| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of trips | (5) OLS Number of trips | (6) Tobit Number of trips |
|---|---|---|---|---|---|---|
| Panel A: response to temperature in the current month | | | | | | |
| Temp. current month | 0.350*** | 0.422*** | 1.064*** | −0.00 622*** | 0.0417*** | 0.0418*** |
| | (0.00 690) | (0.00 691) | (0.00 617) | (0.00 201) | (0.00 203) | (0.00 203) |
| Constant | 32.13*** | 32.91*** | 19.13*** | 7.657*** | 7.863*** | 7.867*** |
| | (0.0655) | (0.0671) | (0.201) | (0.0191) | (0.0197) | (0.0197) |
| $N$ | 2 350 802 | 2 349 069 | 2 351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −11 084 430.4 | −11 118 631.4 | −11 948 158.3 | −8 188 979.3 | −8 242 362.4 | −8 236 234.5 |
| Panel B: response to temperature in the last month | | | | | | |
| Temp. last month | 0.467*** | 0.515*** | 1.238*** | 0.0726*** | 0.107*** | 0.108*** |
| | (0.00 622) | (0.00 624) | (0.00 301) | (0.00 182) | (0.00 183) | (0.00 184) |
| Constant | 31.17*** | 32.22*** | 12.03*** | 7.485*** | 7.721*** | 7.725*** |
| | (0.0697) | (0.0711) | (0.174) | (0.0204) | (0.0209) | (0.0209) |
| $N$ | 2 347 230 | 2 345 505 | 2 348 276 | 2 347 230 | 2 345 505 | 2 345 505 |
| ll | −11 062 130.3 | −11 092 804.7 | −11 565 514.2 | −8 171 297.8 | −8 220 676.4 | −8 214 558.9 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year fixed effects (F.E). | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

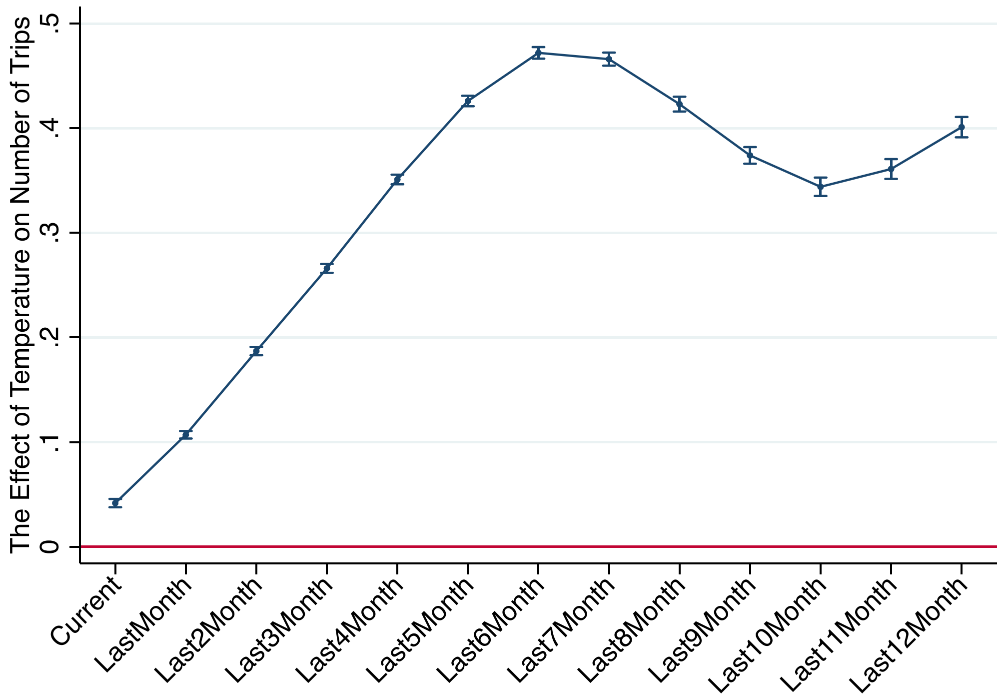
to December 2019 and covers all the zipcodes in the U.S.

We first present results on the relationship between total trip duration and the temperature in current and previous months in table 1. Panel A presents the impact of the temperature of the current month on trip duration and Panel B presents the impact of temperature in the previous month on trip duration. Column 1 presents the model controlling for the month of the year, zipcode, and yearly fixed fixed effects, while column 2 presents the model controlling for the month of the year and zipcode by year fixed effects to allow for differential yearly trends at the zipcode level. Column 3 presents the results based on the outcome equation in the Heckman selection model, where the coefficient associated with temperature can be interpreted as the impact of temperature change on the trip duration conditional on making a trip. Our results show that the average monthly temperature significantly increases the total trip duration. According to the estimation in column 3, we find a 1 °C increase in the average temperature in the current and previous month will extend the total trip duration by 1.064 and 1.238 d on average at the zipcode level, conditional on making the recreation trip, respectively.

To investigate the impact of recent temperature on trip durations, we further compile the average temperature at the visitors' origination zipcodes during the 1–12 months before the trip decisions and apply the same model specifications to control for the month of the year, as well as the zipcode-by-year fixed fixed effects. Results are presented in figure 1(a) where the horizontal axis indicates the time period used to construct the temperature measurement. For example, the label 'Last6Month' indicates that the temperature measurement is based on the average temperature during the last six months of the trip decision. The vertical axis represents the magnitude of impact. Figure 1(a) suggests that the positive impacts of temperature are robust across different constructions of the temperature measurements. Based on our estimates, the impact is lowest when using the average temperature in the current month (1 °C increase in the average temperature extends the total trip duration by 1.064 d, or a 3.68% increase) and highest when using the average temperature in the last ten months (1 °C increase in the average temperature extends the




(a) The Effect of Temperature over the last 12 months on the Trip Duration.




(b) The Effect of Temperature over the last 12 months on the Number of the Trips.

**Figure 1.** The effect of temperature over the last 12 months on trip decisions.

total trip duration by 1.434 d, or a 4.94% increase) conditional on making the trip.

### 3.2. Number of trips and temperature

Similarly, we aggregated the number of trips at the zipcode-by-month level and then matched it with the temperature data to investigate the relationship between temperature and the number of trips. Figure A2 in the appendix presents the distribution of the number of trips in our sample. The mean number of trips is 8.68 per month at the zipcode level. We still use the monthly average temperature at the visitors'

**Table 2.** Recreation activities based on the deviation to long-term temperature in the current and previous month.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of trips | (5) OLS Number of trips | (6) Tobit Number of trips |
|---|---|---|---|---|---|---|
| Panel A: response to deviation of long term temperature in the current month. | | | | | | |
| Dev. of temp. current month | 0.337*** | 0.524*** | 0.571*** | 0.0442*** | 0.102*** | 0.105*** |
| | (0.00 567) | (0.00 587) | (0.00 433) | (0.00 165) | (0.00 173) | (0.00 171) |
| Constant | 36.58*** | 39.71*** | 16.26*** | 8.177*** | 9.131*** | 9.137*** |
| | (0.0938) | (0.0967) | (0.162) | (0.0274) | (0.0284) | (0.0285) |
| *N* | 2 350 802 | 2 349 069 | 2 351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −11 083 937.6 | −11 116 461.7 | −11 572 907.4 | −8 188 622.2 | −8 240 806.3 | −8 234 675.9 |
| Panel B: response to deviation of long-term temperature in the last month. | | | | | | |
| Dev. of temp. last month | 0.410*** | 0.563*** | 2.084*** | 0.0909*** | 0.138*** | 0.139*** |
| | (0.00 520) | (0.00 537) | (0.00 843) | (0.00 152) | (0.00 158) | (0.00 159) |
| Constant | 36.81*** | 39.47*** | 41.55*** | 8.612*** | 9.429*** | 9.482*** |
| | (0.0814) | (0.0835) | (0.224) | (0.0237) | (0.0245) | (0.0247) |
| *N* | 2 347 230 | 2 345 505 | 2 348 276 | 2 347 230 | 2 345 505 | 2 345 505 |
| ll | −11 061 834.6 | −11 090 687.3 | −11 927 261.9 | −8 170 288.0 | −8 218 502.3 | −8 157 337.4 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. The long-term temperature is calculated based on the average temperature in the same zipcode in the past ten years. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

origination location and the fixed effects estimation strategies. Results are presented in columns 4 to 6, controlling for different sets of fixed effects based on ordinary least square and Tobit specifications, in table 1. Panel A presents the impact of the temperature of the current month on the number of trips and panel B presents the impact of temperature in the previous month on the number of trips. Our results show that the average monthly temperature significantly increases the number of trips. According to our preferred estimation in column 6, we find a 1 °C increase in the average temperature in the current and previous months will increase the number of trips by 0.0418 and 0.108 d on average at the zipcode level, respectively. Figure 1(b) further presents the results on the relationship between the number of trips and the average temperature from the last 1–12 months. Our results also show that the magnitude of impact is highest using the average temperature in the last six months (1 °C increase in the average temperature extends the total number of trips by 0.472, or a 5.44% increase).

The above results provide strong and consistent evidence on the positive impact of temperature on outdoor recreation activities. We find that using the average temperature in the last six months or longer enables a relatively stable and consistent estimation of the magnitude of impacts. Using the average temperature in the last six months, we find that the temperature has a larger proportional effect on the number of trips compared to the trip duration. As a result, the average trip duration is reduced. If the average duration per trip stays the same, the increase in the number of trips would result in the same proportional increase in the trip duration. Therefore, our results suggest the temperature increases the outdoor recreation activities through increasing the extensive margin (i.e. the number of trips) and slightly suppressing the intensive margin (i.e. the average duration of a trip), although the net effect is still positive as evaluated by the total trip duration. This result still holds when we use the estimates from the average temperature in the last 7–12 months.

In addition, instead of using the absolute temperature, we use the deviation from the normal temperature (the average temperature from the last ten years) to investigate how temperature shocks will impact outdoor recreation decisions. Results are presented in table 2. Our results also suggest that a larger deviation from normal temperature will significantly increase outdoor recreation activities through both trip duration and the number of trips. To account for spatial autocorrelation in temperature at broader scales, we control for the state fixed effects instead of zipcode level fixed effects, results are presented in table A2 in the appendix. Our results still hold when we control for the state fixed effects instead. Since PRISM dataset does not use actual temperature, we conducted additional analyses using daily weather data from the Global Historical Climate Network (GHCN-Daily) and aggregate the temperature at the month-zipcode level. We gather the weather measurements from each weather station of the zipcode's centroid. We also weight observations by the station's inverse distance squared from the zipcode's centroid. Our main conclusions still hold that temperature increases will significantly increase outdoor recreation activities based on the GHCN-Daily data.

We further investigate the difference between out-of-state and in-state trips. The out-of-state trip is defined as when the destination and the origination locations are in different states. The mean durations are 10.95 and 19.95 d per month at the zipcode level for the out-of-state and in-state trips, while the mean trip numbers are 3.82 and 5.46 per month at the zipcode level for the out-of-state and in-state trips, suggesting visitors tend to visit more frequently and stay longer for the in-state destinations. Based on the summary statistics, we find that the out-of-state trips represent about 36% of the total trips in terms of total duration and 41% in terms of trip number. We replicate the analyses on the effect of temperature using the in-state and out-of-state subsamples to compare the potential differences between the in-state and out-of-state samples. Figures 2(a) and (b) present the in-state and out-of-state comparison on the total trip duration and number of trips, respectively. Our results show that the effect of temperature on trip decisions is primarily driven by in-state trips. Compared to in-state trips, the temperature has a much lower impact on the out-of-state trips both on the total duration and the number of trips, even though most of the estimates are still statistically significant, potentially due to the large sample size. Since out-of-state trips require more planning and are usually more costly, when individuals respond to weather changes (e.g. mitigate the impact of temperature increase) by increasing outdoor activities, in-state recreational trips are much easier to materialize.

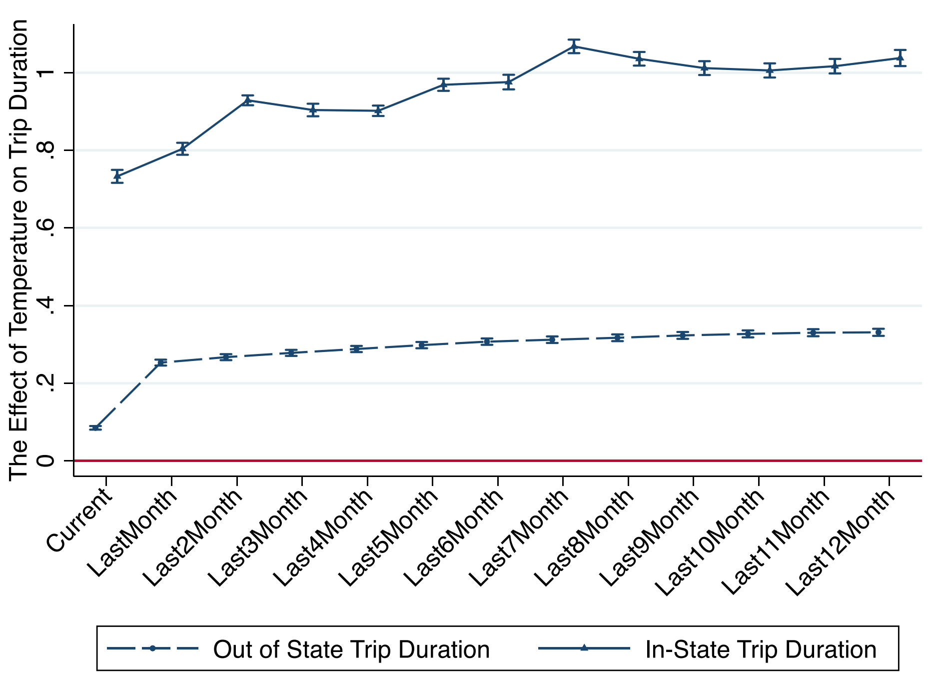
### 3.3. Heterogeneous impacts of temperature on trip decisions

The impact of temperature on trip decisions can be heterogeneous depending on the range of temperature. To investigate the heterogeneous impacts of temperature on trip decisions, we used a binned approach to allow for a nonlinear relationship between the temperature and trip decisions. The impact of temperature will be constant in the same bin but differ across different bins. The distribution of average monthly temperature in our data is presented in figure A3 in the appendix. We divided the temperature into the following eight bins: $<0$ °C, 0 °C–5 °C, 5 °C–10 °C, 10 °C–15 °C, 15 °C–20 °C, 20 °C–25 °C, 25 °C–30 °C, and $>30$ °C. Tables A3–A6 present the estimated results based on the average monthly temperature in the past month, past four months, past eight months, and past twelve months, respectively. Figures 3 and 4 summarize the heterogeneous impacts on the trip duration and the number of trips using different temperature measurements based on the estimation results controlling for the month of the year and the zipcode-by-year fixed effects, respectively.

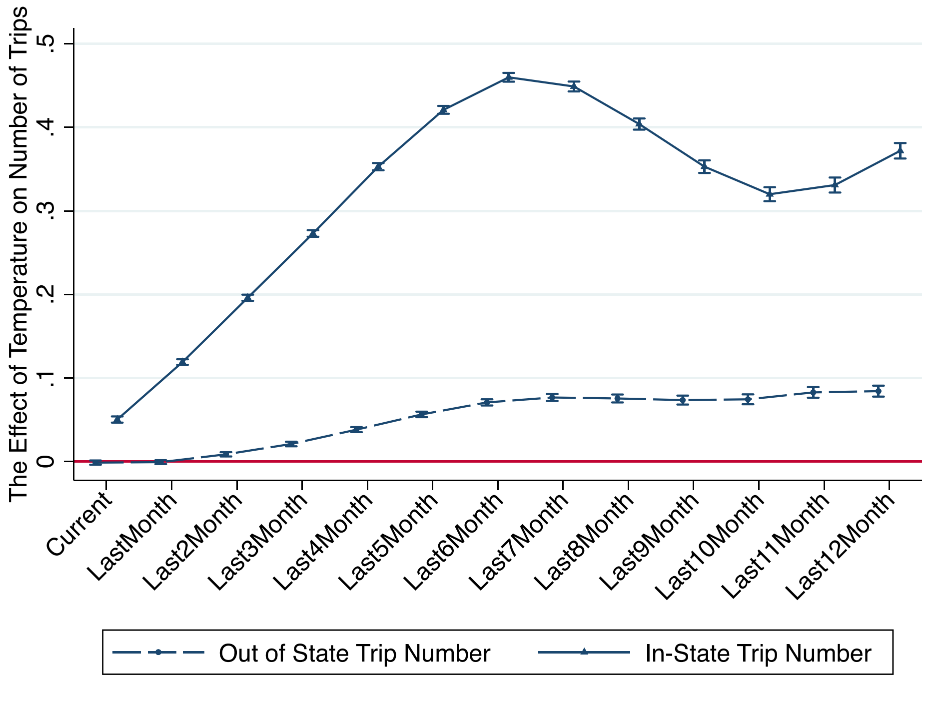
Based on figure 3, our results indicate that temperature increase has a positive impact on the trip duration across all temperature intervals. We also find that the impact of temperature on the trip duration conditional on making the trip seems to be the largest at a mild temperature (the 15 °C–20 °C interval). Figure 4 presents the heterogeneous impacts of temperature on the number of trips. We find that when the monthly temperature is below 5 °C, the temperature increase will likely reduce the number of trips as individuals experiencing low temperatures are more likely to reduce travel when the temperature gets warm. The negative effects are significant when the temperature is based on recent history. While our results suggest that temperature increases will generally decrease the number of trips when the temperature is below 5 °C in the short term, the total trip duration still increases under a low temperature, suggesting that visitors will compensate for the reduced number of trips with a longer trip duration. Thus, our results indicate that when the temperature is low, individuals will reduce travel but they will increase travel to avoid the negative impact at a high temperature as the temperature increases.

## 4. Discussion

We demonstrate a substantial, positive impact of temperature on outdoor recreation activities. Existing literature has shown that increased temperature is likely to result in a higher mortality or morbidity rate, as well as increased mental issues [31–35]. Since outdoor recreational activities can relieve stress and improve physical health, outdoor recreation serves as an important mitigation strategy to combat climate change conditional on a moderate temperature at the destination location [36]. However, recreational activities can also put people at a higher risk of health problems such as heat stress and heat stroke as individuals are exposed directly to the environment, especially during hot weather which




(a) The Effect of Temperature over the last 12 months on the In and out-of-state Trip Duration.




(b) The Effect of Temperature over the last 12 months on the In and out-of-state Trip Numbers.

**Figure 2.** Effect of temperature over the last 12 months on the in-state and out-of-state trip decisions.

is becoming more frequent and extreme. Our recreation data and corresponding conclusions are based on the visits to the federal sites. Though we have no reason to believe outdoor recreation activities at federal sites will differ significantly from visits to state or private sites, future research could study if the temperature changes impact outdoor recreation activities at private sites differently.

Our results suggest that the increased outdoor recreational activities may contribute to higher spending in the recreational sector. If individuals are moving to cooler places to avoid excessive heat, the cost of traveling and related expenses can be seen as a defensive expenditure which would be used as one measure to approximate the cost of temperature shocks. However, the increased recreational spending

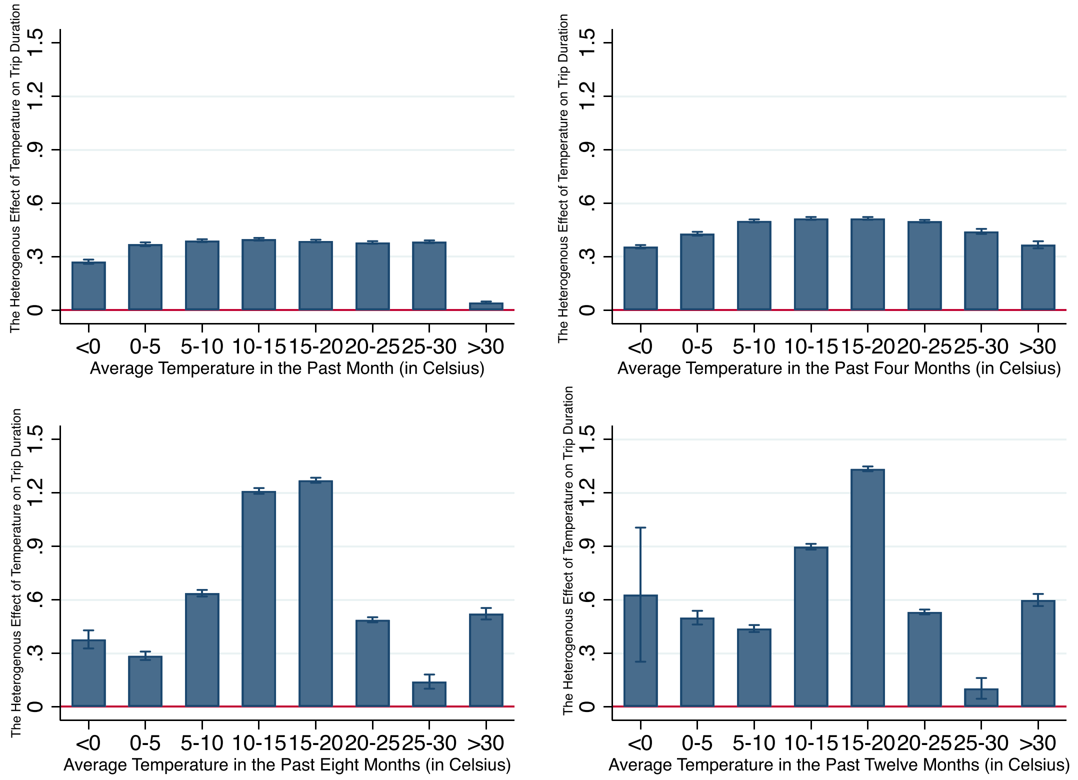



**Figure 3.** Heterogenous effect of temperature on trip duration.
Note: the heterogeneous impacts on the trip duration using the average temperatures in the last month, last four months, last eight months, and last twelve months.

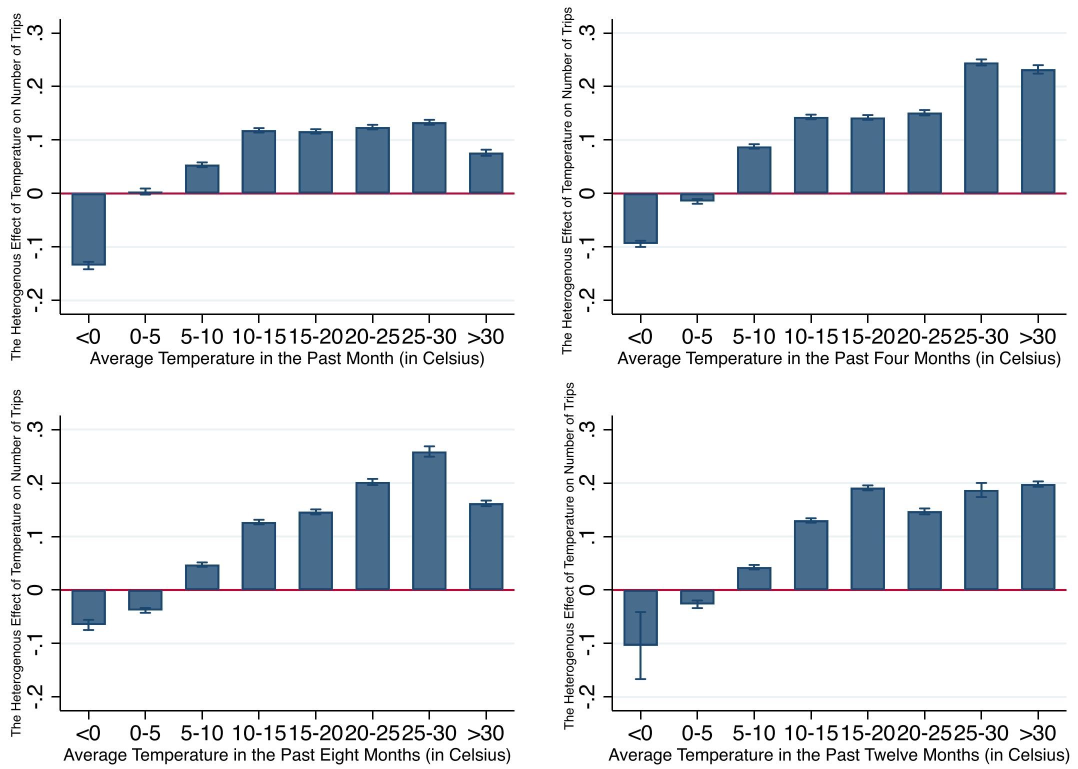



**Figure 4.** Heterogenous effect of temperature on the number of trips.
Note: the heterogeneous impacts on the number of trips using the average temperatures in the last month, last four months, last eight months, and last twelve months.

does not imply the temperature increase contributes positively to the economy. Our results only focus on the impact of temperature on one sector where we identify potential positive benefits. More analyses are needed to rigorously estimate the net impact of increased recreational activities from temperature rises accounting for other possible societal and economic impacts associated with that level of temperature rise. Since the benefits are significantly larger under a high-temperature range, future policies can increase the accessibility and availability of outdoor recreation sites at high-temperature to meet the increased demand from temperature increase.

Note that our results focus on the short-term impact of temperature changes on recreation activities. The empirical strategies rely on the short-term temperature shocks to identify the impact of temperature on outdoor recreation activities. We are unable to estimate the role of climate adaption in outdoor recreation activities since the fixed effects remove the impacts of long-term adaptations. The adaptation may limit or increase the incentive to go outdoor, which may increase or decrease the overall effects of temperature on outdoor recreation activities, respectively. Future research can explore the role of adaptation to fully assess the overall effects of climate change on recreation activities.

## Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

## Conflict of interest

The author declares no competing interests.

## Acknowledgement

The author acknowledges funding from USDA National Institute of Food and Agriculture, Hatch Regional project 1014661.

# Appendix

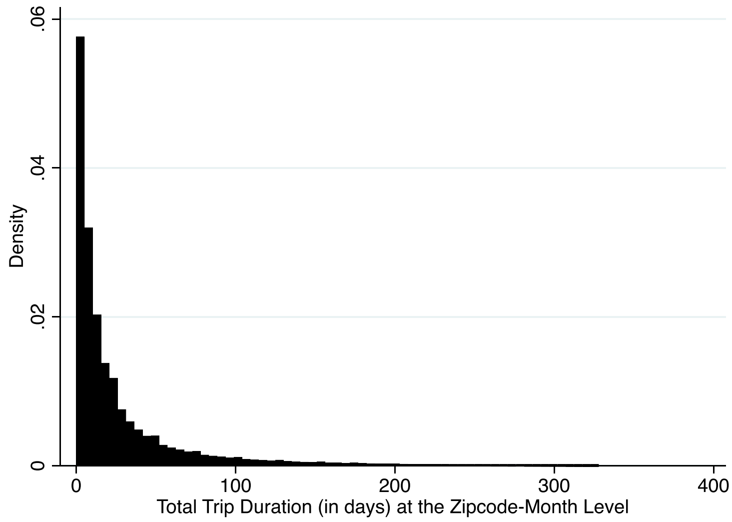



**Figure A1.** Distribution of trip duration in the data sample.
Note: that the figure presents the distribution of the total trip duration (in days) at the zipcode-by-month level.

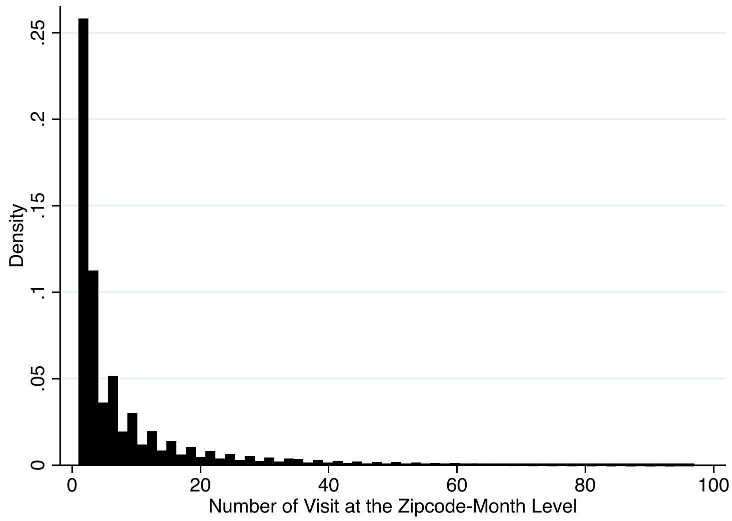



**Figure A2.** Distribution of number of trips in the data sample.
Note: that the figure presents the distribution of the number of trips at the zipcode-by-month level.

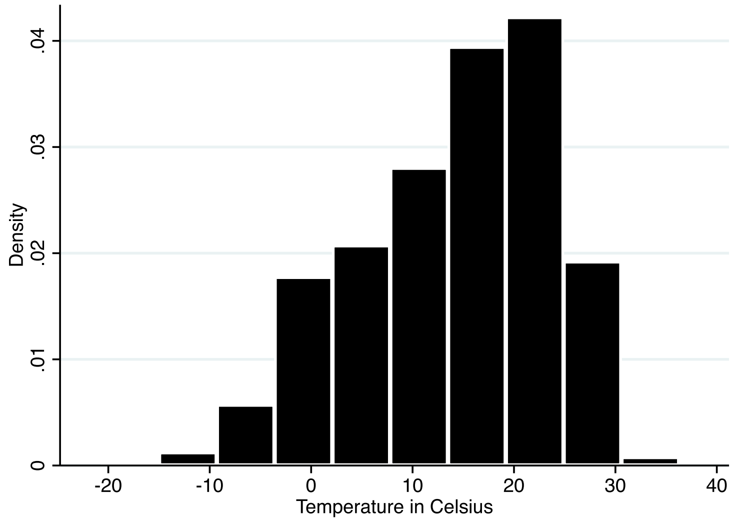



**Figure A3.** Distribution of temperature in the data sample.
Note: that the figure presents the distribution of temperature (in Celsius) at the zipcode-by-month level.

**Table A1.** Logarithm of trip duration and temperature in the current and previous month.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Trip duration | (5) OLS Trip duration | (6) Outcome equation Trip duration |
|---|---|---|---|---|---|---|
| Temp. current month | 0.00 479*** | 0.00 745*** | 0.0380*** | | | |
| | (0.000 219) | (0.000 220) | (0.000 154) | | | |
| Temp. last month | | | | 0.00 524*** | 0.00 713*** | 0.0354*** |
| | | | | (0.000 198) | (0.000 199) | (0.000 157) |
| Constant | 2.601*** | 2.625*** | 2.078*** | 2.599*** | 2.632*** | 2.282*** |
| | (0.00 208) | (0.00 214) | (0.00 491) | (0.00 222) | (0.00 227) | (0.00 567) |
| $N$ | 2 350 802 | 2 349 069 | 2 351 290 | 2 347 230 | 2 345 505 | 2 348 276 |
| ll | −2 976 057.6 | −3 024 145.2 | −4 053 052.0 | −2 968 893.7 | −3 013 289.4 | −4 085 575.9 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

**Table A2.** Recreation activities based on the deviation to long-term temperature in the current and previous month controlling for state level fixed effects.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of trips | (5) OLS Number of trips | (6) Tobit Number of trips |
|---|---|---|---|---|---|---|
| Panel A: response to deviation of long term temperature in the current month. | | | | | | |
| Dev. of temp. current month | 1.831*** | 1.858*** | 0.672*** | 0.494*** | 0.503*** | 0.504*** |
| | (0.00 792) | (0.00 790) | (0.00 481) | (0.00 231) | (0.00 230) | (0.00 231) |
| Constant | 55.25*** | 55.66*** | 20.03*** | 13.79*** | 13.94*** | 13.95*** |
| | (0.134) | (0.134) | (0.258) | (0.0391) | (0.0389) | (0.0390) |
| $N$ | 2 350 802 | 2 349 069 | 2 351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −12 045 662.4 | −12 036 917.8 | −11 524 377.9 | −9 153 460.3 | −9 139 432.4 | −9 132 527.7 |
| Panel B: response to deviation of long-term temperature in the last month. | | | | | | |
| Dev. of temp. last month | 1.700*** | 1.726*** | 0.601*** | 0.475*** | 0.485*** | 0.488*** |
| | (0.00 733) | (0.00 732) | (0.0142) | (0.00 214) | (0.00 213) | (0.00 215) |
| Constant | 49.52*** | 49.78*** | −624.0*** | 12.38*** | 12.48*** | 12.55*** |
| | (0.118) | (0.118) | (1.806) | (0.0345) | (0.0343) | (0.0346) |
| $N$ | 2 347 230 | 2 345 505 | 2 348 276 | 2 347 230 | 2 345 505 | 2 345 505 |
| ll | −12 028 324.8 | −12 019 874.7 | −12 865 897.6 | −9 138 844.5 | −9 125 130.4 | −9 056 280.4 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| State F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| State by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. The long-term temperature is calculated based on the average temperature in the same zipcode in the past 10 years. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

**Table A3.** Heterogenous effect of temperature on trip decisions: past one month.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of Trips | (5) OLS Number of trips | (6) Tobit Number of trips |
|---|---|---|---|---|---|---|
| Temp.bin $< 0\,^{\circ}$C | $-0.109^{***}$ | $-0.104^{***}$ | $0.272^{***}$ | $-0.155^{***}$ | $-0.135^{***}$ | $-0.135^{***}$ |
| | (0.0116) | (0.0119) | (0.00 610) | (0.00 339) | (0.00 349) | (0.00 350) |
| $0\,^{\circ}$C $\leqslant$ Temp.bin $< 5\,^{\circ}$C | $0.0411^{***}$ | $0.137^{***}$ | $0.370^{***}$ | $-0.0709^{***}$ | $-0.0281^{***}$ | $-0.0281^{***}$ |
| | (0.00 960) | (0.00 980) | (0.00 539) | (0.00 280) | (0.00 288) | (0.00 288) |
| $5\,^{\circ}$C $\leqslant$ Temp.bin $< 10\,^{\circ}$C | $0.405^{***}$ | $0.443^{***}$ | $0.390^{***}$ | $0.0223^{***}$ | $0.0534^{***}$ | $0.0535^{***}$ |
| | (0.00 764) | (0.00 775) | (0.00 418) | (0.00 223) | (0.00 228) | (0.00 228) |
| $10\,^{\circ}$C $\leqslant$ Temp.bin $< 15\,^{\circ}$C | $0.595^{***}$ | $0.652^{***}$ | $0.398^{***}$ | $0.0783^{***}$ | $0.118^{***}$ | $0.118^{***}$ |
| | (0.00 718) | (0.00 724) | (0.00 387) | (0.00 209) | (0.00 213) | (0.00 213) |
| $15\,^{\circ}$C $\leqslant$ Temp.bin $< 20\,^{\circ}$C | $0.580^{***}$ | $0.630^{***}$ | $0.388^{***}$ | $0.0768^{***}$ | $0.116^{***}$ | $0.116^{***}$ |
| | (0.00 721) | (0.00 725) | (0.00 370) | (0.00 210) | (0.00 213) | (0.00 213) |
| $20\,^{\circ}$C $\leqslant$ Temp.bin $< 25\,^{\circ}$C | $0.576^{***}$ | $0.644^{***}$ | $0.380^{***}$ | $0.0764^{***}$ | $0.124^{***}$ | $0.124^{***}$ |
| | (0.00 745) | (0.00 748) | (0.00 368) | (0.00 217) | (0.00 220) | (0.00 220) |
| $25\,^{\circ}$C $\leqslant$ Temp.bin $< 30\,^{\circ}$C | $0.669^{***}$ | $0.735^{***}$ | $0.384^{***}$ | $0.0853^{***}$ | $0.133^{***}$ | $0.133^{***}$ |
| | (0.00 805) | (0.00 807) | (0.00 393) | (0.00 235) | (0.00 237) | (0.00 237) |
| Temp.bin $\geqslant 30\,^{\circ}$C | $0.339^{***}$ | $0.356^{***}$ | $0.0433^{***}$ | $0.0532^{***}$ | $0.0760^{***}$ | $0.0760^{***}$ |
| | (0.00 985) | (0.01 000) | (0.00 286) | (0.00 287) | (0.00 294) | (0.00 294) |
| Constant | $30.87^{***}$ | $31.62^{***}$ | $10.70^{***}$ | $7.250^{***}$ | $7.438^{***}$ | $7.442^{***}$ |
| | (0.0686) | (0.0702) | (0.171) | (0.0200) | (0.0206) | (0.0207) |
| *N* | 2 350 802 | 2 349 069 | 2 351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −11 079 985.3 | −11 114 284.2 | −11 576 982.7 | −8 185 042.7 | −8 238 012.0 | −8 231 888.0 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

**Table A4.** Heterogenous effect of temperature on trip decisions: past four months.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of Trips | (5) OLS Number of Trips | (6) Tobit Number of Trips |
|---|---|---|---|---|---|---|
| Temp.bin < 0 °C | −0.201*** | −0.117*** | 0.356*** | −0.135*** | −0.0955*** | −0.0944*** |
| | (0.00 973) | (0.00 993) | (0.00 479) | (0.00 284) | (0.00 292) | (0.00 294) |
| 0 °C ⩽ Temp.bin < 5 °C | 0.163*** | 0.236*** | 0.429*** | −0.0609*** | −0.0162*** | −0.0150*** |
| | (0.00 763) | (0.00 768) | (0.00 550) | (0.00 223) | (0.00 226) | (0.00 227) |
| 5 °C ⩽ Temp.bin < 10 °C | 0.531*** | 0.597*** | 0.501*** | 0.0390*** | 0.0871*** | 0.0879*** |
| | (0.00 727) | (0.00 724) | (0.00 422) | (0.00 212) | (0.00 213) | (0.00 214) |
| 10 °C ⩽ Temp.bin < 15 °C | 0.696*** | 0.752*** | 0.515*** | 0.0925*** | 0.142*** | 0.143*** |
| | (0.00 750) | (0.00 743) | (0.00 409) | (0.00 219) | (0.00 218) | (0.00 220) |
| 15 °C ⩽ Temp.bin < 20 °C | 0.673*** | 0.718*** | 0.515*** | 0.0919*** | 0.142*** | 0.142*** |
| | (0.00 797) | (0.00 787) | (0.00 395) | (0.00 233) | (0.00 231) | (0.00 232) |
| 20 °C ⩽ Temp.bin < 25 °C | 0.698*** | 0.729*** | 0.499*** | 0.1000*** | 0.150*** | 0.151*** |
| | (0.00 870) | (0.00 857) | (0.00 395) | (0.00 254) | (0.00 252) | (0.00 253) |
| 25 °C ⩽ Temp.bin < 30 °C | 1.056*** | 1.067*** | 0.442*** | 0.198*** | 0.244*** | 0.245*** |
| | (0.00 989) | (0.00 978) | (0.00 718) | (0.00 289) | (0.00 288) | (0.00 289) |
| Temp.bin ⩾ 30 °C | 0.177*** | 1.181*** | 0.367*** | 0.163*** | 0.232*** | 0.232*** |
| | (0.0141) | (0.0137) | (0.0102) | (0.00 412) | (0.00 404) | (0.00 405) |
| Constant | 31.36*** | 32.26*** | 9.774*** | 7.419*** | 7.625*** | 7.664*** |
| | (0.0663) | (0.0675) | (0.170) | (0.0193) | (0.0198) | (0.0200) |
| *N* | 2 350 802 | 2 349 069 | 2351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −11 072 630.0 | −11 097 433.0 | −11 573 563.8 | −8 178 444.1 | −8 221 092.0 | −8 160 000.6 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

**Table A5.** Heterogenous effect of temperature on trip decisions: past eight months.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of trips | (5) OLS Number of trips | (6) Tobit Number of trips |
|---|---|---|---|---|---|---|
| Temp.bin < 0 °C | 0.101*** | 0.138*** | 0.378*** | −0.0845*** | −0.0653*** | −0.0654*** |
| | (0.0163) | (0.0165) | (0.0259) | (0.00 475) | (0.00 483) | (0.00 485) |
| 0 °C ⩽ Temp.bin < 5 °C | 0.120*** | 0.170*** | 0.286*** | −0.0731*** | −0.0400*** | −0.0382*** |
| | (0.00 783) | (0.00 785) | (0.0121) | (0.00 228) | (0.00 230) | (0.00 232) |
| 5 °C ⩽ Temp.bin < 10 °C | 0.387*** | 0.451*** | 0.637*** | 0.00 311 | 0.0468*** | 0.0474*** |
| | (0.00 716) | (0.00 707) | (0.00 944) | (0.00 209) | (0.00 207) | (0.00 209) |
| 10 °C ⩽ Temp.bin < 15 °C | 0.628*** | 0.696*** | 1.211*** | 0.0748*** | 0.127*** | 0.127*** |
| | (0.00 760) | (0.00 740) | (0.00 821) | (0.00 222) | (0.00 217) | (0.00 218) |
| 15 °C ⩽ Temp.bin < 20 °C | 0.592*** | 0.671*** | 1.271*** | 0.0799*** | 0.146*** | 0.146*** |
| | (0.00 847) | (0.00 818) | (0.00 725) | (0.00 247) | (0.00 240) | (0.00 241) |
| 20 °C ⩽ Temp.bin < 25 °C | 0.706*** | 0.805*** | 0.488*** | 0.119*** | 0.201*** | 0.202*** |
| | (0.0101) | (0.00 983) | (0.00 731) | (0.00 296) | (0.00 288) | (0.00 290) |
| 25 °C ⩽ Temp.bin < 30 °C | 0.777*** | 0.906*** | 0.141*** | 0.161*** | 0.257*** | 0.259*** |
| | (0.0168) | (0.0168) | (0.0203) | (0.00 492) | (0.00 493) | (0.00 495) |
| Temp.bin ⩾ 30 °C | 0.0254** | 0.946*** | 0.522*** | 0.105*** | 0.161*** | 0.162*** |
| | (0.0110) | (0.00 898) | (0.0164) | (0.00 321) | (0.00 263) | (0.00 265) |
| Constant | 31.73*** | 32.40*** | 25.01*** | 7.485*** | 7.594*** | 7.628*** |
| | (0.0675) | (0.0678) | (0.270) | (0.0197) | (0.0199) | (0.0201) |
| *N* | 2 350 802 | 2 349 069 | 2 351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −11 078 083.6 | −11 076 433.0 | −11 928 303.6 | −8 182 243.3 | −8 196 472.4 | −8 135 490.3 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

**Table A6.** Heterogenous effect of temperature on trip decisions: past twelve months.

| | (1) OLS Trip duration | (2) OLS Trip duration | (3) Outcome equation Trip duration | (4) OLS Number of trips | (5) OLS Number of trips | (6) Tobit Number of trips |
|---|---|---|---|---|---|---|
| Temp.bin $< 0\,^\circ$C | 0.349*** | 0.365*** | 0.629*** | −0.121*** | −0.104*** | −0.104*** |
| | (0.108) | (0.109) | (0.192) | (0.0315) | (0.0319) | (0.0320) |
| $0\,^\circ$C $\leqslant$ Temp.bin $< 5\,^\circ$C | 0.187*** | 0.258*** | 0.500*** | −0.0688*** | −0.0264*** | −0.0268*** |
| | (0.0122) | (0.0123) | (0.0196) | (0.00 357) | (0.00 361) | (0.00 363) |
| $5\,^\circ$C $\leqslant$ Temp.bin $< 10\,^\circ$C | 0.304*** | 0.418*** | 0.439*** | −0.0192*** | 0.0415*** | 0.0426*** |
| | (0.00 732) | (0.00 723) | (0.0100) | (0.00 213) | (0.00 212) | (0.00 214) |
| $10\,^\circ$C $\leqslant$ Temp.bin $< 15\,^\circ$C | 0.547*** | 0.692*** | 0.898*** | 0.0542*** | 0.129*** | 0.130*** |
| | (0.00 742) | (0.00 723) | (0.00 815) | (0.00 216) | (0.00 212) | (0.00 213) |
| $15\,^\circ$C $\leqslant$ Temp.bin $< 20\,^\circ$C | 0.747*** | 0.877*** | 1.335*** | 0.113*** | 0.192*** | 0.191*** |
| | (0.00 829) | (0.00 805) | (0.00 689) | (0.00 242) | (0.00 236) | (0.00 237) |
| $20\,^\circ$C $\leqslant$ Temp.bin $< 25\,^\circ$C | 0.608*** | 0.729*** | 0.532*** | 0.0649*** | 0.148*** | 0.147*** |
| | (0.00 976) | (0.00 949) | (0.00 693) | (0.00 285) | (0.00 279) | (0.00 280) |
| $25\,^\circ$C $\leqslant$ Temp.bin $< 30\,^\circ$C | 0.596*** | 0.834*** | 0.103*** | 0.0571*** | 0.188*** | 0.187*** |
| | (0.0221) | (0.0229) | (0.0297) | (0.00 645) | (0.00 671) | (0.00 673) |
| Temp.bin $\geqslant 30\,^\circ$C | 0.262*** | 0.728*** | 0.599*** | 0.0371*** | 0.197*** | 0.198*** |
| | (0.0118) | (0.00 881) | (0.0173) | (0.00 343) | (0.00 259) | (0.00 260) |
| Constant | 31.23*** | 31.94*** | 23.36*** | 7.389*** | 7.529*** | 7.570*** |
| | (0.0669) | (0.0671) | (0.324) | (0.0195) | (0.0197) | (0.0198) |
| *N* | 2 350 802 | 2 349 069 | 2 351 290 | 2 350 802 | 2 349 069 | 2 349 069 |
| ll | −11 079 475.0 | −11 073 919.7 | −11 930 928.3 | −8 183 513.2 | −8 194 059.5 | −8 133 107.3 |
| Temp. at the destination | Yes | Yes | Yes | Yes | Yes | Yes |
| Month of the year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Zipcode F.E. | Yes | | | Yes | | |
| Yearly F.E. | Yes | | | Yes | | |
| Zipcode by year F.E. | | Yes | Yes | | Yes | Yes |

Note: Standard errors are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

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