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Spatial Patterns of China's Ski Resorts and Their Influencing Factors: A Geographical Detector Study

Yan Fang [1], Yiyi Jiang [1,*], Chin-Hsun Ken Tsai [2], Binghao Luo [1] and Ming-Hsiang Chen [3]

[1] School of Recreational Sports and Tourism, Beijing Sport University, Beijing 100084, China; fangyan@bsu.edu.cn (Y.F.); 1004320180814@bsu.edu.cn (B.L.)
[2] Department of Apparel, Events, and Hospitality Management, College of Human Sciences, Iowa State University, Ames, IA 50011-1078, USA; kentsai@iastate.edu
[3] School of Hospitality Business Management, Carson College of Business, Washington State University, Pullman, WA 99164-4742, USA; ming-hsiang.chen@wsu.edu
* Correspondence: yiyijiang@bsu.edu.cn

Abstract: This study uses geographic information systems (GIS) and geographical detector techniques to explore the national and regional pattern of the spatial distribution of China's ski resorts, and quantitatively identifies the main factors that influence their location. Results show that although China's ski areas are geographically clustered, ski resorts are more likely to be located at high latitudes (northeast and northwest China) than at low latitudes (central and south China). Among the most influential factors are the winter sporting mega-events that explain 70% of the location of China's ski areas; the 2022 Winter Olympics accounted for 14%. The main factors that contribute to the distribution of ski areas depend on the regions and types of ski resorts. Implications for the ski resorts industry, such as the different practice for hot and cold spot areas of China's ski resorts, and the future development direction of ski industry, are discussed.

Keywords: ski resorts; geographic information systems (GIS); spatial analysis; geographical detector; influence factors; Winter Olympics

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1. Introduction

Sports tourism, one of the world's fastest-growing travel and tourism sectors, is becoming crucial for destination planning and development [1]. With the introduction of leisure and sports activities in the second half of the 20th century, many mountain areas have become attractive tourist destinations [2]. Ski resort-based tourism, including services and infrastructure improvement, economic and income diversification, and the creation of "psychological stability" among residents [3], is a pillar of the tourism industry in many mountain areas. For example, ski tourism accounts for approximately 4.5% of Austria's GNP, which is about half of the country's total tourism revenue [4]. The socioeconomic of ski resort-based tourism in Alpine countries epitomizes the transformation of sporting activities into industrially produced and consumed outdoor leisure activities [5]. The world's 2000 outdoor ski resorts and 90 indoor snow centers have attracted approximately 400 million skiers over the last 18 years [6].

In contrast to the mature ski tourism markets in many countries of Europe and North America, the ski industry in China is an apparent emerging market. With significant growth over the last two decades, China has now become one of the world's largest ski tourism markets, reaching 19.7 million skier visits and 742 ski resorts in 2018 [7]. It will soon surpass some global leaders such as Switzerland (with 21.2 million skier visits in the 2016–2017 season) [8]. Ski tourism in China began in 1996 and has boomed in the last decade; however, skiing participation rates in China (currently at only 1% of the global average) are still considerably lower than in other countries [8]. This growth has been driven by the increase in personal wealth, which has led to a large increase in domestic and inbound tourism.

The 2022 Winter Olympics will strengthen winter sports in China, because the government has enacted a series of policies to build China's skiing industry. According to China's government, 800 ski resorts will be built by 2022. More than 300 million Chinese people are expected to participate in winter sports by 2025, generating USD 155.4 billion in revenue for the ski industry alone [9].

Ski areas are essential facilities for skiing, which are important for the development of ski tourism and the regional economy. Geographical inequalities, however, are identified in the distribution of ski resorts. More than one-third of all ski resorts in the world are located in the Alpine region, capturing 43% of skiers' visits, followed by North America (21%) [6]. The uneven spatial distribution of ski areas is also observed in China, where 60% of ski areas are located in the north and northeast [7]. In mature ski tourism markets, a critical factor in the location of ski areas are the natural resources [10]. The number of ski resorts seems to have stabilized. In China, however, more ski resorts are being built.

In order to better understand and predict the development of the ski industry, it is important to understand spatial patterns in the distribution of ski resorts at the regional scale as well as the main factors of influence. By combining spatial analysis based on geographic information systems, we propose a new approach—the geographical detector—which explores the national and regional pattern of the spatial distribution of China's ski resorts, identifies the main factors that influence the location of ski resorts, and provides useful information for planning and marketing purposes, such as how to predict and select locations for different types of ski resorts, and develop sound marketing strategies according to the distribution pattern.

The research contribution is threefold. This paper, unlike similar studies, is based on a quantitative rather than a qualitative methodology. No studies in the literature [11,12] on spatial analysis in tourism research have used spatial tools to detect regional differences in influence. For this reason, we used the geographical detector to analyze factors that influence the distribution of ski resorts from a spatial perspective, and to determine whether there are significant regional variations in the impact of those factors.

In addition, although some studies have examined the nationwide spatial distribution of China's ski resorts [13,14], their results were less accurate due to considerable regional differences. China has ski resorts in 28 provinces [7]; therefore, it is essential to explore spatial distribution and influencing factors in different areas. Lastly, the literature has not distinguished ski resorts with markedly different snow qualities [13,14]. Although there are more than 700 ski areas across China, fewer than 10% of them meet international standards for high quality [15]. In other words, most of them are either poorly equipped or are suitable only for novice skiers. In these circumstances, it is necessary to determine the extent to which the geographical distribution of ski areas with and without aerial lifts varies across China.

The rest of the paper is organized as follows. The next section presents the literature on possible factors affecting the spatial distribution of China's ski resorts. Section 3 describes the research methodology and data sources. Section 4 identifies the pattern of the spatial distribution of China's ski resorts, followed by a quantitative analysis of the spatial distribution factors. The last section presents the main findings.

2. Review of the Literature

2.1. Factors That Influence the Distribution of Ski Resorts

Current research shows that natural, economic, and social factors can be used to identify possible ski towns [10]. Ground factors and climatic variables are central in determining whether or not a ski resort can be built. The minimum criterion for a ski area is adequate snowfall, which depends on low temperatures, precipitation, air humidity, and prevailing winds [10,16].

As far as the topography is concerned, slope is an element that separates novice from expert skiers. Elevation is essential for skiing activities and the maintenance of a favorable snow layer [17]. Moreover, a water source would be beneficial for snowmaking [18]. For

example, at Colorado's White River National Forest, 20–30 cm of snow are added to the slopes at each resort by snowmaking runs. The water used for snowmaking is pumped from the White River below the ski slopes and transported to snowmaking basins [19].

Sporting mega-events, most notably the Olympic Games, not only support the construction of new sports facilities, but also foster investments in tourism development (e.g., the dramatic increase in hotel accommodation capacity) [20]. Tourist and recreation functions are provided by these sports facilities and infrastructure, which usually contribute to winter tourism and community amenities [21]. Winter sports events are therefore important in the development of infrastructure and skiing culture [22], particularly in areas where the ski industry is still lagging behind. Bidding and holding sporting mega-events can promote construction, as well as increasing sports facility demand. Zhangjiakou, a host city of the Beijing 2022 Winter Olympic Games, has boosted its local ski industry development due to it co-hosting the 2022 Winter Olympic with Beijing, for example. In addition, culture is incorporated into the changes brought on by mega-sports activities, which is almost unavoidably created in the process of planning the event [23]. The cultural component of sports mega-events has received increasing attention because it has become increasingly important, both in terms of artistic activities and in terms of identity and way of life [24]. The Winter Olympics is arguably a game for the comparatively wealthy Global North; therefore, hosting this winter sports mega-event in less developed countries not only serves to boost its status as a global economic and cultural powerhouse [25], but also plays a vital role in fostering a ski culture and converting this activity into a lifestyle [26].

The factors affecting the demand for skiing should also be considered in the selection of the site. According to a previous study [27], population density is the primary driver of outdoor recreation demand, and the resident population affects the generation of regional recreation trips from a particular origin zone, such as skiing [28]. Moreover, accessibility is a vital prerequisite at any tourist destination [29]. Based on the comparison of the results of the studies, the main factor influencing the choice of location and destination are travel distance and climatic factors (e.g., snow conditions, ski slopes) [30]. With climate change, the appeal of snow-safe destinations is strongly influenced by price and travel time [31]. The distance of the ski resort from where the skiers live or stay is important for the choice of destination.

In order to find more potential skiers, economic factors, e.g., GDP per capita, are also valid in explaining arrivals [32], and the demand for skiing is expected to increase as income rises [33]. Additionally, tourism revenue, tourist carrying capacity, and tourism infrastructure can be used as indicators to measure ski tourism demand [34], because new ski resorts are more likely to be established in regions/destinations that offer sufficient recreation-related activities, and these factors can demonstrate the local ability to cope with ski tourism impacts.

2.2. Factors That Influence the Spatial Distribution of China's Ski Resorts

The natural, economic, and social factors that influence the location of the ski resorts mentioned above also apply to those in China [13,35]. However, government regulatory factors are a uniquely significant factor in the development of China's ski resorts [36,37], which is testament to the initiative's success [38]. Following its successful bid for the 2022 Winter Olympics, the Chinese government released a series of policy documents supporting the development of the ski industry. The number of policies related to ski resorts could, therefore, reflect the development of China's ski industry. Due to its regional emphasis, this study relies on provincial policies for the ski industry rather than national ones, such as the Hebei Province ice and snow industry development plan (2018–2025), and the ice and snow sports industrial development project of Jilin City. Furthermore, sporting mega-events are particularly important for the development of China's ski industry. For example, the third Asian Winter Games held in Harbin in 1996 marked the beginning of ski tourism in China, where ski areas were first opened to the public.

As a result of the literature review, natural, economic, social, cultural, and political factors were chosen to explain the location of ski resorts, as shown in Table 1. Due to the disparate influence of sporting events, the weight assignments for national sporting events, and small and large international events (e.g., Olympic Games) were set at 1, 3 and 5, respectively. Moreover, fictitious data were used to evaluate the effects of Olympic host cities on the location of ski areas, which are divided into two categories (0 = No, 1 = Yes). Other data were divided into five classes using the *k*-means classification technique using ArcGIS (geographic information system) software.

Table 1. The possible factors that influence the spatial distribution of China's ski resorts.

Factors	Subfactors	Code	Classification
Natural factor	Elevation	X_0	5
	Slope	X_1	5
	Terrain relief	X_2	5
	Distance to the nearest river	X_3	5
	Temperature in the winter season (November–April)	X_4	5
	Precipitation in the winter season (November–April)	X_5	5
	Wind speed in the winter season (November–April)	X_6	5
	Relative humidity in the winter season (November–April)	X_7	5
Economic factor	GDP per capita	X_8	5
	International tourism revenue	X_9	5
	Domestic tourism revenue	X_{10}	5
Social factor	Resident population	X_{11}	5
	Population density	X_{12}	5
Traffic accessibility	Traffic density	X_{13}	5
	Distance to the nearest road	X_{14}	5
Cultural factors	Whether it is an area for holding the 2022 Winter Olympics	X_{15}	2
	The number of international/national winter sports events	X_{16}	5
Political factor	The number of provincial policies	X_{17}	5

3. Data and Methodology

3.1. Data Resources

The location of each ski resort was obtained through a map website on October 11, 2019, and was checked for integrity and authenticity by multi-source information (e.g., search engine, reports of China's ski resorts). The latitudes and longitudes of 776 confirmatory samples were converted to GIS-compatible point data using ArcMap10.2 (Figure 1). To understand the spatial distribution of the different types of ski resorts as well as their primary influence factors, we looked at all of China's ski resorts (776) and those with aerial lifts (162).

Terrain data such as elevation, slope, and terrain relief were obtained from the Chinese Academy of Geological Sciences' resource and environment data cloud platform [39], which calculates using the Shuttle Radar Topography Mission (SRTM) 90 m resolution digital elevation model (DEM). The climate dataset used in the winter season analysis (November–April) was the standard value of the surface climate dataset in China from 1981 to 2010, the DEM of the SRTM through ArcGIS downloaded from China's meteorological data sharing service system. With 825 weather observation stations across China, the station attribute information (e.g., station ID, longitude, latitude) and mean monthly climate data (e.g., temperature, humidity, precipitation, wind speed) are included in the dataset, which has been widely used in climate-related research in China [40].

The primary data for traffic density, distance to the nearest road, and river were obtained from the National Geomatics Center of China and were processed by ArcGIS software. Economic and social data were obtained from the 2018 statistics published by the National and Provincial Statistical Bureaus of China. We collected data on the number of winter sports events and provincial policies from government websites and other web pages.

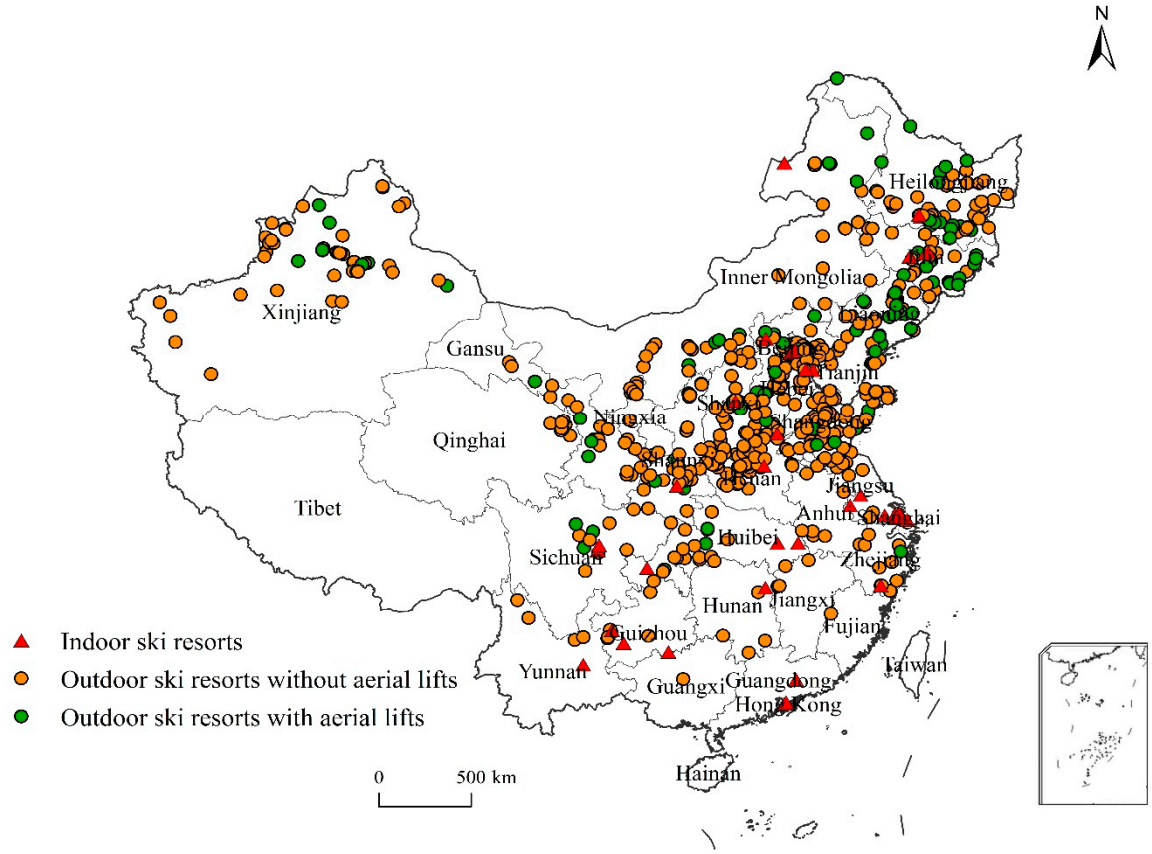


Figure 1. The location of China's ski resorts.

3.2. Methods

3.2.1. Nearest Neighbor Ratio Analysis

The nearest average neighbor tool within ArcGIS is a valid tool for statistically assessing spatial distribution through the output of an R value and a Z-score. The R value was calculated on the basis of the ratio between the observed and the random average distance, showing how the data were clustered or dispersed. The Z-score showed the statistical significance of the calculated R value.

A high confidence level in the calculated R value was indicated by a highly positive/negative Z-score [41]. The distribution was considered to be clustered if the R value was less than 1; it was dispersed if the ratio was greater than 1. The closer the value of the R was to 0, the more clustered the points were likely to be. *p*-values of less than 0.05 were considered to be statistically significant.

3.2.2. Kernel Density Estimation

Kernel density estimation (KDE) is a non-parametric means of determining the pattern of spatial data for estimating the crash intensity for hotspot identification [42]. The premise of the method is that the point pattern has a density at any location in a given region, meaning that it is not just the location where the event occurs [43]. The value of the data

assigned to a specific point is used and spreads across a predefined area. The KDE at point x is defined as:

$$\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^{n} K(\frac{1}{h}(x - x_i)) \quad (1)$$

where $K(\ )$ is the kernel function, h is the bandwidth matrix, x_i is the known points, n is the number of known points within the bandwidth, and d is the data dimensionality.

3.2.3. Spatial Autocorrelation Statistics

(1) Moran's I

Moran's I, as a major global spatial autocorrelation index, is used to determine whether there is spatial autocorrelation in a dataset and its degree of autocorrelation throughout the study region [44]. Possible values of Moran's I range from −1 to 1. A positive value indicates the spatial clustering of similar values, and a negative value identifies the clustering of different values. The Z-score is measured for statistical hypothesis testing, which indicates that spatial autocorrelation is statistically significant at the 5% level if it is greater than 1.96 or less than −1.96. Mathematical formulas for Moran's I index are defined as:

$$\mathrm{I} = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{(\sum_{i \neq j}^{n} \sum_{j=1}^{n} w_{ij})(\sum_{i=1}^{n} x_i - \overline{x}^2)} \quad (2)$$

where n is the total number of pixels, x_i and x_j are the variables of interest in points i and j, respectively, $\overline{x}$ is the average value of x, and w_{ij} is a matrix of spatial weights.

(2) Getis–Ord Gi*

Although global spatial autocorrelation indexes measure whether clustering is present across the study area, cluster structures of high or low concentration cannot be identified. We therefore used Getis–Ord Gi*, a local spatial autocorrelation index statistic, to investigate spatial associations by identifying significant hot and cold spots [45]. A significant hotspot could be identified if Z-scores were greater than 1.96, while a significant cold spot was shown if the Z-score was lower than −1.96 ($p < 0.05$). The statistical equation for calculating Gi* can be written as:

$$G_i^* = \frac{\sum_j^n w_{ij} x_j - \overline{x} \sum_j^n w_{ij}}{S \sqrt{\left(n \sum_j^n w_{ij}^2 - (\sum_j^n w_{ij})^2\right)/(n-1)}} \quad (3)$$

where n is the total observation number, W_{ij} is the weight of the values, $\overline{x}$ is the average of the observed values, and S is the standard deviation. The $\overline{x}$ and S can be defined as:

$$\overline{x} = \frac{\sum_j^n x_j}{n}; \; S = \sqrt{\frac{\sum_j^n x_j^2}{n} - (\overline{x})^2} \quad (4)$$

3.2.4. Geographical Detector

The geographical detector was developed by Wang et al. [46] on the basis of a spatial variance analysis, which examines the relationship between spatial landscape patterns and their influence factors. The method has been used to study the influence factors of natural and socioeconomic phenomena due to its strength in the analysis of mixed categorical and continuous data [47,48]. Four geographical detectors—risk, factor, ecological, and interaction—could be model-based, and the factor detector module is used to detect whether the factor is the cause of the difference in the spatial distributions of the indicator value [46]. We used $P_{D,G}$ obtained from the factor detector to assess the impact of geographical, climatic, social, economic, and political factors on the spatial pattern of China's ski resorts. $P_{D,G}$ can be expressed as follows:

$$P_{D,G} = 1 - \frac{\sum_{i=1}^{m} n_{Di} Var_{Di}}{nVar} \quad (5)$$

where $P_{D,G}$ indicates the power of the determinant, n is the total number of samples, Var is the variance of samples in the study area, m is the number of sub-regions; n_{Di} and Var_{Di} are the number of samples and the variance of sub-region D_i, respectively. $P_{D,G}$ values range from 0 to 1. A value of $P_{D,G}$ equal to 1 indicates that the spatial pattern of ski resorts is adequately explained by the geographical stratum, while a completely random spatial occurrence of the ski resorts is identified if it is equal to 0.

4. Results of the Pattern of the Spatial Distribution of China's Ski Resorts and Discussion

4.1. Nearest Neighbor Ratio Analysis

Table 2 shows the closest neighbor spatial distributions of China's ski resorts in different regions. The spatial distributions of all ski areas and those with aerial lifts are both significantly clustered at national level, but different patterns of distribution appear in different regions. Ski resorts in high-latitude areas (e.g., northeast and northwest China) are more likely to gather than those in low-latitude areas (e.g., central and south China). The phenomenon of dispersion is also more commonly seen in ski resorts with aerial lifts (i.e., east, central, and southwest China). The main reason is the difference in quantity of natural snow. Most of China's ski resorts, especially high-quality ones, are located in areas with much natural snow cover, while few are located in less snowy areas, mainly driven by demand [14].

Table 2. Average nearest neighbor results (NNRs) of China's ski resorts.

Region	All Ski Resorts				Ski Resorts with Aerial Lifts			
	NNR	Spatial Distribution Pattern	Z-Score	*p*-Value	NNR	Spatial Distribution Pattern	Z-Score	*p*-Value
Northeast	0.478	clustered	−14.090	0.000 ***	0.565	clustered	−7.200	0.000 ***
North	0.736	clustered	−2.140	0.032 **	0.689	clustered	−3.991	0.000 ***
East	0.666	clustered	−3.259	0.001 ***	1.287	dispersed	1.899	0.058 *
Northwest	0.330	clustered	−12.621	0.000 ***	0.762	clustered	−2.137	0.033 **
Central	1.045	random	0.308	0.758	5.460	dispersed	14.778	0.000 ***
Southwest	0.972	random	−0.279	0.780	2.161	dispersed	4.968	0.000 ***
South	7.058	dispersed	20.072	0.000 ***	-	-	-	-
Whole country	0.387	clustered	−32.662	0.000 ***	0.463	clustered	−13.067	0.000 ***

Note: ***, ** and * represent 99%, 95%, and 90% confidence levels, respectively; there are no ski resorts with aerial lifts in the south of China.

4.2. Kernel Density Estimation Analysis

Figure 2 shows the distribution of the density of the ski resorts using KDE analysis. Jenk's Natural Breaks was applied to the density classification. The average distribution of ski resorts in China is 0.84/10000 km^2, while the number of ski resorts with aerial lifts is only 0.17 per 10,000 km^2. Figure 2a shows that China's ski resorts are concentrated in regions with somewhat better natural snow conditions, such as Xinjiang province, north, and northeast China. The pattern of high-density distribution of ski resorts varies across the three regions. Those ski resorts are mainly located in Beijing, and four surrounding provinces, Hebei, Shanxi, Shandong, and Henan, in northern China. Most of the ski resorts in northeast China have been built along the Changbai Mountains, while the resorts in Xinjiang province are scattered around the middle range of Tianshan Mountains. Although only about 160 ski areas in China have aerial lifts, the high-density distribution areas are similar to all ski resorts in Xinjiang province, north, and northeast China. Suitable climatic conditions are the main reason for these dense areas. Heilongjiang province, for example, was the site of the Yabuli ski resort and home to the third Asian Winter Games.

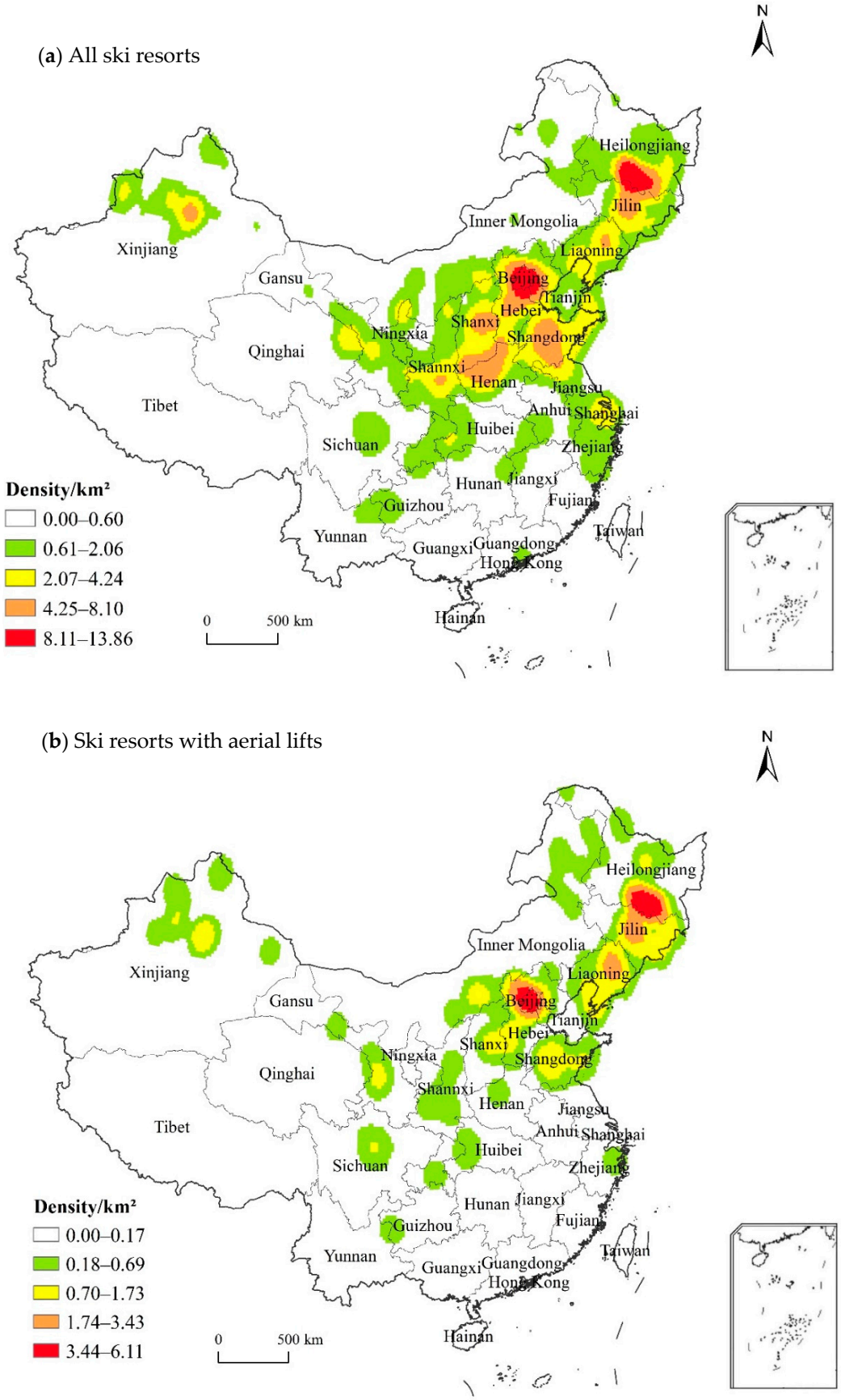


Figure 2. Density estimation of China's ski resorts using kernel density estimation (KDE) ((**a**)-Density estimation of all ski resorts; (**b**)-Density estimation of ski resorts with aerial lifts).

4.3. Spatial Autocorrelation Analysis

4.3.1. Moran's I

As shown in Table 3, Moran's I indices indicated significant clustering of all samples. Both Global Moran's I values are around 0.2, with corresponding Z-scores of 3.82 and 2.92, suggesting that there is significant spatial autocorrelation between all of China's ski resorts and those with aerial lifts ($p < 0.05$). In other words, regions with ski areas tend to be closer to each other instead of being randomly distributed across China.

Table 3. Global spatial autocorrelation indices of Moran's I for China's ski resorts.

All Ski Resorts			Ski Resorts with Aerial Lifts		
Moran's I	Z-score	*p*-value	Moran's I	Z-score	*p*-value
0.204	3.821	0.000 ***	0.191	2.918	0.004 ***

Note: *** represent 99% confidence levels, respectively.

4.3.2. Hotspot Analysis

Definite hotspots (in red) and cold spots (in blue) of the density of ski resorts in China were obtained from the Getis–Ord Gi* analysis (Figure 3). Heilongjiang and Liaoning provinces were consistent hotspots for each analysis. More hotspots are shown in all ski areas, including Inner Mongolia and northeast China. However, the spatial distribution of the ski areas in Figure 3a,b shows a high variability of clustered cold spots. Large cold spots have been found in southern China (e.g., Guangdong, Guangxi), while cold spots of ski resorts with aerial lifts in northwest China (e.g., Gansu, Shaanxi) are evident due to the heat and humidity in southern China; thus, no ski resorts have aerial ski lifts.

(**a**) All ski resorts

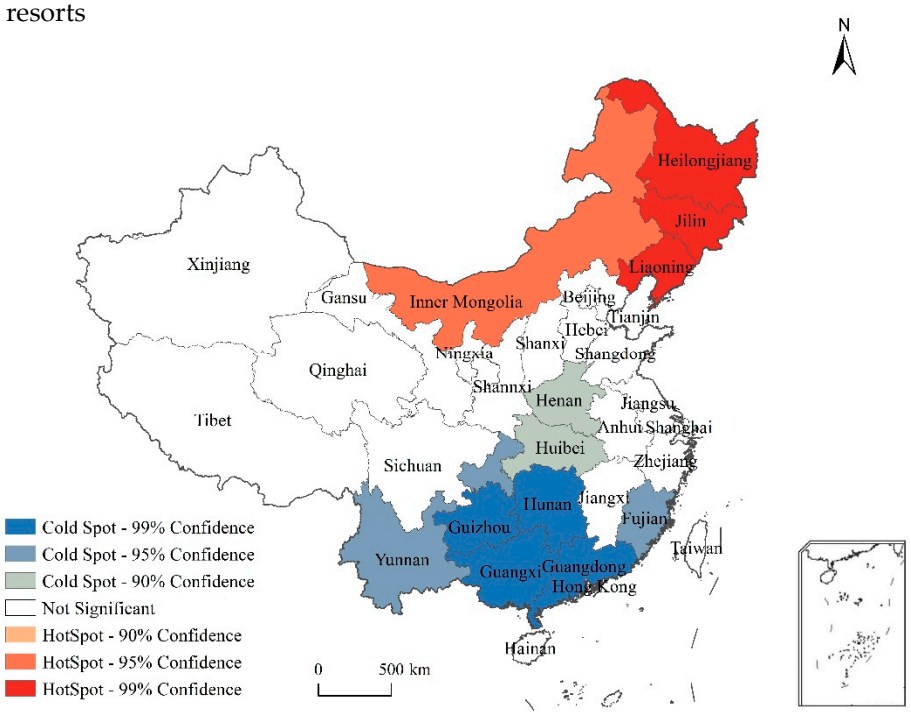


Figure 3. *Cont.*

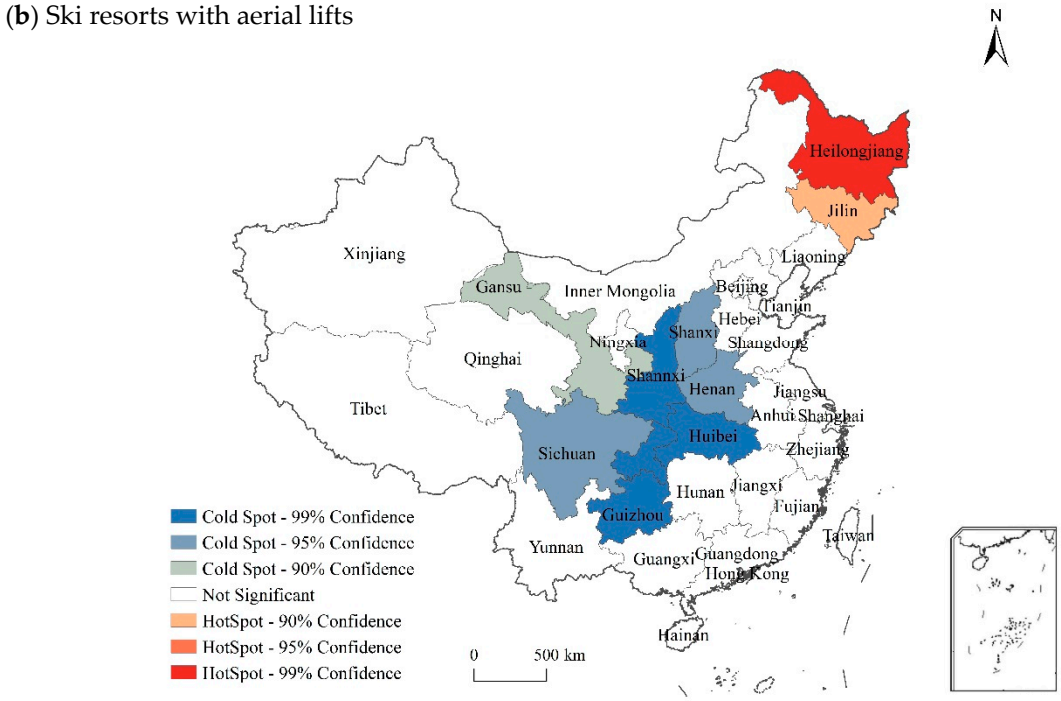


Figure 3. Hotspot analysis of China's ski resorts ((**a**)-Hotspot analysis of all ski resorts; (**b**)-Hotspot analysis of ski resorts with aerial lifts).

5. Results of Factors Affecting the Distribution of China's Ski Resorts and Discussion

5.1. Factors That Influence the Distribution of All Ski Resorts

According to the calculation using the geographical detector (Table 4), the main factors affecting the cluster formation of in China's ski resorts are temperature, precipitation, wind speed, relative humidity during the winter, rivers, accessibility, GDP per capita, government policies, domestic tourism revenue, resident population, and the 2022 Winter Olympics and other national and international winter sports events. The spatial distribution of ski resorts in China is driven by multi-party systems involving natural, economic, political, cultural, and location factors.

National and international winter sports events can explain around 70% of the spatial distribution of China's ski resorts. It should be noted that the impact of the 2022 Winter Olympics was examined separately, in order to clarify its role in the pattern of spatial distribution. The results showed that the 2022 Winter Olympics was associated with almost 14% of the explanatory power. These mega winter sports help to explain the other major factors affecting the spatial distribution of ski resorts. Studies show that the process of deciding who will host mega winter sports events is complicated, involving variables related to the spatial distribution of ski resorts, such as climate (e.g., altitude, precipitation, snowfall) and socioeconomic considerations (e.g., GDP, population, transport, tourism infrastructure) [49,50].

In China, winter sports events are mainly held in the provinces of Jilin and Heilongjiang. Among these were the 1st through 12th Winter Games of the People's Republic of China, the Third and Sixth Asian Winter Games, and the 24th World University Winter Games. In recent years, Xinjiang province has hosted the 13th National Winter Games, and Beijing and Zhangjiakou are hosting cities of the 2022 Winter Olympics. As a result, most of China's ski areas are in regions that have hosted international/national winter sports events; 42% of ski resorts were located in these areas in 2018.

Table 4. The major influence factors of spatial distribution of China's ski resorts.

	X_0	X_1	X_2	X_3	X_4	X_5
$P_{D,G}$	0.004	0.012	0.021	0.181	0.158	0.144
p-value	0.920	0.471	0.188	0.000 ***	0.000 ***	0.000 ***
	X_6	X_7	X_8	X_9	X_{10}	X_{11}
$P_{D,G}$	0.057	0.124	0.045	0.090	0.233	0.233
p-value	0.006 ***	0.000 ***	0.031 **	0.203	0.058 *	0.058 *
	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
$P_{D,G}$	0.008	0.012	0.192	0.135	0.703	0.066
p-value	0.816	0.534	0.000 ***	0.036 **	0.000 ***	0.000 ***

Note: ***, ** and * represent 99%, 95%, and 90% confidence levels, respectively.

5.2. Factors That Influence the Distribution of Ski Resorts in Different Regions

Table 5 shows similarities and differences in the influencing factors that shape the spatial distribution of ski resorts across China. The main factors contributing to the distribution of ski areas are good natural snow, international/national winter sports events, resident population, and domestic tourism revenue. However, the explanatory power varies by region. Winter sports events have greater explanatory power in northeast China as well as in the resident population, while domestic tourism revenues have a more significant impact in north China. Moreover, the factors affecting the distribution of ski resorts in north China are more complicated, including international tourism revenues, population density, GDP per capita, and the 2022 Winter Olympics. As far as the sphere of influence of the 2022 Winter Olympics is concerned, it mainly affects the pattern of the spatial distribution of the ski resorts in the host cities of Beijing and Zhangjiakou in north China.

However, the explanatory power of natural factors (e.g., precipitation, relative humidity, distance to the nearest river) and accessibility (e.g., traffic density, distance to the nearest road) is becoming more influential in regions of eastern and central China without good natural snow. Climatic factors affect the selection of ski areas; therefore, it is important to choose an area with suitable climatic conditions for operation, especially in places where, in most parts, climatic conditions are less than optimal for running a ski resort. In addition, heavy dependence on artificial snow due to limited snow resources highlights the importance of nearby rivers.

5.3. Factors Affecting the Distribution of Ski Resorts with and without Aerial Lifts

There were significant differences in the factors affecting the spatial distribution of the types of ski resorts (Table 6). International and national winter sports events accounted for nearly 85% of the spatial distribution of ski resorts in China with aerial lifts. The influencing factors were not prominent in the distribution of ski resorts without aerial lifts. Although GDP per capita and temperature in winter were statistically significant based on their *p*-value ($p < 0.05$), only about 13% of the spatial distribution of ski resorts can be explained. There are precise requirements that ski resorts must meet to host mega winter sports events, and one of them is the availability of aerial lifts. For ski areas geared to novice skiers, the high demand for skiing is more important in the choice of a building site. As a result, the income of skiers (GDP per capita) who influence skiing demand is the most critical factor for the distribution of ski resorts without aerial lifts.

Table 5. The major influence factors of spatial distribution of ski resorts in different regions.

Region	Major Influence Factors	$P_{D,G}$	*p*-Value
Northeast	X_{16}	0.938	0.000 ***
	X_{11}	0.921	0.000 ***
	X_{10}	0.531	0.040 **
North	X_{10}	0.819	0.000 ***
	X_{11}	0.762	0.006 ***
	X_9	0.724	0.024 **
	X_{16}	0.671	0.036 **
	X_{12}	0.593	0.018 **
	X_8	0.585	0.023 **
	X_{15}	0.475	0.039 **
East	X_{11}	0.654	0.042 **
	X_{14}	0.494	0.008 ***
	X_3	0.405	0.019 **
Central	X_3	0.546	0.000 ***
	X_7	0.458	0.000 ***
	X_{14}	0.402	0.013 **
	X_{13}	0.396	0.076 *
	X_5	0.285	0.024 **
Southwest	X_9	0.768	0.016 **
	X_{11}	0.756	0.020 **
	X_3	0.486	0.035 **
	X_{14}	0.423	0.048 **
South	X_3	0.766	0.000 ***
	X_{10}	0.384	0.034 **

Note: ***, ** and * represent 99%, 95%, and 90% confidence levels, respectively; there were no significant factors in northwest China according to the *p*-values.

Table 6. Major influencing factors of the spatial distribution of China's ski resorts with and without aerial lifts.

Ski Resorts with Aerial Lifts			Ski Resorts without Aerial Lifts		
Major Influence Factors	$P_{D,G}$	*p*-Value	Major Influence Factors	$P_{D,G}$	*p*-Value
X_{16}	0.850	0.000 ***	X_8	0.0825	0.042 **
X_{15}	0.221	0.000 ***	X_4	0.0497	0.023 **
X_4	0.133	0.000 ***			

Note: *** and ** represent 99% and 95% confidence levels, respectively.

6. Implications, Conclusions and Future Work

This study used GIS and geographical detectors to analyze the patterns of and significant influences on the spatial distribution of ski resorts in China. We highlighted the importance of spatial analysis on the regional scale, focusing on different types of ski resorts. The results of this study suggest that the geographical distribution of China's ski areas is significantly clustered at the national level. Although the factors affecting their spatial distribution are complex, the number of international and national winter sports events can explain approximately 70% of the locations of ski areas in China. In addition, almost 14% of the explanatory power was identified as the 2022 Winter Olympics.

In comparison, different patterns of distribution appeared in different regions. Generally speaking, ski areas located in high-latitude regions are more likely to gather than those in low-latitude areas. In addition, dispersion was observed in ski resorts with aerial lifts in east, central, and southwest China. The main contributors to the distribution of ski areas also varied by region and type. For example, winter sports mega-events have a higher explanatory power in northeast China and on the resident population, while domestic tourism revenues have a more significant impact in north China. For different types of

ski areas, winter sports mega-events accounted for almost 85% of the spatial distribution of China's ski resorts with aerial lifts, while GDP per capita had the highest explanatory power in ski resorts without them.

Many ski resorts are built in regions that have naturally adequate skiable terrain. An excellent example of this is the Alps, where more than one-third of all ski resorts are located. Previous studies tend to highlight natural factors, such as climate and snow conditions, in the discussion of location criteria for ski resorts [10,45,51]. However, factors that influence new ski resorts' emergence have proven more multifaceted, as our findings show. Furthermore, the driving factors for different types of ski resorts and different regions vary significantly.

6.1. Managerial Implications

The ski resort selection process is of paramount importance because it affects both short-term and long-term profits [52]. The present study confirmed the previous empirical study's finding that the essential attribute for a ski resort is the seasonality of snow conditions [10]. A further novel finding was that technology might upend the location decision process; for example, some ski resorts are built in areas with less natural snowfall. The snowmaking systems (technology) will make artificial snow to help the resorts provide the best snow conditions to skiers. The longer a ski resort is in operation, the better it must be able to adjust to fluctuating weather conditions. Therefore, stakeholders should conduct a climate change risk assessment that looks at not only the physical location but also technological factors.

The spatial distribution of ski resorts in China is not uniform; therefore, various operating policies should be developed for different distribution patterns. For hotspots such as north and northeast China and Xinjiang province, the benefits of agglomeration and the 2022 Winter Olympics can make them internationally famous destinations. In particular, the construction of world-class ski destinations, the establishment of a regional competition and cooperation mechanisms and the implementation of integrated strategies are needed. The complementary advantages, the sharing of resources, retention strategies, the sharing of benefits, and the development of these areas together will lead to the optimization and upgrading of the ski industry structure and will strengthen China's ski resorts' competitiveness as well as brands.

Neighboring ski resorts should take full advantage of the positive spillover effects of the neighborhood to attract more potential customers, such as providing cost-effective skiing products, uncrowded ski areas, reasonable accommodation, and service. In addition, these cities need to undertake joint promotion, plan travel packages with neighbors, and expand marketing networks to become popular ski destinations along with their neighbors' hotspot clusters. The cold spot areas could be planned to overcome the competitive disadvantages of the featured and compelling non-skiing activities. More attention should be paid to the most reliable source markets—local residents and people in neighboring cities—and preferential measures should be taken for these source markets.

6.2. Limitations and Future Work

A drawback of this study is that only ski areas in 2019 could be analyzed due to data availability, ignoring the evolution of time and space. It was impossible to conduct a dynamic analysis of the newly added ski resorts, which focuses on distribution and influencing factors. Consequently, results would be more accurate if a dynamic analysis were used. Furthermore, studying ski areas in relation to sporting mega-events and their drivers would be critical. A longitudinal analysis would help to better understand how certain events and ski resorts correlate, and to clearly explain the cause and effect.

Moreover, future research should consider the factors associated with ski areas' sustainable development during the location selection process. Achieving environmental, economic, and social objectives sustainably are important for successful ski resort operation. The natural environment is crucial for a thriving ski resort [53], because it could have pos-

sible effects on soil, vegetation [54], wildlife degradation [55], and river system pollution. Thus, assessing ecological services and carrying capacities should be incorporated into future ski area distribution research. Moreover, the valuable prospect of working with local business partners, industry associates, and community relationships [56] to promote long-term economic sustainability in skiing resorts is desirable for future work. Future studies should also evaluate residents' benefits from ski resort development to achieve the social sustainability objective. After such analyses, ski resort development could move more sustainably and have a more stable long-term future.

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References

1. Hudson, S. *Sport and Adventure Tourism*; Haworth Hospitality Press: New York, NY, USA, 2012; p. 1. ISBN 978-11-3639-384-6.
2. Varvaressos, S.; Soteriades, M. Mountain tourism and winter resorts: A study of Greek ski centers. *Arch. Econ. Hist.* **2007**, *2*, 119–144.
3. Lasanta, T.; Laguna, M.; Vicente-Serrano, S.M. Do tourism-based ski resorts contribute to the homogeneous development of the Mediterranean mountains? A case study in the Central Spanish Pyrenees. *Tour. Manag.* **2007**, *28*, 1326–1339. [CrossRef]
4. Agrawala, S. *Climate Change in the European Alps: Adapting Winter Tourism and Natural Hazards Management*; OECD Publishing: Paris, France, 2007; p. 26. ISBN 978-92-6403-168-5.
5. Weiss, O.; Norden, G.; Hilscher, P.; Vanreusel, B. Ski tourism and environmental problems: Ecological awareness among different groups. *Int. Rev. Sport Sociol.* **1998**, *33*, 367–379. [CrossRef]
6. Vanat, L. 2020 International Report on Snow & Mountain Tourism—Overview of the Key Industry Figures for Ski Resorts. Available online: https://vanat.ch/RM-world-report-2020.pdf (accessed on 10 June 2020).
7. Wu, B.; Wei, Q.H. China Ski Industry White Book (2018 Annual Report). Available online: http://sports.sina.com.cn/others/magicski/2020-02-18/doc-iimxyqvz3883763.shtml (accessed on 12 March 2020).
8. Vanat, L. 2017 International Report on Snow & Mountain Tourism—Overview of the Key Industry Figures for Ski Resorts. Available online: https://www.vanat.ch/RM-world-report-2017-vanat.pdf (accessed on 18 June 2019).
9. The State Council of the People's Republic of China. Planning for Ice-Snow Sports Development 2016–2025. Available online: http://www.gov.cn/xinwen/2016-11/25/content_5137611.htm (accessed on 10 June 2019).
10. Silberman, J.A.; Rees, P.W. Reinventing mountain settlements: A GIS model for identifying possible ski towns in the US Rocky Mountains. *Appl. Geogr.* **2010**, *30*, 36–49. [CrossRef]
11. Kline, C.; Hao, H.; Alderman, D.; Kleckley, J.W.; Gray, S. A spatial analysis of tourism, entrepreneurship and the entrepreneurial ecosystem in North Carolina, USA. *Tour. Plan. Dev.* **2014**, *11*, 305–316. [CrossRef]
12. Van Berkel, D.B.; Munroe, D.K.; Gallemore, C. Spatial analysis of land suitability, hot-tub cabins and forest tourism in Appalachian Ohio. *Appl. Geogr.* **2014**, *54*, 139–148. [CrossRef]
13. Sun, S.M.; Liu, B.; Guo, Z.; Wang, F.; Wang, X.Y.; Qiu, Z.Y. Evolution of spatial distribution characteristics and influencing factors of skiing resorts in China since reform and opening up. *J. Shenyang Sport Univ.* **2019**, *38*, 8–15.
14. Wang, S.J.; Xu, X.W.; Xie, J. Spatial pattern, formation mechanism and structure optimization of China's ski resorts. *Econ. Geogr.* **2019**, *39*, 222–231.
15. Wang, S.J.; Xu, X.W.; Deng, J.; Zhou, L.Y. Chinese skiing-tourism destination: Spatial patterns, existing problems and development countermeasures. *J. Glaciol. Geocryol.* **2017**, *39*, 902–909.
16. McClung, D.; Schaerer, P.A. *The Avalanche Handbook*, 3rd ed.; Mountaineers Books: Seattle, WA, USA, 2006; pp. 21–22. ISBN 978-08-988-6809-8.
17. Voiculescu, M.; Popescu, F. Management of Snow Avalanche Risk in the Ski Areas of the Southern Carpathians–Romanian Carpathians. In *Sustainable Development in Mountain Regions*; Zhelezov, G., Ed.; Springer: Dordrecht, The Netherlands, 2016; pp. 191–213. ISBN 978-94-007-0131-1.
18. Falk, M.; Vanat, L. Gains from investments in snowmaking facilities. *Ecol. Econ.* **2016**, *130*, 339–349. [CrossRef]
19. David, G.C.; Bledsoe, B.P.; Merritt, D.M.; Wohl, E. The impacts of ski slope development on stream channel morphology in the White River National Forest, Colorado, USA. *Geomorphology* **2009**, *103*, 375–388. [CrossRef]

20. Chalkley, B.; Essex, S. Urban development through hosting international events: A history of the Olympic Games. *Plan. Perspect.* **1999**, *14*, 369–394. [CrossRef]
21. Essex, S.; Chalkley, B. Mega sporting events in urban and regional policy: A history of the Winter Olympics. *Plan. Perspect.* **2004**, *19*, 201–204. [CrossRef]
22. Zhang, Y.; Ye, H.B.; Chen, Y.X. Current Development and Prospect of the Skiing Resorts in Chongli County under the Background of Winter Olympics. *China Winter Sports* **2016**, *38*, 78–82.
23. Preuss, H. The conceptualisation and measurement of mega sport event legacies. *J. Sport Tour.* **2007**, *12*, 207–228. [CrossRef]
24. Klausen, A.M. Introduction. In *Olympic Games as Performance and Public Event: The Case of the XVII Winter Olympic Games in Norway*; Klausen, A.M., Ed.; Bergham Books: New York, NY, USA, 1999; p. 3. ISBN 978-15-7181-706-8.
25. Lee, J.W. A game for the global north: The 2018 Winter Olympic Games in Pyeongchang and South Korean cultural politics. *Int. J. Hist. Sport* **2016**, *33*, 1411–1426. [CrossRef]
26. Shan, C.L.; Zhang, W.; Hao, P.F. Influence of Beijing Winter Olympics on Chinese Ice and Snow Movement. *J. Nanjing Sports Inst.* **2018**, *1*, 40–44.
27. Willibald, F.; van Strien, M.J.; Blanco, V.; Grêt-Regamey, A. Predicting outdoor recreation demand on a national scale—The case of Switzerland. *Appl. Geogr.* **2019**, *113*, 102–111. [CrossRef]
28. McAllister, D.M.; Klett, F.R. A modified gravity model of regional recreation activity with an application to ski trips. *J. Leis. Res.* **1976**, *8*, 21–34. [CrossRef]
29. Mrnjavac, E.; Marsanic, R. Intelligent transportation systems in improving traffic flow in tourism destinations. *J. Hosp. Tour.* **2007**, *13*, 627–636.
30. Bédiová, M.; Ryglová, K. The main factors influencing the destination choice, satisfaction and the loyalty of ski resorts customers in the context of different research approaches. *Acta Univ. Agric. Silvic. Mendelianae Brun.* **2015**, *63*, 499–505. [CrossRef]
31. Unbehaun, W.; Pröbstl, U.; Haider, W. Trends in winter sport tourism: Challenges for the future. *Tour. Rev.* **2008**, *63*, 36–47. [CrossRef]
32. Martins, L.F.; Gan, Y.; Ferreira-Lopes, A. An empirical analysis of the influence of macroeconomic determinants on World tourism demand. *Tour. Manag.* **2017**, *61*, 248–260. [CrossRef]
33. Falk, M.; Hagsten, E. Importance of early snowfall for Swedish ski resorts: Evidence based on monthly data. *Tour. Manag.* **2016**, *53*, 61–73. [CrossRef]
34. Lyngdoh, B.F. Tourism Attractiveness of Meghalaya: An Exploration of Entrepreneurial Opportunities. *IUP J. Entrep. Dev.* **2013**, *10*, 7–23.
35. Liu, J.M.; Liu, A.L.; Chen, T. Influencing factors and countermeasures of ski resort development distribution with inner Mongolia Municipality's ski tourism development as example. *Prog. Geogr.* **2005**, *24*, 105–112.
36. Kan, J.C.; Wang, F. Driving factors and innovation paths of skiing industry upgrading under the strategy of Winter Olympic Games in China. *China Sport Sci.* **2016**, *36*, 11–20.
37. Wang, F.; Zhu, Z.Q. Study on the construction of large scale ski resort in promoting the development of skiing industry. *China Sport Sci.* **2017**, *37*, 11–19.
38. Bergman, J. China's Ski Industry is Set to Soar Following Olympic Win. Available online: https://www.theguardian.com (accessed on 22 March 2020).
39. Chinese Academy of Sciences. Chinese Academy of Geological Sciences' Resource and Environment Data Cloud Platform. Available online: http://www.resdc.cn (accessed on 18 May 2019).
40. Yin, J.; Zhang, X. Multi-scenario-based hazard analysis of high temperature extremes experienced in China during 1951–2010. *J. Geogr. Sci.* **2013**, *23*, 436–446. [CrossRef]
41. Clark, P.J.; Evans, F.C. Distance to nearest neighbor as a measure of spatial relationships in populations. *Ecology* **1954**, *35*, 445–453. [CrossRef]
42. Silverman, B.W. *Density Estimation for Statistics and Data Analysis*, 1st ed.; Routledge: New York, NY, USA, 2018; pp. 1–2. ISBN 978-04-1224-620-3.
43. Lloyd, C.D. *Local Models for Spatial Analysis*, 2nd ed.; CRC Press: New York, NY, USA, 2010; pp. 28–29. ISBN 978-03-6786-493-4.
44. Moran, P.A. The interpretation of statistical maps. *J. R. Stat. Soc. Ser. B* **1948**, *10*, 243–251. [CrossRef]
45. Ord, J.K.; Getis, A. Local spatial autocorrelation statistics: Distributional issues and an application. *Geogr. Anal.* **1995**, *27*, 286–306. [CrossRef]
46. Wang, J.F.; Li, X.H.; Christakos, G.; Liao, Y.L.; Zhang, T.; Gu, X.; Zheng, X.Y. Geographical detectors-based health risk assessment and its application in the neural tube defects study of the Heshun Region, China. *Int. J. Geogr. Inf. Sci.* **2010**, *24*, 107–127. [CrossRef]
47. Liang, P.; Yang, X. Landscape spatial patterns in the Maowusu (Mu Us) Sandy Land, northern China and their impact factors. *Catena* **2016**, *145*, 321–333. [CrossRef]
48. Teng, T.W.; Qin, L.T.; Hu, S.L. Spatial distribution and influencing factors of national mass makerspaces in the Yangtze River Delta. *Sci. Geol. Sin.* **2018**, *38*, 1266–1272.
49. Maennig, W.; Zimbalist, A.S. *International Handbook on the Economics of Mega Sporting Events*; Edward Elgar Publishing: Cheltenham, UK, 2012; pp. 70–84. ISBN 978-08-5793-026-2.
50. Persson, C. The Olympic Games site decision. *Tour. Manag.* **2002**, *23*, 27–36. [CrossRef]

51. Frank, D. Ski Resort Site Selection in Washington Station. Available online: https://digitalcommons.tacoma.uw.edu/cgi/viewcontent.cgi?article=1038&context=gis_projects (accessed on 13 March 2021).
52. Semih, T.; Seyhan, S. A multi-criteria factor evaluation model for gas station site selection. *Evaluation* **2011**, *2*, 12–21.
53. Kuščer, K.; Dwyer, L. Determinants of sustainability of ski resorts: Do size and altitude matter? *Eur. Sport Manag. Q.* **2019**, *19*, 539–559. [CrossRef]
54. Wipf, S.; Rixen, C.; Fischer, M.; Schmid, B.; Stoeckli, V. Effects of ski piste preparation on alpine vegetation. *J. Appl. Ecol.* **2005**, *42*, 306–316. [CrossRef]
55. Patthey, P.; Wirthner, S.; Signorell, N.; Arlettaz, R. Impact of outdoor winter sports on the abundance of a key indicator species of alpine ecosystems. *J. Appl. Ecol.* **2008**, *45*, 1704–1711. [CrossRef]
56. Tinsley, R.; Lynch, P. Small tourism business networks and destination development. *Int. J. Hosp. Manag.* **2001**, *20*, 367–378. [CrossRef]