Air Pollution and Online Customer Reviews: Evidence from Restaurant Reviews

Completed Research Paper

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Abstract

Air pollution can damage individuals' physical and mental health, as well as affecting mood. Prior studies show that air quality can influence people's mood, and severe ambient air pollution can lead to bad mood, thus affects individuals' behavior. However, the existing studies fail to confirm the relationship between air quality and online customer review. This paper takes online restaurant reviews as an example to examine the impact of air quality, a critical environmental indicator, on online customer reviews across 15 cities in China from December 2013 to October 2017. The results show that air quality index (AQI) in diners' destination (the city where a restaurant is located) has a significantly negative impact on review rating and such a relationship is positively moderated by the AQI in diners' hometown. Our results can offer helpful references for both the researchers and practitioners.

Keywords: Air quality, Online customer reviews, Review rating, Mood

Introduction

Major cities in China have experienced frequent fog and haze which cause a series of acute and chronic health problems since 2012. With an increasing public awareness of the environment, the Air Quality Index (AQI) was used to measure air quality replacing the former Air Pollution Index (API) in early 2012. AQI is an index that reports daily air quality, describes the levels of air cleaning and pollution, and indicates the health issues that can be caused by that levels(Levy and Yagil, 2011). The Baidu indexes for AQI, fog and haze and PM2.5 from January 2011 to February 2018 in Figure 1

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show that people have been paying high attention to air quality since 2013, and there is a certain seasonal pattern in people's search behavior about air quality, namely, the search index is much higher in winter. Air pollution has become an important environmental factor affecting people's physical and mental health.

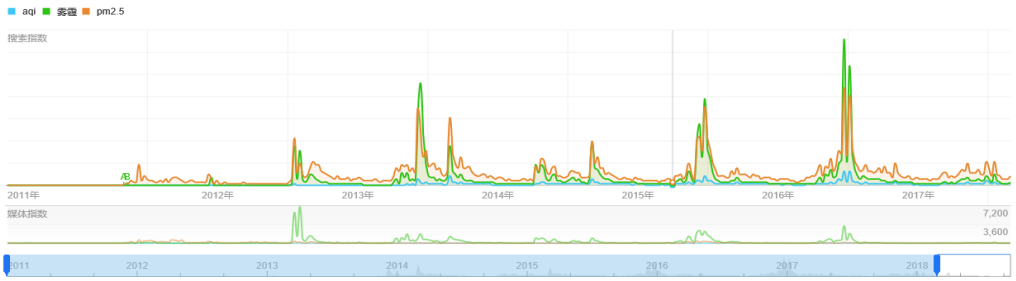

Figure 1. The Baidu index for AQI, fog and haze and PM2.5

Researchers in behavioral finance domain have found that air quality affects people's decision-making process. The prior research has shown that people's mood are affected by environmental factors like weather conditions and air quality, which in turn affect their investment behavior and consumption behavior(He and Liu, 2018; Hirshleifer and Shumway, 2003; Lepori, 2016; Levy and Yagil, 2011). In addition, Bakhshi et al. (2014) demonstrated that the emotions caused by weather can influence online consumer reviews. All these studies provide a theoretical basis for our study. However, the existing literature has not answered the question that whether the mood caused by air pollution will affect individual's consumption behavior and their online review behavior. The existing studies mentioned above indicate that it is feasible to study the relationship between the mood caused by air quality and online consumer reviews.

Therefore, this study seeks to address this research gap by taking online restaurant reviews as an example, namely, exploring how the mood caused by air pollution influence online consumers' review behavior. More specifically, we will investigate the impact of AQI in diners' destination on review rating and test the moderating effect of AQI in diners' hometown.

The remainder of this paper will be structured as follows. Section 2 reviews the related works and provides the theoretical background. Section 3 and 4 develop the hypotheses and research methodology. We report the descriptive and empirical results in section 5. At last, we conclude the study and discuss the implications.

Literature Review

Air pollution and mood

Former psychological studies relate mood to climatic factors, such as weather conditions and air quality, and believe that mood contains valuable information about the environment. Weather conditions such as snowfall, rainfall, cold and cloudiness will affect people's outdoor activities and such gloomy weather can easily cause people's depression mood (Harmatz et al., 2000; Keller et al., 2005). Numerous research in psychology demonstrates that good mood relates to low level of humidity and sunshine (Cunningham, 1979; Sanders and Brizzolara, 1982). Like the weather conditions, as an important aspect of the climate, air quality pertains to physical comfort which is crucial to emotional changes. Both Short-term and long-term exposure to severe air pollution can cause physical discomfort and human health problems, as well as bad mood (Seaton et al., 1995; Yin et al., 2018). Severe air pollution can seriously affect people's physical health, especially in the respiratory system. The discomfort caused by severe air pollution then causes people's anxiety and irritability mood (Adgate et al., 2014). Zijlema et al. (2016) studied the effects of air pollution on mood in 70,928 individuals from four European cohorts. The study confirmed a significant

relationship between air pollution and depression mood. Tallon et al. (2017) demonstrated that long-term exposure to high concentrations of PM2.5 and NO2 and other air pollutant can cause peoples' bad mood and finally results in cognitive impairment.

Mood, decision making and behavior

The mood is a psychological reaction that people have immediately and perceptually when they are in the process of perception of external things, which is contextual and erratic, and it changes with people's experience. Prior studies have shown that mood can greatly influence people's judgment and decision-making (Parrott and Sabini, 1990; Schwarz and Clore, 1983). Even if their mood at the time has nothing to do with the decisions they have to make, their decision-making will also be affected (Lucey and Dowling, 2005). Individuals in a good mood tend to have more positive evaluations for many things, such as life, work, people and consumer products and services. In contrast, individuals in a bad mood tend to give negative feedbacks (Isen et al., 1978; Wright and Bower, 1992). People in a depression mood tend to make negative decisions, while people in a high mood tend to make positive decisions (Morris, 2000). Individuals encounter a series of emotional changes in their consumption process caused by goods, services or environmental factors (Richins, 1997). They are likely to express different moods, such as sadness, anger, anxiety, joy, happiness and love, through online reviews when they experience online consumptions (Nyer, 1997).

Air pollution and behavior

Previous studies have demonstrated that people's investment behavior and consumption behavior are associated with the mood caused by climatic conditions, such as weather conditions and air pollution. Numerous researches are about the impact of weather conditions on people's behavior, while relatively few studies investigate the impact of air quality. However, considering that both weather conditions and air quality pertain to climatic conditions, the studies on weather conditions have high reference significance.

Hirshleifer and Shumway (2003) studied the impact of cloudiness on stock returns across 26 countries from 1982 to 1997 to find that people tend to have a good mood in a good day sunshine, which leads to a positive stock returns. Even after controlling for other weather conditions like rainfall and snowfall, the results were consistent and still significant. Lu and Chou (2012) studied the weather effects on the stocks of the Shanghai Stock Exchange (SSE) in China. The results show that weather can affect investors' trading activities, but it cannot significantly affect stock returns. Kaustia and Rantapuska (2016) studied the effects of climate variables such as weather and length of day on Finnish stock market, and found that these weather-related emotional variables can affect investors' investment and trading behaviors, and the effects have a strong seasonal pattern. Bakhshi et al. (2014) firstly studied the weather effect on online reviews, arguing that offline consumption in a restaurant can also be influenced by weather conditions, and people express a good or bad mood caused by weather through online reviews. It also demonstrated that temperature, precipitation, snow and seasonal trends can significantly affect diners' online reviews on restaurants.

Levy and Yagil (2011) pointed out that the mood caused by air pollution can affect investors' behavior and then affects stock returns, and confirmed that air pollution negatively affects stock returns and the relationship is affected by the distance between the exchange and the polluted area. The longer the distance is, the smaller the impact will be. Lepori (2016) found that air quality can affect investors' mood and then influences domestic equity returns, and the relationship is mediated by the trading floor community through a natural experiment.

Hypothesis development

Effect of air quality on review rating

Consumers express their overall consumption satisfaction with the product and service by giving a review rating in an online review (Gu and Ye, 2014). Qi et al. (2017) studied the impact of indoor air quality on five-star hotel reviews and found that air quality is an important factor affecting customer

satisfaction, indicating that customers will consider both indoor and outdoor air quality when reviewing. Bakhshi et al. (2014) have shown that weather conditions are exogenous factors that influence diners' reviews, in that they affect diners' mood and behavior, and then affect their satisfaction with the restaurants. They proved that adverse weather can cause bad mood, and negatively correlates with review rating. As seen in Figure.1, the Baidu search index on air quality shows that people are increasingly aware of the harmful effects of severe air pollution on human health. From the psychological perspective, severe air pollution can cause pessimistic sentiment, which can easily cause negative behaviors (He and Liu, 2018). Thus, we propose the following hypothesis:

H1: The AQI (low air quality represented by high AQI) in diners' destination negatively influences the review rating.

Moderating effect of air quality in diners' hometown

McKercher et al. (2015) pointed out that the notions of tourists about the weather in the destination depend on the difference between the weather in tourists' hometown and the weather in their destination. The notion of tourists about air quality is consistent with the weather. Similar to the weather, air quality can affect the destination image. The destination image can influence tourists' behavior. Destination image can positively affects tourists' willingness to provide word-of-mouth recommendations (Kock et al., 2016; Simpson and Siguaw, 2008). Namely, tourists are likely to express their notion about the destination image through online reviews. We thus put forward the destination image hypothesis: the AQI in diners' hometown can influence the notion of diners about the destination image. Thus, if the AQI is more severe in diners' hometown, the diners will have a better notion about the destination image, which will not cause a too bad mood of the diners and a negative review to the restaurant.

According to the psychological researches, long-term exposure to severe air pollution can cause individuals' depressive mood, and even can influence neurocognitive function and lead to mood disorders (Tallon et al., 2017; Tzivian et al., 2015; Vert et al., 2017). We thus put forward the long-term negative emotion hypothesis: long-term exposure to severe air pollution in diners' hometown will lead to diners' high expectation of good air quality in diners' destination. Once the air quality in diners' destination is not very good, the diners will be disappointed and they will give a low review rating to the restaurants.

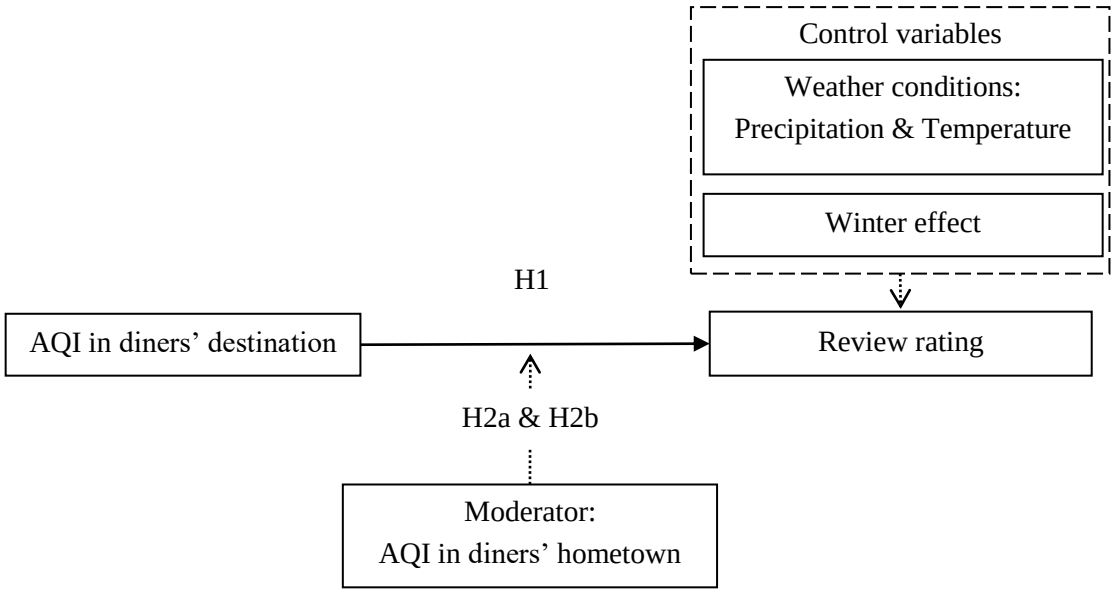

Figure 2. Research model

Hence, we form competing hypotheses for the moderating effect of AQI in diners' hometown:

H2a: The AQI in diners' hometown moderates the relationship between the AQI in diners' destination and the review rating, that is, the influential power of AQI in diners' destination lessens when the AQI in diners' hometown is high.

H2b: The AQI in diners' hometown moderates the relationship between the AQI in diners' destination and the review rating, that is, the influential power of AQI in diners' destination strengthens when the AQI in diners' hometown is high.

The research model for our study is shown in Figure 2.

Research Methodology

Data collection

We randomly select 15 major cities from 23 provinces, 4 municipalities and 5 autonomous regions in China to study the relationship between air quality and restaurant reviews. These cities have different AQI release date, where Zhengzhou released on January 1, 2013; Changchun, Changsha, Chengdu, Chongqing, Dalian, Guiyang, Harbin, Jinan, Lhasa, Nanchang, Nanning, Xiamen, and Yinchuan released on December 2, 2013; and Sanya released on December 31, 2013. Thus, we set the starting time from December 2013.

We collected AQI data for each city from www.aqistudy.cn. This website is a non-profit platform and provides the climatic information (e.g. AQI) for nearly all the cities in China. We also developed a crawler to collect the restaurant-related data from Dianping(www.dianping.com). Dianping is the most popular and commonly used website in restaurant review area in China. The registered users can express their satisfaction about the restaurant in which they have had a meal by providing an online review on this website. The information provided by the users includes a review text, a review rating, and the average price per person for their dining, and so on. This information can be the reference for potential customers to choose a restaurant. As we control the impact of weather conditions in our research, we collected weather conditions-related data from NOAA (https://www.ncdc.noaa.gov) and http://www.tianqihoubao.com. The former is a website providing climatic information for nearly all the cities over the world, and the latter is a website providing climatic information for all the cities in China. Finally, our sample contains 150 restaurants with 673,773 reviews from December 2013 to October 2017, and we match the corresponding data of air quality and weather conditions. After pre-processing and excluding observations with missing values, 269,492 observations are remained.

Variables

Dependent variable

The existing researches take review rating as the indicator of online customers' satisfaction with the product and service (Gu and Ye, 2014; Lu et al., 2013). Thus, we use the review rating to study the impact of air quality on diners' review behavior. We collected reviews of the top ten restaurants in the number of reviews the restaurants had received in each city from Dianping. For each restaurant, we collected all available review-related information, including reviewers (diners)-related information, restaurant-related information and the timestamps. The review rating in Dianping ranges from 1 star (lowest) to 5 stars (highest).

Independent variable

The daily air quality index (AQI) data for each city from December 2013 to October 2017 are collected from www.aqistudy.cn. AQI ranges from 0 to 500. We assume that the day when a review is written is the same as the day when a diner forms his/her opinion on the restaurant, and the opinion is influenced by the AQI in diners' destination that day. AQI in diners' destination is natural logarithmic transformed.

Moderating variable

Though the diners travel to other cities, the air quality in their hometown can still influence for several days. Following the approach in Wang et al. (2018), when processing the AQI in diners' hometown, we considered the lagging effect in the behavioral responses of diners to AQI in their hometown. That is, using the average AQI in diners' hometown seven days before he/she wrote the review. AQI in diners' hometown is also natural logarithmic transformed.

Control variables

The control variables in our study include weather conditions and winter effect.

Weather conditions control variables. In order to examine whether the impact of air quality on diners' review behavior is affected by weather conditions, we include precipitation and temperature as control variables in the regression. We collected weather data about precipitation and temperature from NOAA (https://www.ncdc.noaa.gov). We also collected weather data from http://www.tianqihoubao.com to supplement the missing precipitation data from NOAA. Precipitation is determined to be zero only when the daytime and night weather recorded at http://www.tianqihoubao.com are neither "snow" nor "rain", and we added these data to the corresponding missing data from NOAA. Others are considered to be missing data. We assume that the day when a review is written is the same as the day when a diner forms his/her opinion upon the restaurant, and the opinion is influenced by the weather conditions that day. Only the weather data about temperature are natural logarithmic transformed.

Winter effect control variable. China has faced severe fog and haze weather every year in winter since 2012. Both air quality and weather conditions are highly in a seasonal pattern. For example, winter months in the United States are usually associated with cloudier weather, and many possible causal relationships show strong annual seasonality (Hirshleifer and Shumway, 2003). However, winter months in China are usually associated with rain or snow, and northern cities in China depend on coal burning for heating in winter, which can lead to severe fog and haze. The Baidu index of AQI, fog and haze and PM2.5 in Figure 1 shows that winter months are associated with higher search index. To control for potential winter effect, we include a dummy variable for the winter effect in the regression.

Table 1 presents the descriptions of all these variables.

Table 1. Variable description

Variable type	Variable	Description	Data source
Dependent variable	*Rating*	Review rating given by a diner ranging from 1 star to 5 stars	Dianping
Independent variable	*AQI_destination*	Air quality index in a diner's destination on the day he/she wrote a review (This variable is natural logarithmic transformed.)	www.aqistudy.cn
Moderating variable	*AQI7_hometown*	Average air quality index in a diner's hometown seven days before he/she wrote a review (This variable is natural logarithmic transformed.)	www.aqistudy.cn
Control variable	*Prcp*	The precipitation in a diner's destination on the day he/she wrote a review	NOAA http://www.tianqihoubao.com
	Temp	The temperature in a diner's destination on the day he/she wrote a review (This variable is natural logarithmic transformed.)	NOAA
	Winter	Winter effect	

Model development

Dianping uses a 5-star rating scheme, namely, the review ratings in Dianping are ranging from 1-5 stars, which are ordered data. Ordered logistic regression model is well suited for such discrete data with natural order (Bakhshi et al., 2014). We introduce a latent variable, y^*, which denotes *Rating*. We can write the model as follows:

$$Rating = \begin{cases} 1 \quad if \quad y^* \le r_0 \\ 2 \quad if \quad r_0 < y^* \le r_1 \\ 3 \quad if \quad r_1 < y^* \le r_2 \\ \qquad ..... \\ J \quad if \quad r_{J-1} \le y^* \end{cases}$$

Where J denotes review rating categories, $r_0 < r_1 < r_2 < ..... < r_{J-1}$ are the parameters to be estimated. The model with independent variable, control variables and interaction term is expressed as follows, where *AQI_destination*×*AQI7_hometown* is the interaction term between AQI in diners' destination and AQI in diners' hometown. In addition, we use the decentralized *AQI_destination* and *AQI7_hometown* (realized by 'center' command in Stata 14.1) to calculate the interaction term:

$$y^* = \beta_0 + \beta_1 AQI\_destination + \beta_2 AQI7\_hometown + \beta_3 AQI\_destination \times AQI7\_hometown + \beta_4 Prcp + \beta_5 Temp + \beta_6 Winter + \varepsilon$$

We use the nested model statistics in Stata 14.1 to realize adding control variables, independent variable and interaction term to the model, respectively.

Results

Descriptive analysis

Table 2 shows the Correlation Matrix and Variance Inflation Factor (VIF) values of main variables in our study. The results show that the correlations between two variables are all small. And the values of VIF (less than 1.5) indicate no multicollinearity (Mason and Perreault Jr, 1991).

Table 2. Correlation matrix and VIF values of main variables

Variables	1	2	3	4	5	6	7
Rating	1.000						
AQI_destination	-0.041	1.000					
AQI7_hometown	-0.003	0.299	1.000				
AQI_destination×*AQI7_hometown*	-0.014	0.235	0.046	1.000			
Prcp	0.005	-0.140	-0.066	0.008	1.000		
Temp	0.015	-0.275	-0.203	-0.130	0.008	1.000	
Winter	-0.006	0.196	0.300	0.101	-0.089	-0.516	1.000
Mean	4.386	4.222	4.459	0.062	0.150	4.071	0.254
SD	0.915	0.551	0.375	0.236	0.460	0.450	0.435
VIF		1.240	1.180	1.070	1.030	1.430	1.450

Main analysis

Table 3. Results of the ordered logistic regression model

	(1)	(2)	(3)
AQI_destination		-0.183(0.007)***	-0.193(0.008)***
AQI7_hometown			0.088(0.011)***
AQI_destination×*AQI7_hometown*			-0.058(0.017)***
Prcp	0.024 (0.008)***	-0.006(0.008)	-0.004(0.008)
Temp	0.080 (0.010)***	0.026(0.010)***	0.026(0.010)**
Winter	0.014(0.010)	0.028(0.010)***	0.012(0.010)
Cut 1	-3.509***	-4.506***	-4.166***
Cut 2	-2.702***	-3.699***	-3.359***
Cut 3	-1.440***	-2.436***	-2.096***
Cut 4	-0.0648	-1.058***	-0.718***
Obs#	269492	269492	269492
LR Chi2	84.89	721.18	797.36
Notes: Standard errors are included in parentheses. *: $p<0.1$; **: $p<0.05$; ***: $p<0.01$.			

We examine the impact of *AQI_destination* on review rating and the moderating effect of *AQI7_hometown* on this impact using an ordered logistic regression model. The ordered logistic regression results shown in Table 3 support the hypotheses of *H1* and *H2b*. Column 1 shows the impact of control variables on review rating, indicating that the weather conditions can significantly affect review rating, where the coefficients of precipitation and temperature are 0.024 ($p<0.01$) and 0.080 ($p<0.01$), respectively. Column 2 shows the impact of AQI in diners' destination on review rating. The results show that AQI in diners' destination can significantly affect review rating, and the coefficient is –0.183 ($p<0.01$). Thus, *H1* is supported, which indicates that the poorer the air quality in diners' destination is, the lower the review rating given to the restaurant will be. Column 3 shows that the significant interaction with the AQI in diners' hometown (-0.058, $p<0.01$) moderates the effect. The negative sign of the coefficient of the interaction term suggests that the poorer the air quality in diners' hometown is, the more likely it is for the diners to have a bad mood due to the bad air quality in their destination, and the review rating will be lower. That is, the AQI in diners' hometown can strengthen the negative impact of the AQI in diners' destination on review rating. Thus, *H2b* is supported. In addition, we can see from table 3, the Pseudo R^2 from column 1 to column 3 are 0.0001, 0.0013 and 0.0014, respectively, indicating that adding the variable of *AQI_destination* , the variable of *AQI7_hometown* and their interaction term can improve the explanatory power of the model.

Robustness checks

Changing the time window

We change the time window of AQI in diners' hometown. We replace the average AQI in the recent 7 days with the average AQI in the recent 3 days, which is denoted by *AQI3_hometown*. The results of the models with an alternative time window are presented in table 4 and are consistent with our main analysis. The coefficient of *AQI_destination* is -0.198 ($p<0.01$) and the coefficient of the interaction term is -0.038 ($p<0.1$). Thus, *H1* and *H2b* are supported once more.

Table 4. Results of the ordered logistic regression model (replacing AQI7_hometown with AQI3_hometown)

	Coefficient	Standard error	Sig.
AQI_destination	-0.198***	0.008	0.000
AQI3_hometown	0.079***	0.009	0.000
AQI_destination×*AQI3_hometown*	-0.038***	0.014	0.007
Prcp	0.005	0.008	0.557
Temp	0.023**	0.010	0.021
Winter	0.015	0.010	0.146
Cut 1	-4.238***	0.066	
Cut 2	-3.431***	0.066	
Cut 3	-2.168***	0.065	
Cut 4	-0.790***	0.065	
Obs#	269492		
LR Chi2	797.42		
Note: *: p<0.1; **: p<0.05; ***: p<0.01.			

Linear regression model

We also use a linear regression model to examine the impact of AQI in diners' destination on review rating and the moderating effect of AQI in diners' hometown. The model with independent variable, control variables and interaction term is expressed as follows:

$$Rating = \beta_0 + \beta_1 AQI\_destination + \beta_2 AQI7\_hometown + \beta_3 AQI\_destination \times AQI7\_hometown + \beta_4 Prcp + \beta_5 Temp + \beta_6 Winter + \varepsilon$$

The linear regression results shown in Table 5 also support *H1* and *H2b*. The coefficient of *AQI_destination* is -0.066 (p<0.01), which indicates a significantly negative impact of *AQI_destination* on review rating. The coefficient of the interaction term is -0.017 (p<0.05), which indicates a significantly positive moderating effect of *AQI7_hometown*. Although the values of these coefficients are different from the main analysis, the results of the linear regression model are largely consistent with our main analysis.

Table 5. Results of the linear regression model

	(1)	(2)	(3)
AQI_destination		-0.066(0.003)***	-0.069(0.004)***
AQI7_hometown			0.026(0.005)***
AQI_destination×*AQI7_hometown*			-0.017(0.008)**
Prcp	0.011 (0.004)***	0.001(0.004)	0.001(0.004)
Temp	0.035 (0.005)***	0.015(0.005)***	0.015(0.005)***
Winter	0.008(0.005)	0.013(0.005)***	0.007(0.005)
cons	4.239(0.019)***	4.599(0.027)***	4.499(0.033)***
Obs#	269492	269492	269492
F	24.6	114.91	81.79
R^2	0.0003	0.0017	0.0018
Notes: Standard errors are included in parentheses.*: p<0.1; **: p<0.05; ***: p<0.01.			

The results of the robustness checks above show that the relationship between air quality and restaurant review rating are robust.

Conclusion

The results of the main analysis show that the AQI in diners' destination can affect diners' mood, and then negatively influences review rating. The results of the moderating effect show that the AQI in diners' hometown supports the long-term negative emotion hypothesis, namely, the AQI in diners' hometown has a significantly positive moderating effect on the relationship between the AQI in diners' destination and review rating. And these results all pass our robustness checks.

This paper has theoretical and practical implications as follows: (1) In this paper, we take a first look at online customer reviews (restaurant reviews) to study whether the air quality can influence diners' review behavior, and whether the air quality can influence review rating. (2) This paper considers the moderating effect of air quality in diners' hometown, filling the research gap in extant research of neglecting the impact of air quality in the diners' hometown on online restaurant reviews. (3) This paper confirms that the air quality can not only influence people's physical and mental health, but also influence their behavior in their daily life due to the bad mood caused by air pollution, and even their online review behavior can be greatly affected. Therefore, the environmental departments should do well in air treatment so that people will not be disturbed by air pollution. (4) For restaurants, the indoor air quality of the restaurant should be improved to provide fresh air for diners, so that the bad mood caused by outdoor air pollution can be alleviated and they will not vent bad moods to their online reviews.

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