Journal of Cleaner Production 276 (2020) 124204

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

The impacts of climate variables and climate-related extreme events on island country's tourism: Evidence from Indonesia

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ARTICLE INFO

Article history:
Received 22 April 2020
Received in revised form
8 September 2020
Accepted 14 September 2020
Available online 16 September 2020

Handling editor: Bin Chen

Keywords:
Climate change
Tourism
Extreme events
Impact

ABSTRACT

Tourism is one of the main economic sectors, which is impacted by climate change on a global scale. Yet, whether and to what extent climate change influences tourism in island countries with tropical weather has not been fully understood. Here, we seek to fill this gap by evaluating the role of climate variables and climate-related extreme events on the number of international tourists in Indonesia empirically. A panel dataset of 5 provinces in Indonesia, which accounted for more than 80 percent of international tourists traveling to Indonesia between 2008 and 2018, was used to perform a feasible generalized least square (FGLS) regression. Consistent with previous findings, the empirical results show that both temperature and relative humidity particularly explain the variations in the number of international tourists in Indonesia. Every 1% increment of temperature and relative humidity is associated with a decrease in the number of international tourists in Indonesia by 1.37% and 0.59%, respectively. This study also suggests that the effect of climate change and climate-related extreme events is not homogeneous among tourists from different regions. These findings develop novel insights for climate change adaptation for policymakers and the tourism industry in Indonesia as well as in other warm destinations.

1. Introduction

Tourism is one of the most significant economic contributors in the world, representing 10.4% of the global Gross Domestic Product (GDP) (World Travel and Tourism Council, 2019). About one out of ten jobs available worldwide was either directly or indirectly linked with this sector (World Travel & Tourism Council, 2018). The World Tourism Organization (UNWTO) reported that more than 1.3 billion international trips and approximately USD 1,340 billion of international tourism receipts were made in 2017, with each indicated growth at 7% and 5% from the previous year, respectively (UNWTO, 2018). In particular, Asia and the Pacific led the growth in both arrivals and the number of tourists, accounting for 7% of the global total in 2018 (UNWTO, 2019).

Despite being one of the largest contributors to global warming (Lenzen et al., 2018), tourism itself is highly influenced by climate change (IPCC et al., 2014). It is remarkably exposed to both direct (e.g., sea-level rise, rising temperature) and indirect physical effects (e.g., changing water availability, the spread of certain diseases) (IPCC et al., 2014). With regard to the direct physical impact, it is reported that climate change and associated extreme events change the natural attractiveness or climate comfort of destinations (López-Dóriga et al., 2019; Wabnitz et al., 2018). Concerning the indirect physical effect, the changing pattern of global precipitation due to climate change might lead to water scarcity in tourism spots (Gössling et al., 2012). Moreover, mosquito-borne diseases such as malaria might be more prevalent in the areas where average rainfall increases and the humidity facilitates disease transmission (Reiter, 2001).

Although the effect of climate change on tourism has been extensively studied and well-documented in the existing literature (López-Dóriga et al., 2019; Smith and Fitchett, 2020; Steiger and Scott, 2020), the impacts are diversified across regions (Hewer and Gough, 2018; Liu et al., 2019; Scott et al., 2020). For example, some regions observed a decline in the number of tourists associated with temperature rise (Falk and Lin, 2018; Pintassilgo et al., 2016) while others indicated a positive impact of temperature rise on tourism (Giannakopoulos et al., 2011; Hamilton et al., 2005).

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https://doi.org/10.1016/j.jclepro.2020.124204
0959-6526/

Due to the regional heterogeneity, it is necessary to assess the impact of climate change across the region and within a specific context (Scott et al., 2020).

As a rapidly growing tourist destination in the world, the number of international arrivals in Indonesia has grown significantly by more than 10% over the last five years (Ministry of tourism and economy creative of the republic of Indonesia, 2019; Rosselló et al., 2020), with over 15 million reported entries in 2018 (Statistics Indonesia, 2018a,b). Tourism contributed to 6% of Indonesia's GDP (World Travel and Tourism Council, 2019), making it one of the priorities of the Indonesian government to accelerate its economic growth (Bank of Indonesia, 2017). Indonesia is the largest archipelagic country in the world, which is vulnerable to climate-related extreme events such as floods, droughts, and abrasion. Besides, Indonesia only has two seasons (dry and rainy season) with hot and humid weather all year. The understanding of to what extent the relatively small fluctuation of climate variables and the existence of extreme events would predict the variations of the number of international tourists in Indonesia is limited.

To fill this gap, this research explores the associations of climate variables and climate-related extreme events with Indonesia's tourism. A monthly data of inbound tourism demand from 2008 to 2018 was examined by using a feasible generalized least square (FGLS) method. The findings will support policymakers and tourism actors in terms of enforcing climate policies and improving tourism management in Indonesia. Furthermore, the study contributes to the tourism literature by enriching evidence on the associations between climate change and tourism through a case study in tropical island countries. Although this study focuses on Indonesia as a case study, the implications can be extended to other island countries with similar climate characteristics.

The rest of the paper is organized as follows: Section 2 provides a literature review and demonstrates the state of the art on the impact of climate change on tourism; Section 3 conceptualizes the theoretical framework and develops relevant hypotheses for Indonesia; Section 4 describes the empirical method, details of study areas, and variables used in the research; Section 5 reports the empirical results; Section 6 analyses how consistent or contradicting our findings are with previous findings, provides policy recommendations and research implications and offers a brief conclusion.

2. Literature review

Existing literature with regards to the impact of climate change on tourism documents various influencing mechanisms (as shown in Fig. 1). In general, tourism is exposed to sea-level rise, temperature rise, and changes in climatic variables, which may undermine the attractiveness of the tourism spots (López-Dóriga et al., 2019; Wabnitz et al., 2018). Specifically, sea-level rise and the increasing sea surface temperature may exacerbate the current erosional trend of the shoreline (Jiménez et al., 2017; López-Dóriga et al., 2019), harm marine biodiversity (Birchenough, 2017; Wabnitz et al., 2018), and hence threaten coastal tourism. For instance, coral bleaching and loss of turtle nesting habitat caused by rising temperatures and sea-level rise harmed coastal tourism in the Caribbean (Birchenough, 2017). In addition to coastal tourism, other nature-based tourism is affected by climate change as well. For example, ski tourism is affected by climate change as the temperature rise and snowfall reduction deteriorate its attractiveness and increases the maintenance cost (Steiger et al., 2020). The ski season in the United States and Canada is projected to be shortened regardless of low or high emission pathways (Scott et al., 2020). Climate change is also likely to affect glacier tourism as it causes glacier retreat, impairs glacier cultural values, and increases the difficulty in accessing and experiencing glaciers (Wang and Zhou, 2019).

Inclining frequency of extreme events caused by climate change will also have an impact on tourism through the disruption in infrastructure, natural attraction, and cultural heritage (Hamzah et al., 2012; Nurashikin Sungip et al., 2018; Smith and Fitchett, 2020; Toubes et al., 2017). For example, extreme rainfall has a significant effect on tourism demand in national parks as it threatens wildlife, damages tourism facilities, and disrupts tourists' activities (Dube and Nhamo, 2018). Floods are perceived to cause infrastructure damage, heritage loss, and service disruption, leading to a loss of attractiveness and hence depict a negative impact on coastal tourism (Toubes et al., 2017) and urban tourism (Hamzah et al., 2012; Nurashikin Sungip et al., 2018). Moreover, the change in global precipitation patterns may aggravate the problem of water scarcity, especially in arid destinations, resulting in a negative impact on local tourism (Gössling et al., 2012). In addition to weather extremes, climate change may also affect tourism through public health emergencies such as disease spread (Reiter, 2001). It is anticipated that rising temperatures will cause malaria spread from North Africa to Spain, which may scare the public away, including the tourists to visit the destination (Perry, 2006).

It is worth noting that the impact of climate change is not always negative (Köberl et al., 2016). Climate change will shift the preferred tourism destination to higher latitudes and altitudes, meaning that the destination that is located within the range of higher latitude and altitude will witness the rise of tourism demand (Hamilton et al., 2005). A study in Sardinia and Cap Bon suggested that climate change improve the tourism sector in the shoulder season in which the annual net impact is expected to be slightly positive (Köberl et al., 2016). Another example is that the rise of temperature in Greece is expected to prolong the tourist season, thus, contributing positively to tourism revenues (Giannakopoulos et al., 2011).

The emerging amount of literature on the impacts of climate change on tourism reveals that there is substantial heterogeneity across regions (Hewer and Gough, 2018; Liu et al., 2019; Scott et al., 2020). As mentioned above, the impact of temperature rises may harm ski tourism in Europe (Damm et al., 2017; Falk and Lin, 2018) and North America (Scott et al., 2020) but favors the climate comfort in the higher-latitudes destinations (Hamilton et al., 2005). The distinct influence of drought on tourism provides another typical example of the spatial heterogeneity. Some papers pointed out that an increase in the frequency of droughts hurts the tourism sector in Caribbean Small Island Developing States (SIDS) and Zimbabwe through limited availability of water (Cashman and Nagdee, 2017; Dube and Nhamo, 2020). However, a study in Sabi Sands Game Reserve of South Africa revealed that droughts did not have severe consequences for its nature-based tourism (Smith and Fitchett, 2020).

Since the impact of climate change is not uniform across the region (Hewer and Gough, 2018; Liu et al., 2019; Scott et al., 2020), investigating the associations between climate change and tourism in various tourist destinations is deemed necessary. To the best of the authors' knowledge, how and to what extent the climatic variables and extreme weather events predict international tourism in an island country with a tropical climate are not fully unveiled. This study aims to fill this gap by investigating how climate variability and extreme events would affect the number of international tourist demand, with Indonesia as a case study.

3. Hypothesis development

This section developed hypotheses on whether and how various climatic variables and extreme events correlate with Indonesia's

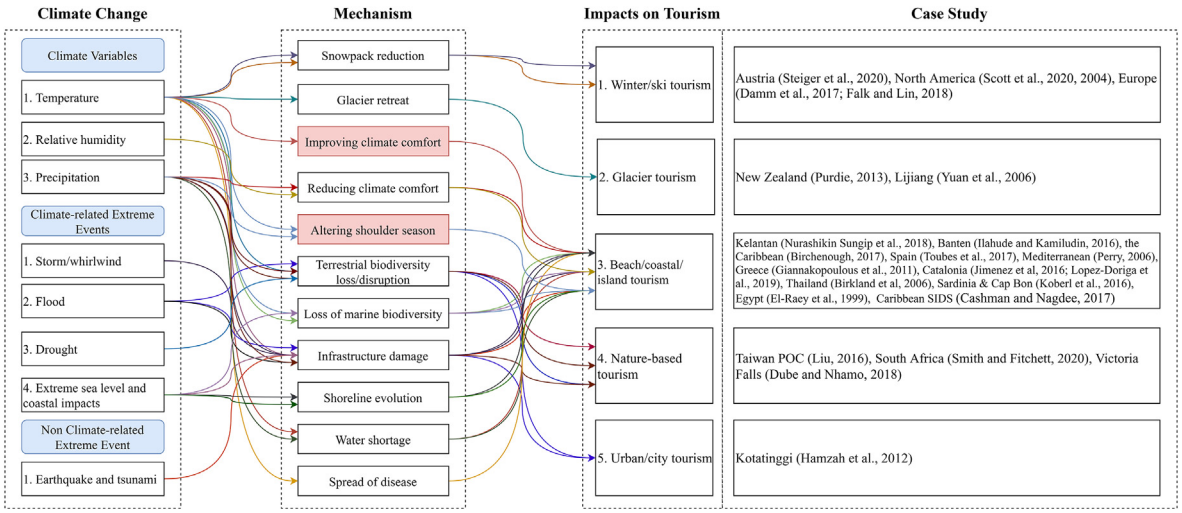

Fig. 1. Possible influencing mechanisms of the impacts of climate change on tourism. The red boxes indicate positive impacts. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

tourism demand.

3.1. Temperature

Temperature plays a significant role in tourism since it is closely correlated with climate comfort and the natural attractiveness of destinations (Ainsworth et al., 2016; Wisha and Khoirunnisa, 2017). As Indonesia is located on the equator line, it is conjectured that the temperature rise will decrease climate comfort and tourism demand. The hypothesis is constructed as follows:

Hypothesis 1. Temperature is negatively associated with international tourism demand in Indonesia

3.2. Relative humidity

The relative humidity is correlated with temperature to some extent. Since Indonesia is a hot and humid country with a relatively stable temperature, increasing humidity will probably decrease climate comfort and negatively affect the number of international tourists. Therefore, the hypothesis is given as follows:

Hypothesis 2. Relative humidity is negatively associated with the international tourism demand in Indonesia

3.3. Precipitation

Precipitation is a vital climate parameter for beach tourism (Georgopoulou et al., 2019) and, to some extent, is even more significant than temperature (Liu, 2016). Indonesia only has two seasons (the dry season and rainy season). The precipitation is expected to be intense during the rainy season, which usually takes place for approximately six months. Since heavy rainfall halts outdoor tourism activity, the hypothesis is given as follows:

Hypothesis 3. Precipitation is negatively related to the international tourism demand in Indonesia

3.4. Floods

Floods affect tourism as they may damage tourism infrastructure, facilities, and services (Nurashikin Sungip et al., 2018). Floods are closely related to precipitation, which indicates that higher precipitation may drive more frequent flood events in some cases. It is hypothetically perceived that this extreme event may harm tourism demand in Indonesia.

Hypothesis 4. Floods are negatively related to the international tourism demand in Indonesia

3.5. Droughts

As the growth in global tourism is coupled with water-intense activity and growing demand for accommodation, water resources become more crucial in tourist destinations (Gössling et al., 2012). Droughts may affect water supply and thus decrease tourism demand. With the changing pattern of droughts in Indonesia, it is perceived that drought events may exacerbate water-scarce destination and thus affect tourism negatively. The hypothesis about droughts is provided as follows:

Hypothesis 5. Drought is negatively related to the international tourism demand in Indonesia

3.6. Whirlwind

Studies suggest that strong winds hinder tourism in many cases (Cashman and Nagdee, 2017; Forster et al., 2012). Although Indonesia is relatively safe from tropical cyclones since it is located in the equator, storm winds still exist and could be related to tourism demand. Storm winds officially documented by the Indonesian National Board for Disaster Management are whirlwinds, which are defined as a strong wind with a speed of 40–50 km/h that disappears in a short time (Indonesian National Board of Disaster Management, 2019). Thus, the sixth hypothesis is developed as follows:

Hypothesis 6. Whirlwind is negatively related to the international tourism demand in Indonesia

3.7. Abrasion

Abrasion may harm tourism infrastructure near the coastal area (Ilahude and Kamiludin, 2016). As Indonesia is one of the countries with the longest coastline in the world, abrasion will harm the key attractions and tourism facilities. Thus, it is hypothesized that coastal erosion would cause the decline of tourism demand in Indonesia.

Hypothesis 7. Abrasion is negatively related to the international tourism demand in Indonesia

3.8. Earthquakes and tsunamis

Apart from climate-related extreme events, other forms of natural disasters such as earthquakes and tsunamis also influence the demand for tourism (Rosselló et al., 2020). Lying between the "Ring of Fire," Indonesia is susceptible to earthquakes and tsunamis. Therefore, it is hypothesized earthquakes and tsunamis are negatively related to international tourism demand in Indonesia.

Hypothesis 8. Earthquakes and tsunamis are negatively related to the international tourism demand in Indonesia.

4. Materials and methods

4.1. Study sites

This study selects five provinces with the largest number of international tourist arrivals in Indonesia, namely Jakarta, Bali, Riau Islands, East Java, and North Sumatra (Fig. 2a). Their collective contribution depicts more than 80% of total international visitors to Indonesia in 2018 (Statistics Indonesia, 2018a,b). 70% of the tourists are from seven regions, which are Southeast Asia (Philippines, Malaysia, Singapore, and Thailand), East Asia (China, Japan, and South Korea), India, Middle East (Saudi Arabia and Egypt), Australia, Europe (England, France, Germany, Netherlands, and Russia), and the USA (Fig. 2b). Among all countries, Southeast Asian and East Asian countries contribute most tourists, making up over half of Indonesia's international tourists since 2015.

4.2. Panel data regression model

To test the hypotheses mentioned above, this study employed a panel dataset of 5 provinces for a period of 11 years (from 2008 to 2018). Hausman test is performed to determine the appropriate estimation method for the regression. The test indicated that the fixed effect model is preferable than random effects (Table 1).

The following model is constructed as follows:

$$\ln(TOU_{pm}) = \beta_0 + \beta_1 \ln(t_{pm}) + \beta_2 \ln(rh_{pm}) + \beta_3 \ln\left(pcp_{pm}\right) + \beta_4 flo_{pm} + \beta_5 whi_{pm} + \beta_6 dro_{pm} + \beta_7 abr_{pm} + \beta_8 et\nu_{pm} + \partial_m + \partial_p + \epsilon_{pm} \quad (1)$$

in which $\ln(TOU_{pm})$ represents the logarithm of the number of international tourists of the province p in month m. $\ln(t_{pm})$, $\ln(rh_{pm})$, and $\ln(pcp_{pm})$ represent the logarithm of monthly average temperature, average relative humidity, and total precipitation, respectively. flo_{pm}, whi_{pm}, dro_{pm}, and abr_{pm}, refer to the frequency of flood, whirlwind, drought, and abrasion, respectively. This model also includes time dummy variables (∂_m) to capture month-specific effects, such as holiday seasonality. The provincial dummy variables (∂_p) is also employed to capture unobservable individual effects, such as the distance and the transportation convenience from the tourist's origin country to the destination, and the marketing

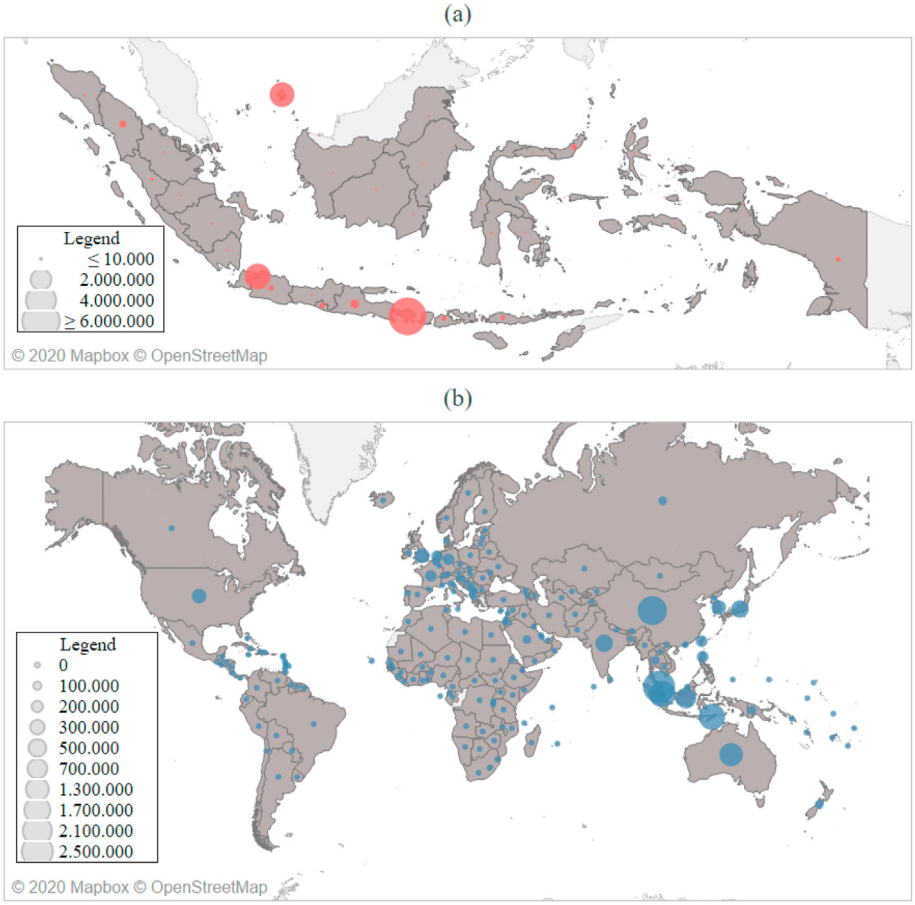

Fig. 2. Distribution of international tourists in Indonesia by destination (a) and by country of origin (b).

Table 1
Hausman Test Result. The regression model is constructed as follows.

Variables	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	Fixed	Random	Difference	S.E.
Temperature	386.29	−19049.95	19436.23	1665.23
Relative humidity	−2089.09	916.42	−3005.51	805.25
Precipitation	−25.66	−37.81	12.15	5.69
Floods	954.97	−6060.99	7015.96	564.26
Whirlwind	23.43	−2777.87	2801.31	369.25
Droughts	−976.53	−13156.96	12180.43	943.91
Abrasion	−1526.95	15630.53	−17157.48	869.49
Earthquakes and tsunamis	1310.47	−56.09	1366.56	336.92
Chi^2	484.09			
Prob > chi^2	0.00			

strategy for tourism in each province. ε_{pm} represents the error term. While temperature and relative humidity are measured in average, the precipitation used in this research is daily precipitation summed for a month, following previous study designs (Cashman et al., 2012; Köberl et al., 2016).

Due to the presence of spatially- and temporally-correlated errors and the possibility of group-wise heteroskedasticity in the panel dataset, a series of heteroskedasticity and autocorrelation tests were performed.

The result of heteroskedasticity and autocorrelation tests in Table 2 reveals that inter-individual homoscedasticity, autocorrelation and group sectional independence exist. Considering the presence of such condition, the Feasible Generalized Least Square (FGLS) method is used in this model as it is both robust to autocorrelation and panel heteroskedasticity, following previous studies (Ali et al., 2017; Amin et al., 2015; Mitchell et al., 2012). This method is estimated by using panel-corrected standard errors with a common auto-regressive (AR1) model, which allows the error to be heteroskedastic and the autocorrelation within groups with the same autoregressive coefficient.

4.3. Dependent variables

Various indicators were used to represent tourism demand, including the length of stay, the number of tourists, international tourist arrivals, and tourism spending (Damm et al., 2017; Dogru et al., 2019; Katircioglu et al., 2019; Köberl et al., 2016; Liu, 2016). In this research, the number of international tourists is used as the dependent variable to examine how climate change impacts the demand for inbound tourism in Indonesia. The dataset of international tourist arrivals was extracted from the Passenger Exit Survey (PES) conducted by the Ministry of Tourism of Indonesia. The number of tourists in each province is represented by the tourists arriving in the airport and/or the seaport located in each province. One exception is that the figure used for international tourists flying to Jakarta was that of the Soekarno Hatta International Airport, which is geographically located in the neighboring province of Banten. Almost all international flights heading to Jakarta land in this airport. It is worth noting that the international tourists included in this research are not limited to those traveling due to recreational purposes and business (which accounted for 87.48% of journeys in 2014 according to Statistics of Indonesia), but also include tourists motivated by other reasons, such as educational and diplomatic reason.

4.4. Independent variables

The climate variables used in this research are monthly average temperature, total precipitation, and average relative humidity. All climate variables datasets are collected from the National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration, 2019), except for precipitation, which is observed by the ground station of Meteorological, Climatological, and Geophysical Agency of Indonesia (Meteorological, Climatology, and Geophysical Agency of Indonesia, 2019). The other group of variables used in this analysis is extreme events, including flood, whirlwind, drought, abrasion, earthquakes, and tsunamis, the data of which are derived from the National Agency for Disaster Countermeasure of Indonesia (Indonesian National Board of Disaster Management, 2019).

4.5. Controlled variables

Considering the climate variables of the tourists' country of origin may affect the tourism flow (Zhang and Kulendran, 2017), this study employs the temperature of tourists' origin country as a controlled variable. The dataset for 2008–2016 is collected from the World Bank Group (World Bank, 2020). The dataset for 2017–2018 is collected from the National Oceanic and Atmospheric Administration (National Oceanic and Atmospheric Administration, 2019), since the data of these two years are limited from the World Bank Group.

5. Results

5.1. Descriptive statistics

Table 3 shows the descriptive statistics of the sample data. In general, the sample has a stable temperature with a mean of 27.61 °C. The lowest average monthly temperature was observed in

Table 2
The result of heteroskedasticity and autocorrelation test.

Test	Test for	Result
Modified Wald test (Greene, 2003)	Groupwise heteroskedasticity	Reject H_0, presence of inter-provincial homoscedasticity
Wooldridge test (Wooldridge, 2002)	Autocorrelation	Reject H_0, presence of autocorrelation
Pesaran's test (Pesaran, 2004)	Cross-sectional independence	Reject H_0, presence of group sectional independence
Friedman's test (Friedman, 1937)		
Frees' test (Frees, 1995)		

Table 3
Descriptive statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
Temperature	659	27.61	0.72	25.45	29.92
Relative humidity	659	79.22	5.22	60.05	90.09
Precipitation	649	163.12	147.85	0	828.3
Flood	660	2.42	5.16	0	42
Whirlwind	660	1.96	4.71	0	40
Droughts	660	0.28	1.58	0	18
Abrasion	660	0.08	0.39	0	5
Earthquakes and tsunamis	660	1.61	4.03	0	43
Number of tourists	660	124,452.3	122,103.7	927	624,263

Bali in July 2011 at 25.45 °C, while the highest was captured in East Java at 29.92 °C in November 2015. As for relative humidity, East Java had relatively low humidity overall compared to other provinces with the lowest recorded at 60.05% in September 2008, while North Sumatra was relatively wetter than other provinces, peaking at 90.09% in December 2013. With regards to precipitation, East Java showed an increasing trend over the past five years, while the contrary pattern was recorded in Jakarta, Riau Islands, and North Sumatra. Since Indonesia only has two seasons with the rainy season (October–March) and dry season (April–September), the difference of the total precipitation across the month is significant. Moreover, flood, earthquakes and tsunamis are the most common extreme events in Indonesia. As East Java has a considerably larger area than the other provinces, it observed most of the extreme events.

Regarding tourist numbers, it is found that Bali has been Indonesia's favorite tourist destination for international travelers. It shows an increasingly significant trend over the last couple of years and peaks in July 2018 with 624,623 tourists. Jakarta and Riau Islands have also shown a steady increase over the years, but their combination is still not comparable to Bali. North Sumatra and East Java had a relatively smaller number of tourists, but the numbers are increasing steadily.

5.2. The effects of climate-related features on inbound tourist

The empirical results show that temperature and relative humidity significantly influence international tourist visits in Indonesia, with a 90% confidence level (Table 4). Specifically, a 1% increase in temperature is associated with 1.37% of tourists decrease, and the same change in relative humidity correlates with 0.59% of tourist decrease. Overall, the temperature has the most significant magnitude among all variables across the models, which underlines that temperature is one of the most influencing factors for the number of international tourists in Indonesia. This finding is consistent with previous studies (Amelung and Nicholls, 2014; He et al., 2019; Scott et al., 2008; Yazdanpanah et al., 2016), which is understandable because temperature is one of the key climate elements that determine the climate comfort at the destination (Hamilton and Lau, 2005). Similar to temperature, relative humidity also plays a pivotal negative role in the number of international tourists in Indonesia. However, contrary to previous findings (Fauzel, 2019), precipitation does not show significant impacts on our sample. This inconsistency might be due to limited ground observational data of precipitation in our sample.

The effects of extreme events on tourism, on the other hand, have a more different outlook compared to the hypotheses. The empirical evidence suggests that only whirlwind and earthquakes and tsunamis have significant correlations with the number of visitors in Indonesia, albeit with unexpected signs. The positive correlation between whirlwind and tourism demand could be explained that the whirlwind in Indonesia is relatively less severe compared to other destructive tropical cyclones, and it usually reaches its peak during the monsoon season, which happens to be a peak season (Christmas, Gregorian New Year, and Chinese New Year). The positive correlations between earthquake and tsunami and tourism demand may be explained by the fact that earthquakes frequently occur in Indonesia but are not destructive in the tourist

Table 4
The effect of climatic variables and extreme events on the number of tourists.

	All	Southeast Asia	East Asia	India	Middle East	Europe	Australia	USA
Temperature	−1.370**	0.234	−1.130	0.011	−0.304	−0.990	−0.886	−2.096***
	(0.536)	(0.661)	(1.070)	(1.051)	(1.839)	(0.708)	(0.710)	(0.704)
Relative humidity	−0.589*	0.054	−0.378	−0.576	0.708	−1.239***	−1.019**	−1.023***
	(0.305)	(0.396)	(0.477)	(0.561)	(1.080)	(0.407)	(0.447)	(0.390)
Precipitation	−0.004	−0.013	−0.013	0.025	−0.030	0.013	0.017	0.006
	(0.006)	(0.011)	(0.015)	(0.017)	(0.032)	(0.011)	(0.012)	(0.011)
Floods	−0.001	−0.003*	−0.003**	−0.001	−0.001	−0.002	−0.002	−0.004***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.004)	(0.001)	(0.002)	(0.001)
Whirlwind	0.004**	0.000	0.000	−0.001	0.003	0.006***	0.004**	0.003*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.004)	(0.001)	(0.002)	(0.001)
Droughts	−0.005	−0.022	−0.069**	−0.056	0.234**	0.001	0.003	−0.021
	(0.005)	(0.029)	(0.032)	(0.041)	(0.098)	(0.034)	(0.041)	(0.033)
Abrasion	0.000	−0.011	0.001	0.013	0.077*	0.025	0.003	0.016
	(0.009)	(0.016)	(0.018)	(0.022)	(0.046)	(0.016)	(0.020)	(0.016)
Earthquakes and tsunamis	0.005**	0.003*	0.000	0.001	−0.007	0.001	0.000	−0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.005)	(0.002)	(0.002)	(0.002)
N	618	224	224	224	224	224	224	224
R-squared	0.992	0.9829	0.9899	0.9829	0.9751	0.9889	0.9943	0.9877

Note: Coefficients of time and province-dummy variables and constant were included in this model but not reported. Standard errors are shown in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01.

destination. Furthermore, the news of earthquakes and tsunamis might affect tourists' behavior on destination choice through media exposure. This result is in line with previous findings that the number of tourists is likely to rebound after severe damage of earthquakes (Huan et al., 2015; Huang et al., 2020; Mendoza et al., 2012).

5.3. The impact of climate change on tourism by country of origin

This study extends theoretical conjecture that the significance and magnitude of climate change and climate-related extreme events are not homogeneous among tourists' country of origin (Table 4). It is found that neither of the climatic factors affects the tourist number from Southeast Asia, East Asia, India, and the Middle East. This can be interpreted as most tourists from Southeast Asia and East Asian are traveling to Indonesia for a short period, including one-day trips; thus the reliance on climate is considerably low. Besides, the temperature in Southeast Asia is relatively similar to Indonesia due to its location, which explains why such impact does not apply to Southeast Asian. There is a more complex outlook on climate factors and extreme events influencing tourists from Europe to travel to Indonesia. Relative humidity and whirlwind are the most significant factors affecting European visitors under a 99% confidence level. Similar to the European group, relative humidity and whirlwind also play a significant role in affecting the number of Australian tourists to Indonesia but with a lower confidence level. Americans have a more diverse impact pattern on traveling to Indonesia as temperature, relative humidity, and whirlwind have a more substantial impact on the number of tourists to Indonesia under a 99% confidence level. In sum, the result suggests that the pattern of influence differs between tourists from different regions, suggesting that tourists from different countries may have different preferences of climate when traveling in Indonesia.

5.4. Robustness test

A robustness analysis was conducted by adding controlled variables to test whether the estimated effects are still statistically significant under different sets of variables. The additionally controlled variables of the temperature of tourists' origin country are employed in this model. Temperatures from 18 countries, whose tourists contributed 80% of the total tourists in Indonesia are examined one by one in the model for the robustness test. With these additional sets of variables, the model shows that results are robust, with similar patterns occurring under different sets of controlled variables.

6. Discussion and conclusion

6.1. Practical implications

This research revealed the association of climate variables and climate-related extreme events with the number of international tourists in Indonesia. The findings enhanced essential underpinnings of the extent of the magnitude of climate change impact, which could provide a strong basis for policymakers and the tourism industry.

The first implication is that tourism in Indonesia is expected to adapt to temperature and humidity rise in climate change. Establishing tourism property that could improve tourism comfort may be taken into consideration. Tourism destinations may promote the use of green spaces as it may reduce the perception of thermal discomfort (Lafortezza et al., 2009). Tree planting in tropical destinations is also envisioned as a solution to improve outdoor thermal comfort, as suggested by a study in Taiwan POC (Lin and Tsai, 2017). Moreover, improving cooling equipment in tourists' accommodation may be another possible alternative. Considering the cooling equipment may evoke new climate change issues, the use of clean energy should also be taken as a consideration in implementing this option.

Second, developing a climate-based strategy to attract international tourists may improve the number of international arrivals in Indonesia. Taking advantage of the local climate characteristic and media exposure might lead to a positive association between natural disasters and the number of tourists. The proposal of monsoon tourism is a typical example of this strategy that utilized the rainfall and lush green landscape in Bangladesh which is promoted as a tourist attraction (Chowdhury, 2014). On the other hand, earthquake and tsunami could also be used as a long-term advertising strategy to promote Indonesia's tourism at the same time. Nevertheless, it is still important to improve natural disaster management to boost tourism recovery as the shock of natural disaster reduces the number of international tourists in the short term.

The third implication is to adopt sustainable tourism practices and reinforce the resilience of tourism facilities. In fact, one of the most famous tourism destinations in Indonesia, Bali, has set its own Green Growth 2050 Roadmap as a strategic framework, responding to both economic and climate challenges. One of its strategies focuses on climate and environment, touching upon building resilience to shocks and stress on future climate change risks (Wiranatha et al., 2011). This typical policy is expected to be introduced at the provincial level as an adaptation measure by further testing this model in various tourist destinations, considering each destination has its own challenges on introducing such frameworks and tourists from different regions have different preferences on climate (Law et al., 2016).

6.2. Limitations and recommendations

Although this study has controlled many factors, the possibility of omitted variables cannot be fully ruled out. For example, tourists may shift from competitive destinations such as Thailand and Vietnam to Indonesia when those destinations are unable to provide their service due to natural disasters or political instability. Future studies should include additional controlled variables, such as terrorism, disease outbreak, civilian conflicts, and free-visa policy. Moreover, incorporating the number of domestic tourists would give a broader view of the impact of climate variables and climate-related extreme events on overall tourism. Further investigation on the economic implications such as GDP and employment are strongly encouraged, which depicts a meaningful subject for future research. Further research on future tourism under various climate change scenarios is also highly recommended.

7. Conclusions

This paper presented empirical evidence with regard to the associations between climate change and international tourism in Indonesia. It contributes to the current limited understanding of the impact of climate change and climate-related extreme events on the tourism sector in the tropical island country. One significant finding to emerge from this study is that temperature and relative humidity possessed significant impacts on international tourism demand. Furthermore, this research confirmed that tourists from different regions have different climate preferences before making their trip to Indonesia. These findings suggest that there is a need for policymakers and tourism actors to adapt to climate change by enforcing adaptive policies and improving the resilience of tourism destinations. The study also enriches the theoretical basis of the

impacts of climate change on tourism demand. Future research would benefit from an extension of the research to tourism implications under different climate change scenarios.

Funding

This work was supported by the National Key Research and Development Program of China [No. 2017YFA0603602]; the National Natural Science Foundation of China [No. 71773062, No. 71525007, and No. 71904201]; and the Science Foundation of China University of Petroleum-Beijing [No. 2462018YJRC026].

Author Contributions

J.S. designed and conducted the research. X.Z., Y.L., and C.W. refined the methodology of research. All authors contributed in providing constructive input and analysis as well as interpretation of the result in this manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to extend special thanks to the Meteorological, Climatology, and Geophysical Agency of Indonesia and the province of Bali for providing climatic variables and extreme events dataset. The authors would also like to thank Piet Derboven for proofreading on the manuscript.

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