Ecological Economics 170 (2020) 106589

Contents lists available at ScienceDirect

Ecological Economics

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

The impact of climate change on demand of ski tourism - a simulation study based on stated preferences

Robert Steiger[a,*], Eva Posch[b], Gottfried Tappeiner[c], Janette Walde[d]

[a] Department of Public Finance, University of Innsbruck, Universitätsstraße 15, 6020 Innsbruck, Austria
[b] Institute of Geography, University of Innsbruck, Innrain 52, 6020 Innsbruck, Austria
[c] Department of Economics, University of Innsbruck, Universitätsstraße 15, 6020 Innsbruck, Austria
[d] Department of Statistics, University of Innsbruck, Universitätsstraße 15, 6020 Innsbruck, Austria

ARTICLE INFO

JEL classifications:
R11
D9
Q56
Z3

Keywords:
Winter tourism
Climate change
Regional impact
Choice experiment
Alpine region
Demand simulation

ABSTRACT

Climate change will affect tourism as one of the sectors most dependent on natural resources. Due to the strong dependency of many peripheral areas on tourism, climate change has the potential to destabilize regional economies. The objective of this paper is to assess the impacts of climate change on ski tourism demand. A tourist survey (n = 1957) with a choice experiment conducted in 53 ski areas in Austria provides the data for our analyses. Results show that snow is the most important factor for destination choice. Nevertheless, preferences of respondents are heterogeneous. Measures that enhance price-performance ratio, i.e. lowering lift ticket prices and avoiding crowding, turn out to be the most suitable compensation for suboptimal snow conditions. As long as substitute ski areas with better snow conditions exist, destinations with marginal snow conditions are likely to face severe demand losses (up to 60%). Nevertheless, dynamic pricing has the potential to compensate medium snow reliability. If all destinations are affected by deteriorating snow conditions, total demand reduces by 64% if snow reliability is low. If these conditions and effects are limited to the beginning and the end of the ski season, demand is projected to decline by 18%.

1. Introduction

Climate change is a major challenge in the 21st century affecting both natural and human systems (IPCC, 2014). Economic sectors with a high dependency on natural resources are particularly affected by a climate change induced alteration of these resources. Consequently, regional economies with a high dependency on such industries are facing an uncertain future and decision makers are required to assess climate change risks and take action against potential impacts in order to foster sustainable development.

The IPCC (2018) marked tourism as one of the key economic sector affected by climate change. In many peripheral areas, tourism is an important pillar for the economic stability. The European Alps are an important example with 120 million guests (Permanent Secretariat of the Alpine Convention, 2010), over 330 million overnight stays (Mayer et al., 2011) generating directly and indirectly 15% of jobs (BAKBasel, 2018). The relevance of tourism is even more pronounced when looking at the regional level, where tourism often represents the main economic activity and source of income, especially in more peripheral and/or higher elevated areas (Tappeiner et al., 2008).

Tourism in general is dependent on natural resources, as e.g. in the Italian Alps where districts with high environmental performance (measured by land degradation) tend to have a specialization in tourism (Salvati and Carlucci, 2011). Tourism is also characterized by high fixed costs (investments) or seasonal step-fixed costs (labor) (Adams, 2019). Therefore, in this sector a region's economic success is especially dependent on capacity utilization. Most tourism municipalities in the Alps have a two peak season, with 48% of overnight stays being generated in the winter season (ASTAT, 2018). Winter tourism is highly dependent on natural resources, first and foremost on snow (Shih et al., 2009). Lack of snow has repeatedly affected tourism performance indicators in past winter seasons in the Alps (Abegg, 1996; Steiger, 2011b) and other markets (Dawson et al., 2009; Pickering, 2011) and was also found to have contributed to the permanent closing of ski resorts (Beaudin and Huang, 2014).

With strong links to up- and downstream industries (e.g. food producers, retail, construction, etc.) tourism has substantial multiplier effects (Castillo et al., 2017) and not only affects income, but also

* Corresponding author.
E-mail addresses: robert.steiger@uibk.ac.at (R. Steiger), eva.posch@uibk.ac.at (E. Posch), gottfried.tappeiner@uibk.ac.at (G. Tappeiner), janette.walde@uibk.ac.at (J. Walde).

https://doi.org/10.1016/j.ecolecon.2019.106589
Received 12 September 2019; Received in revised form 2 December 2019; Accepted 30 December 2019

investments and intermediate input. A reduced winter tourism, questioning the profitability of the accommodation sector, could thus have far-reaching consequences for the stability of tourism-dependent economies. Without exaggeration, such a development has the potential to change the economic and social landscape of the alpine arc.

Future prospects of winter tourism have repeatedly been questioned due to the impacts of climate change, both in academia (Scott et al., 2012; Steiger et al., 2019) and in public discussion (Ma and Kirilenko, 2019). The extent of the consequences, especially on a regional to local level, still has not been fully clarified. Moreover it has been noted that demand reactions to changing climatic conditions are still under-researched (Gössling et al., 2012). In a recent review of the scientific literature on climate change and winter tourism, Steiger et al., 2019 found that the majority (46%) of studies are impact and vulnerability assessments focusing on the availability of snow, whereas skier behavioral response studies represent the smallest group with only 10% of studies. They concluded that more knowledge on potential tourist responses to changing climate conditions is required to better inform decision makers on potential risks and opportunities.

With this paper, we want to contribute to a better understanding of climate change impacts on tourism demand and to improve the knowledge base for sustainable winter tourism development. The aim of this paper is to estimate the reaction of winter tourists to potential future snow scenarios. More specifically, we want to address the following questions:

- What are impacts on distribution of demand in a situation where one destination has marginal snow conditions but nearby substitutes are available versus a situation where all alpine destinations are affected by snow deficiency?
- Which snow scenarios would still be bearable with corresponding adaptation of suppliers and which scenarios have the potential to trigger reactions that go beyond the tourism industry?

In order to investigate the above questions and to assess climate change impacts for alpine regions, we also need to address the following questions on tourists' preferences:

- How important are anticipated and actual snow conditions for ski destination choice?
- Are all current ski tourists equally sensitive to snow or do more and less snow sensitive groups exist?
- Is it possible to compensate marginal snow conditions with additional non-snow activities?

It is neither possible to answer all of these questions with a high degree of certainty nor to completely estimate the quantitative effects. Although using quantitative methods, the contribution of this article is to structure and both qualitatively and quantitatively assess customer reaction, in order to draw evidence-based conclusions on regional effects of climate change and climate variability. Our approach contributes to the climate change and winter tourism literature in several novel aspects We use results of a choice experiment completed by a sample of skiing guests in Austria representative (see Methods) for the main source markets to simulate the impacts of climate change on winter tourism demand. Hence, the simulation uses individual data and additionally takes the heterogeneity of preferences and reactions to climatic changes into consideration. We show demand changes both on a local (i.e. individual ski areas) and on a market-level (i.e. Austria). Finally, we investigate the potential of adaptation measures to compensate deteriorating snow reliability and snow conditions.

2. Literature review

The scientific literature largely agrees that climate change represents a serious risk to ski tourism (Steiger et al., 2019). Snow depth and snow cover duration in the Alps have already declined in the 20th century (Klein et al., 2016; Marty et al., 2017; Schöner et al., 2019) and projections for the upcoming decades show a drastic decline especially at elevations below 2000 m (Gobiet et al., 2014), an altitude where the majority of Austrian ski areas is located. Consequently, the natural ski season (not considering man-made snow) in Austrian ski areas is projected to almost half by the 2050s compared to 1981–2010 (Steiger and Scott, 2020). Furthermore, extreme seasons may become more frequent: the so far warmest winter ever recorded in the Alps (season 2006/07), likely the warmest of at least the last 500 years (Luterbacher et al., 2007), might represent a normal winter by the end of the 21st century (Beniston, 2007).

Climatic conditions required for snowmaking, a meanwhile widespread technology to reduce the risk of lost operation days due to a lack of snow (Steiger and Mayer, 2008), are projected to deteriorate as well (Olefs et al., 2010; Spandre et al., 2015; Hartl et al., 2018). Nevertheless, snowmaking was found to considerably reduce climate change impacts on winter tourism, e.g. for Austria where currently between 84 and 90% of ski areas can be considered as snow reliable (Steiger and Scott, 2020) depending on the definition of the term, whereas without snowmaking only 69% are snow reliable (Steiger and Abegg, 2013). A ski area is considered to be snow reliable if it is able to operate for at least 100 days per season (the so-called 100-days rule; Abegg, 1996). In some studies a second indicator (the Christmas rule) is used in addition to highlight the importance of the two weeks Christmas-New Year holiday (Dawson and Scott, 2013; Scott et al., 2019). In both cases, the rule needs to be fulfilled in seven out of ten years.

The share of snow reliable ski areas will decline to 80% by the 2050s and 31% by the 2080s, but already under the assumption that ski areas would increase current snowmaking capacity (Steiger and Scott, 2020). Rising costs for snowmaking, both in terms of more required investments and higher operating costs of higher capacity facilities, raise the question of economic feasibility of this climate change adaptation strategy (Scott et al., 2008; Steiger and Abegg, 2018). Furthermore, snowmaking cannot fully offset snow deficiencies. Falk and Vanat (2016) show that skier visits declined in French low elevation ski resorts despite snowmaking facilities, whereas demand remained stable in higher elevated ski resorts. Research on demand reactions is becoming increasingly important.

Revealed preference studies in different markets show that snow depth has a positive impact on ski tourism demand (Hamilton et al., 2007; Shih et al., 2009). However, the magnitude of impact is found to differ remarkably between markets and season segments (Falk, 2015; Falk and Hagsten, 2016; Falk and Vieru, 2016; Damm et al., 2017). A positive relationship was also found for altitude of the ski area and profit ratio (Falk and Steiger, 2019).

Analyses of extraordinary snow deficient winter seasons show that total demand losses per season in such years range between 11% in North American (Scott, 2006; Dawson et al., 2009; Rutty et al., 2017) and European markets (Steiger, 2011a, 2011b) and up to 38% in Australia (Pickering, 2011). Within these markets skier visits in low elevation and small ski areas are found to be more sensitive to marginal snow conditions than in larger and higher elevation ski areas. This suggests that a substantial intra-market shift of demand might occur in low snow years with potentially high impacts for certain types of ski resorts (e.g. size and elevation) and regions despite relatively moderate losses for the entire market (Rutty et al., 2015b).

Stated-preference studies with ski tourists demonstrate that snow is the most important factor for destination choice (Richards, 1996; Dickson and Faulks, 2007; Carmichael, 1992; Godfrey, 1999; Riddington et al., 2000) and the primary constraint for participation (Gilbert and Hudson, 2000; Joppe et al., 2013 for Quebec; Unbehaun et al., 2008 for Austria). It is important to note that snow is represented differently in these studies: some include snow as actual snow conditions (e.g. Riddington et al., 2000; Won et al., 2008), which undoubtedly influences tourists' satisfaction and subsequently word-of-mouth recommendations (Matzler et al., 2019). Other studies in contrast include items that can be used to assess the likelihood of good snow conditions, e.g. altitude or number of slopes equipped with snowmaking (e.g. Unbehaun et al., 2008).

In case of a lack of snow, the majority of ski tourists would alter their behavior (Steiger et al., 2019), marking this winter tourism activity as potentially more sensitive than other winter recreation activities, e.g. snowshoeing or hiking (Smith et al., 2016). Spatial substitution, i.e. choosing a different destination with better snow conditions, is identified as the most preferred type of substitution, while the share of skiers stating to forego skiing trips in snow scarce winter seasons is rather low (below 10% in most studies; Steiger et al., 2019). These substitute destinations can be located within the same (regional) market or in more distant markets, which may redistribute demand geographically. Such demand leakages are found for Ontario, Canada where 11–15% of respondents stated to be willing to travel to Québec or nearby US states in case of a lack of snow in their usually preferred ski resort (Rutty et al., 2015b). In Australia, potential leakage is found to be even higher, with 16–38% of skiers to be lost to overseas destinations (König, 1998; Pickering et al., 2010). This higher share might be explained by an only small Australian market with few ski areas and therefore fewer choice alternatives within the market as compared to the example of Ontario.

Previous assessments focus on the type of substitution behavior in past (Dawson et al., 2013) or hypothetical future situations (e.g. König, 1998; Unbehaun et al., 2008; Rutty et al., 2015a). Destination choice in such situations has been only rarely investigated and rather uni-dimensional, e.g. that respondents decide to choose a ‘more snow reliable’ but not further characterized resort (e.g. price level of the substitute resort). For example, Unbehaun et al. (2008) find in their discrete choice experiment that the most important reactions of skiers to hypothetical marginal snow conditions is to travel further, to book later in order to be able to better evaluate snow conditions and to switch to higher altitude resorts. As an exception, Rutty et al. (2015b) ask participants to name the destination to be chosen instead of their usual resort if it would suffer from a lack of snow. Nevertheless, the type of ski resort and its characteristics remain very unspecific.

What has been largely overlooked to date is which ski resort characteristics are relevant for the choice of alternative destinations in snow-deficient situations and if and how non-optimal snow conditions can be compensated by other attributes. To our knowledge the only simulation study on climate change impacts on winter tourism demand based on choice based conjoint results was conducted for cross-country skiing for two destinations in Austria and Finland (Landauer et al., 2012). As others have emphasized (Gössling et al., 2012; Scott et al., 2012; Steiger et al., 2019), behavioral adaptation in the winter tourism sector and its economic consequences for a region in adverse climate conditions remains an under-researched area.

3. Methods

3.1. Survey and sampling

An in-situ survey was conducted in 53 ski areas in Austria (Fig. 1) on 34 different days between December 2015 and March 2016. The selection of ski areas was based on location, to include all federal states; on size, from local ski areas to internationally renowned; and on elevation to include less and more snow reliable ski areas. This in-situ survey was used to collect e-mail addresses for contacting the respondents to participate in a larger online survey and to personally address potential participants. Furthermore, a skiing weekend was raffled among all participants who provided a valid e-mail address to increase the response rate (Appendix 1). Visitors were approached in the ski area, i.e. mountain restaurants, ski lifts and the ticketing area. Thus, we only included winter guests practicing snow sports in the ski area. Skiing (including other alpine snow sports such as snowboarding, telemarking, etc.) is the main activity for 59% of winter guests and a secondary activity for another 4% (Österreich Werbung, 2018). Considering that this also includes destinations with less skiing opportunities (e.g. cities, spa regions and mountain destinations without ski areas), the share of guests with skiing as main activity is likely to be much higher in the destinations, which are in the focus of our research.

As the majority of winter tourists in Austria comes from German speaking countries (Österreich Werbung, 2018), the survey was conducted only in German language and therefore the results are generalizable, and representative (Appendix 3; Unbehaun et al., 2008; Österreich Werbung, 2018) only for these source markets. The total sample consists of 3673 respondents with 1957 persons staying for more than one day (holiday-makers) which were used in this paper for further analysis.

The online questionnaire (Appendix 2) consisted of a block of sociodemographic variables (e.g. age, income), questions on skiing habits (e.g. number of skiing days per year, commitment) and questions on the importance of destination characteristics to identify respondents' preferences. To investigate our research questions, we used - among others - the following three questions for analyses (#8, 9, 16 in Appendix 2). First, participants had to select five out of 12 factors they perceive as relevant for ski destination choice. These 12 factors resulted from a review of previous winter tourism surveys (Richards, 1996; Godfrey, 1999; Dickson and Faulks, 2007; Unbehaun et al., 2008; Konu et al., 2011; Pütz et al., 2011; Joppe et al., 2013; Phillips and Brunt, 2013). Second, respondents had to rank the chosen factors to differentiate them according to importance. Third, in order to identify skiers' sensitivity and their willingness to visit a destination during marginal snow conditions, four different snow scenarios were presented: valley run closed; 25% of ski slopes closed; 50% of ski slopes closed; hardly any natural snow, but ski slopes are covered with man-made snow. Respondents then had to state whether they would intend to visit the destination (yes, perhaps, no).

These questions all exhibit strengths and weaknesses of a stated-preference survey. Using rating scales to assess preferences is associated with some limitations, e.g. it is not appropriate to measure the distance between ranks, or results may suffer from order bias. Furthermore, the ranking conducted in a rather abstract situation might differ from a real decision situation where several attributes are compared. We therefore included a choice experiment with conjoint analysis as the second research tool investigating the same phenomena in order to assess the validity of results by being able to identify contradictions and similarities.

3.2. Conjoint analysis

Conjoint analysis, as one method for choice experiments, originates from socio-economic research, where many applications focused on marketing issues (Rao, 2014). It is widely accepted that the decision situation in a choice-based approach, where multiple attributes of products are compared, is more realistic than other approaches (Desarbo et al., 1995), e.g. ratings of single attributes. In the context of destination choice, choice based conjoint analyses have been used for alpine skiing (Riddington et al., 2000; Unbehaun et al., 2008; Won et al., 2008), cross-country skiing (Landauer et al., 2012; Landauer et al., 2013) and other tourism activities (Arnberger and Haider, 2005; Lindberg and Fredman, 2005; Sorice et al., 2007; Pröbstl-Haider et al., 2015).

The idea of a choice based conjoint (CBC) analysis is to analyse the individual's repeated choices of different products under several hypothetical choice options. Each choice option consists of several attributes where each attribute is further differentiated by several levels. In our case, we include six attributes with two to three levels (Table 1) that are derived from a literature screening where attributes relevant for destination choice are investigated (Simma et al., 2001; Unbehaun et al., 2008; Konu et al., 2011; Landauer et al., 2012; Joppe et al., 2013;

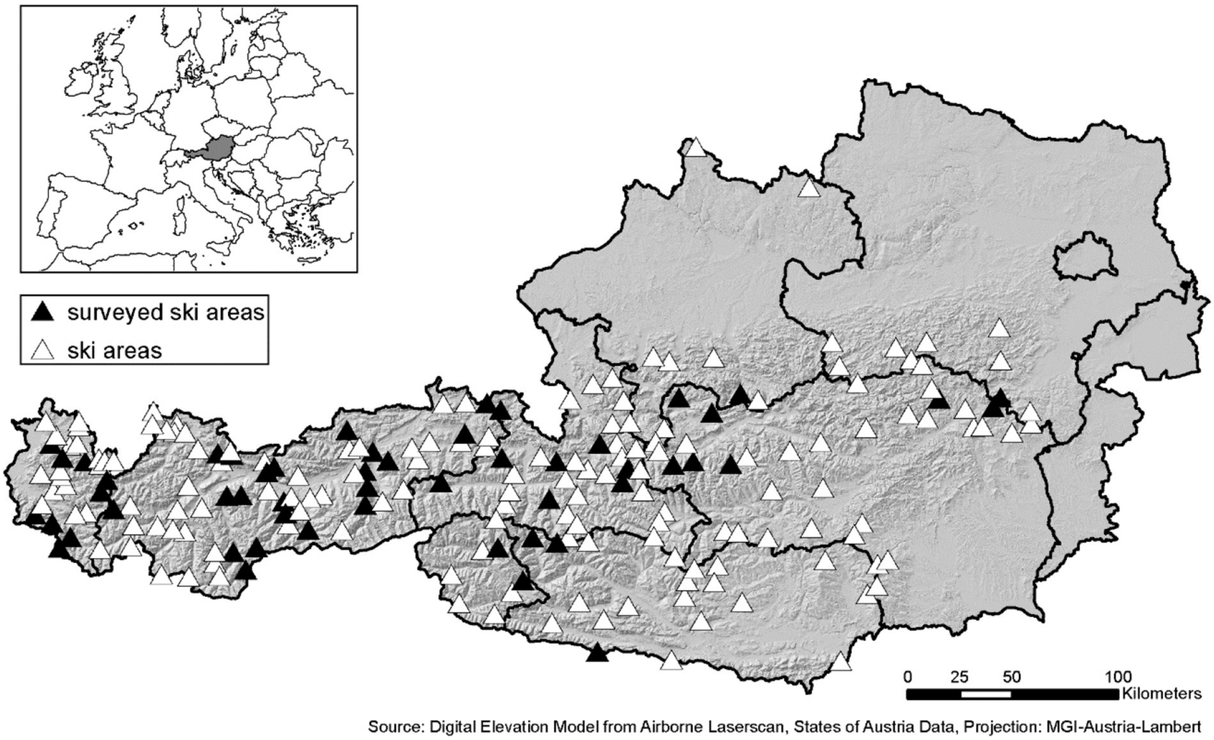


Fig. 1. Surveyed ski areas in Austria.

Table 1
Ski area attributes and levels.

Attribute	Level 1	Level 2	Level 3
Lift ticket price	≤35 €	36–45 €	≥46 €
Ski area size (km of ski slopes)	≤50 km	51–99 km	≥100 km
Snow reliability	High	Medium	Low
Crowding	Non-crowded	Crowded	–
Snow conditions during last visit	Good experiences	No experiences	Bad experiences
Additional non-snow activities	Many	Few	–

Bédiová and Ryglová, 2015) and from a pilot-study ($n = 36$) in winter sports online forums.

We included two different attributes representing snow: an objective measure ‘Snow reliability’, which can be found on ski resort platforms and homepages, and a subjective measure ‘Snow conditions during last visit’, further referred to as ‘snow experience’. There might be discrepancies between these two attributes, e.g. when a ski area only has medium snow reliability but where respondents had good snow experiences due to snowmaking or careful snow grooming. Therefore, we wanted to be able to differentiate respondents' evaluation and reaction to changes in one or both snow attributes. Being snow reliable is important for ski areas to reduce the perceived risk of tourists to experience problems with insufficient snow conditions during the holiday. Consequently, in ski areas with e.g. low snow reliability, the risk is higher for marginal snow conditions than in ski areas with medium or high snow reliability. Snow reliability is usually displayed as a rating (e.g. stars rating) on web-platforms (e.g. skiresort.de; snowforecast.com) where elevation, length of the snow season, cumulative snowfall, etc. is included, while on ski destination web pages this term is often associated with elevation or length of the ski season.

Each choice set consisted of four options: three ski areas with different characteristics and the option to not go on a skiing holiday if none of the displayed ski areas meets the respondent's preferences. For the choice-based conjoint analysis, we used a conventional approach with a linear-additive random utility model and chose a hierarchical Bayes method to estimate conjoint part-worth utilities (for details see Lenk et al., 1996; Sawtooth Software, 2009). The option not to choose any ski area can also be expressed by individual part-worth utilities representing the individual threshold of acceptance of ski area characteristics. The influence exerted by the individual attributes and levels was estimated with a multinomial regression model (Train, 2009)

$$P(i \mid C_n) = \frac{\exp(V_i)}{\sum_{j \in C_n} \exp(V_j)}$$

where $P(i|C_n)$ is the probability that the respondent chooses a product (ski area) i from its choice sets (C_n) and V_i is the utility value of product i that is the sum of part-worth utilities of the product's attribute levels.

The survey and choice experiment were administered with Sawtooth Software. The full set of scenarios, i.e. the total number of possible combinations of all attribute levels, is 324. We decided to choose a randomized design of presented choice sets in contrast to a fixed orthogonal design, as the former can be more efficient in asymmetric designs (Sawtooth Software, 2013), where attributes have different numbers of levels, as in our case (Table 1). Respondents had to make their decisions for eight choice sets with three ski areas each and an option to choose none of the presented ski areas.

The goodness-of-fit of the estimation was evaluated with the root likelihood value (RLH), ranging from 0 to 1 per respondent. The importance of each attribute is measured in percent representing the relative importance of that attribute on the overall rating. The part-worth utility value of each attribute level shows how (positively or negatively) a level contributes to the evaluation of the alternative. Part-worth utilities can be transformed monotonously without influencing their interpretation, as the utility function is ordinal. For better readability and interpretability, part-worth utilities were normalized resulting in values between 0 (representing the least preferred alternative per individual) and 100 (the most preferred alternative) per individual.

3.3. Simulation study

We conduct a simulation study to improve the interpretability of the CBC results. The starting point is a choice set with five options: four ski areas with differing characteristics and the option to forego the winter holiday. The utility V_i^j for ski area j of respondent i ($i = 1, \ldots, 1957$) is calculated with the row vector of zeros and ones (D_j) indicating the presence/absence of the attribute levels in ski area j and the column vector of part-worth utilities (b_i) of respondent i:

$$V_i^j = D_j * b_i$$

If the utility value is below the individual's part-worth utility for not choosing any ski area, then this person foregoes the skiing holiday, and if the utility value is above that threshold, the person chooses the ski area with the highest utility value.

The results are of course dependent on the choice set (i.e. how we characterized the ski areas) and only variables being included in the CBC are considered. Other aspects, which are known to influence destination choice (e.g. price of accommodation, emotional bonds with places or hosts) but that were not implemented in the CBC, cannot be included in the simulation. The simulation is therefore a simplification of reality in order to retrieve the importance of different effects acknowledging that other not considered effects exist.

In a first step, snow reliability is set to 'high' and snow experiences to 'good' in all ski areas, there is no crowding and only few additional non-snow activities exist. The ski areas only differ in size and price.

In a second step, snow reliability is assumed to deteriorate in one ski area (reference destination) while it is unchanged in the remaining ski areas. Effects of lower snow reliability on demand are expected to be strongest in this simulation step as alternative ski areas with better conditions are available.

In a third step, the reference destination reacts to worsening snow reliability with price discounts (i.e. price is reduced by one category) and additional non-snow activities (i.e. many instead of few).

In a fourth step, we model the deterioration of snow reliability not only locally, but as a wide-ranging incident, i.e. snow reliability changes in all ski areas.

In a fifth step all destinations react to worsening snow reliability with lower prices and additional non-snow activities.

With these steps two simulations, simulatoin 1 with changes only in the reference destination and simulation 2 with changes in all destinations, are run with three snow scenarios: in scenario 1 snow reliability deteriorates to 'medium'; in scenario 2 snow reliability deteriorates to 'low'; and in scenario 3 both snow reliability and snow experiences deteriorate to 'low/bad'. While snow scenario 1 and 2 represent a situation with higher variability of snow conditions, snow scenario 3 represents a series of bad winter seasons with a lasting negative impact on snow experiences.

By comparing these scenarios, we assess the magnitude of the impact of marginal snow conditions and snow reliability with all above described limitations.

4. Results

4.1. Survey results

The most frequently chosen factors for ski destination choice out of 12 factors are the snow conditions, price performance ratio and crowding (Fig. 2).

Factors that are not directly related to skiing, such as landscape/nature and additional leisure activities are chosen considerably less. Surprisingly, factors representing snow reliability and the risk of closed ski slopes due to a lack of snow (i.e. altitude, snowmaking capacity) were only rarely chosen.

'Snow conditions' is not only the most frequently chosen factor, but also ranked highest among respondents who chose that factor (Appendix 4). The subsequent seven factors all have the same median ranking value. Therefore 'snow conditions' is clearly the most important destination attribute.

However, the dominance of 'snow conditions' is put into perspective when looking at the distribution of its ranking values (Appendix 5). One quarter of respondents did not select 'snow conditions' at all. For 39% 'snow conditions' is not among the top three destination attributes. This share of respondents seems to have lower preferences for snow. For 64% of respondents snow is not ranked first, meaning that other factors are more important and that marginal snow conditions might in principle be compensable.

The topic of potential compensation of marginal snow conditions can be approached by analyzing the factors people ranked ahead of snow conditions (Fig. 3).

Price performance ratio and uncrowded ski slopes are more important than snow for about a third of the entire sample. Thus these factors can be regarded as the factors with the highest potential for compensation of marginal snow conditions. Additional snow-independent offers in contrast are perceived as more important than snow by only 7% of respondents.

Given the great importance of snow conditions, we wanted to know how sensitive skiers react to different snow conditions (Fig. 4).

Respondents reacted most sensitive to a scenario where half of the ski slopes is closed due to a lack of snow. In such a situation, about one third of skiers would not go on a skiing holiday and rather stay at home. In a scenario with hardly any natural and only machine-made snow on the slopes, about 19% of respondents would not go skiing.

These results give a first impression on the relevance of snow and the suitability of other factors to compensate marginal snow conditions. The magnitude of compensation and the number of skiers rather staying at home with or without compensation can be assessed with results from the choice experiment.

4.2. Choice experiment results

The median goodness-of-fit value (RLH) of the estimation is 0.65, the first quartile is 0.558 and the third quartile is 0.726. Considering that participants had to choose between four alternatives (three ski areas or none of these ski areas), a RLH of 0.25 represents the threshold for a choice by chance, whereas a value of 1 means that ski area choice is completely determined by the six attributes. This indicates a good fit of the model and high consistency of responses in the choice process.

If all attributes were equally important, each variable had an importance of 16.6%. The snow-related attributes clearly dominate the overall evaluation of a ski area, both with a mean value above 20% (Table 2).

Summing up both variables, snow has an average importance of 47.98%. Lift ticket price as the next important factor is considerably less important. However, the importance of attributes shows a high degree of dispersion, being highest for snow experience and lowest for additional non-snow activities. Such a high degree of dispersion in the snow variables could mean that a less (and more) snow sensitive group exists in the sample.

To quantify these less and more snow sensitive groups, the distribution of the sum of both snow variables representing the overall importance of snow is analysed (Fig. 5).

The shape of the curve in Fig. 5 suggests that less and more snow sensitive respondents exist in the sample, but it is not possible to identify clear groups and thresholds. Snow makes < 25% of overall evaluation for 4% of the sample. However, for 37% of respondents, snow is responsible for more than half of overall evaluation. We tested for correlation of socio-demographic variables with snow preference but did not find any significant correlations.

An analysis of attribute levels' part-worth utilities allows assessing the respondents' preference for that level. Three of four attributes with

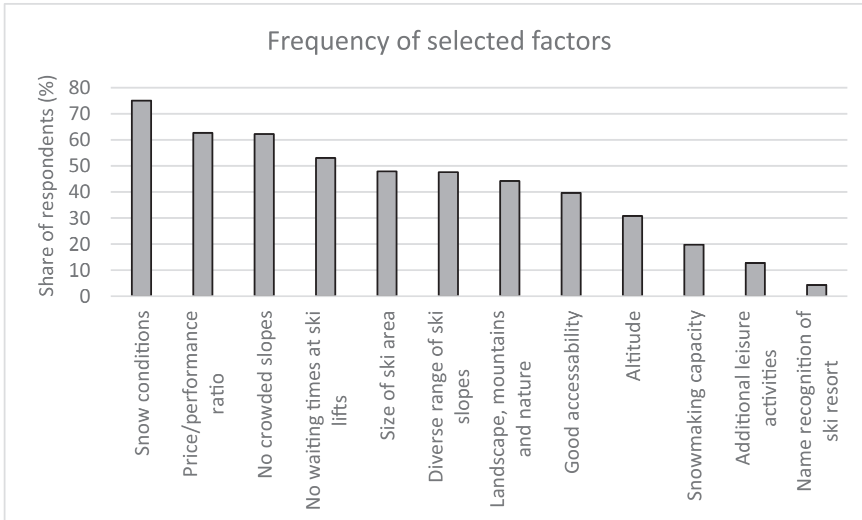


Fig. 2. Factors selected as important for destination choice.

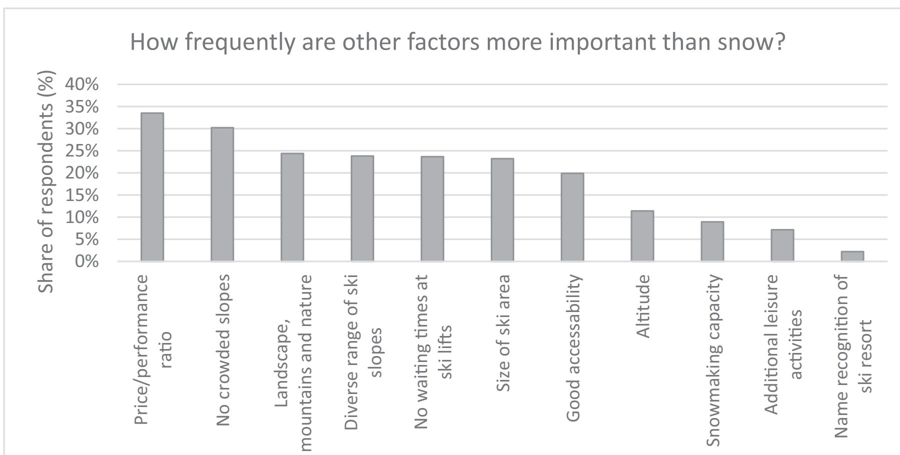


Fig. 3. Frequency of selected factors more important than snow.

three levels exhibit saturation effects (Table 3): lift ticket price, ski area size and – to a lesser extent – snow reliability.

A ski area with high snow reliability gains 6 points over a ski area with medium snow reliability, but medium versus low snow reliability gains 16 evaluation points. Snow experience in contrast shows an almost linear effect, where good experience is 12 points better than no experience and no experience is 13 points better than bad experience.

On average, medium instead of high snow reliability (−6 points)

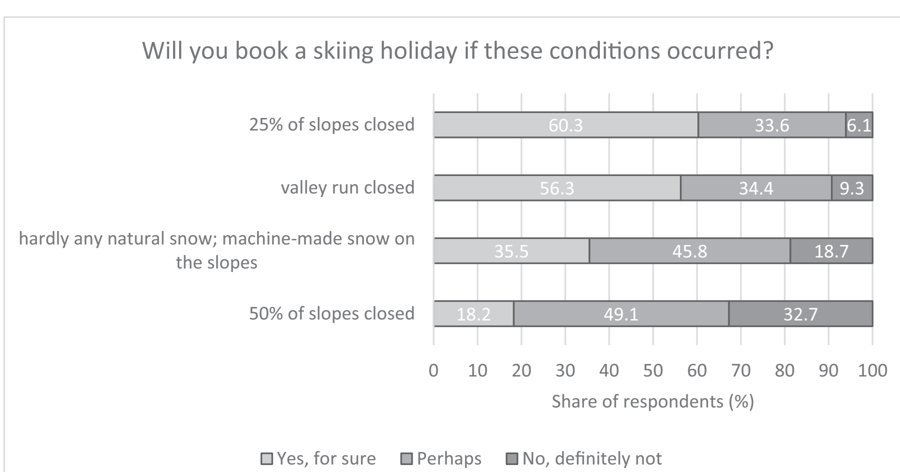


Fig. 4. Scenarios of marginal snow conditions and skiers' stated reaction.

Table 2
Attribute importance.

Attribute	Relative importance (%)					
	Minimum	Q25	Q50	Q75	Maximum	Mean
Lift ticket price	0.24	7.74	13.00	25.61	58.48	17.66
Ski area size (km of ski slopes)	0.12	6.89	10.94	16.72	67.68	15.01
Snow reliability	0.45	15.73	20.76	25.84	61.88	22.93
Crowding	0.03	5.85	10.28	21.63	48.86	13.91
Snow experience	1.59	16.44	21.94	28.46	66.49	25.06
Additional non-snow activities	0.00	1.79	3.90	6.72	52.66	5.44
Sum of both snow variables	9.51	37.40	44.84	61.01	86.08	47.98

Note: Q25 denotes the first quartile, Q50 the median and Q75 the third quartile.

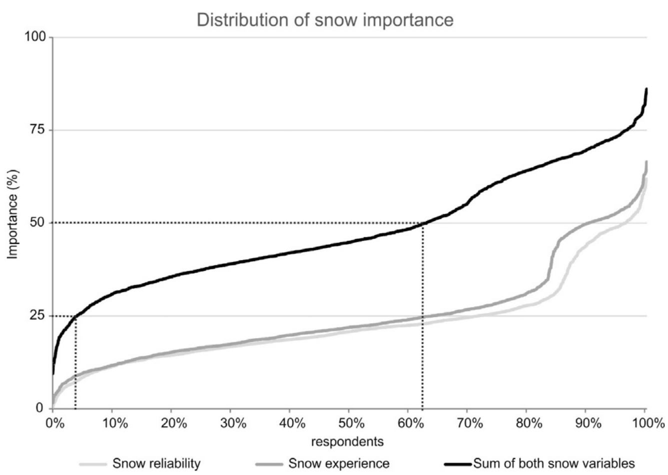


Fig. 5. Distribution of snow importance.

Table 3
Part-worth utilities of destination attribute levels.

Attribute	Standardized part-worth utilities			Level description
	Level 1	Level 2	Level 3	
Lift ticket price	15.05	14.56	0.93	Low, medium, high
Ski area size (km of ski slopes)	1.14	11.03	13.01	Small, medium, large
Snow reliability	22.12	16.22	0.55	High, medium, low
Crowding	13.31	0.60	–	Good, bad
Snow experience	24.86	13.31	0.51	Good, none, bad
Additional non-snow activities	3.93	1.51	–	Many, few

can be compensated by reducing the lift ticket price from high to medium (+14 points). This shows that part-worth utilities are very important when looking for potential compensation measures, as price discounts are only effective for ski areas with high prices, but not for ski areas with medium prices. Low instead of medium snow reliability requires measures to reach a better attribute level in more than one attribute, e.g. lowering ticket prices and offering additional non-snow activities.

4.3. Simulation results

Sample average findings can only give a first impression on potential compensation effects. We therefore present simulation results based on individual data for four typical ski area types in Austria and three snow scenarios with and without adaptation measures (i.e. price discounts, offering additional non-snow activities) compared to a reference scenario. While snow scenario 1 (S1a,b) and 2 (S2a,b) represent a situation with higher variability of snow conditions, snow scenario 3 represents a series of bad winter seasons with a lasting negative impact on snow experiences.

In the reference scenario, almost all are going on a ski holiday (Table 4). The distribution of respondents seems plausible indicating that the model produces reasonable results.

SKI1 benefits from deteriorating snow conditions in SKI2, as its market share increases from 53% in the reference scenario to 68% in S1a. Ski area size has a substantial effect on destination choice if prices are the same (SKI1,2,3). Price also has a considerable effect displayed in the large differences between SKI1 and SKI4 (Table 4). If snow reliability deteriorates in only one ski area (SKI2), then the effects are severe (-56%). This is in accordance with close substitutes. However, results are likely to be too extreme, as bonds and experiences are not considered. If snow reliability changes from high to medium in one destination (S1a,b, Table 4), compensation measures are effective. The fact that price reductions from the medium to the cheap level have a substantial effect highlights the importance of using individual data. This positive effect of price discounts was not visible in the average part-worth utilities (Table 3). With an even further deterioration, effects of compensation measures are very small.

If snow reliability deteriorates to 'medium' in all destinations, then no effects can be seen (S1a, Table 5). Low snow reliability (S2a) causes a 12% decline of demand. However, if snow experience is becoming bad as well (S3a), then 64% would stay at home. Compensation measures are hardly necessary in S2 and almost ineffective in S3.

Assuming marginal snow conditions persist through the entire winter season, expected demand losses are in the range of results presented in Table 5. In the short- to medium term though, marginal snow conditions are becoming more frequent in early and/or late winter and not necessarily throughout the entire season. Furthermore, as winter tourism is characterized by high seasonality, the expected impact also depends on whether marginal snow conditions occur in the low or in the high season. According to Steiger (2010), the early (before Christmas) and late season (April) account for 12% of demand in Austrian ski areas. The Christmas-New Year school holidays (two weeks) account for about 30% of winter revenues. Applying the simulated demand changes (Table 5) only to these season periods, total demand losses would be 18% in S3a instead of the simulated 64% loss.

5. Discussion

Results of our survey and of the choice experiment show that snow is the most important factor for destination choice. In the former, snow conditions gained a significantly higher ranking than all other factors and in the latter, both snow variables are on average responsible for 48% of the overall evaluation of ski area characteristics. This finding is consistent with previous literature (Carmichael, 1992; Klenosky et al., 1993; Richards, 1996; Godfrey, 1999; Dickson and Faulks, 2007; Won et al., 2008; Joppe et al., 2013) and is reasonable as snow represents a physical precondition for practicing this sport. It is noteworthy that both the objective attribute 'snow reliability' and the subjective attribute 'snow experience' are almost equally important.

Nevertheless, results indicate a high variability of respondents' preferences for snow. While results from the survey suggest that between 25 and 39% of the sample have lower preferences for snow, the choice experiment reveals a considerably smaller - less snow sensitive preference - group. This difference is likely due to different methods how respondents had to evaluate the destination choice factors. While in the survey, the choice and ranking of the factors are done in a rather artificial and abstract situation, the setup of the choice experiment is closer to a real life decision situation where several products are compared and evaluated against each other.

Table 4
Simulation 1, snow conditions only change in the reference destination.

	Reference scenario	Simulated demand changes with					
		No reaction in SKI2			Price discounts, additional non-snow activities in SKI2		
		Snow scenarios					
Ski areas		S1a	S2a	S3a	S1b	S2b	S3b
SKI1 (large, mid-priced)	53%	68%	77%	78%	55%	75%	77%
SKI2 (medium size, mid-priced)	32%	14%	3%	1%	30%	7%	3%
Reference destination							
SKI3 (small, mid-priced)	8%	11%	12%	13%	8%	11%	12%
SKI4 (large, high-priced)	6%	7%	7%	7%	6%	7%	7%
Stay at home	1%	0%	1%	1%	0%	0%	1%

Note: snow is assumed to deteriorate only in SKI2.

Simulation results show that - as long as other ski areas for substitution exist – destinations with lower snow reliability will probably be severely affected, while total demand remains quite stable. This finding is supported by analyses of impacts of snow scarce years on demand (Pickering, 2011; Steiger, 2011b) with losses of > 50% for single ski areas, while total demand was substantially less affected, e.g. -7% revenues in Austria (Steiger, 2011b) or visitation in Eastern US -11% (Dawson et al., 2009). However, it has to be considered that if such severe losses occur in the future more often this can have consequences for the entire regional economy and livelihoods through tourism's interlinkages with up- and downstream industries but also for ecology. As Smith et al. (2016) argue, tourism is an important strategy for regional development in many ecologically valuable areas. This strategy could be threatened by climate change. This is also supported by Salvati and Carlucci (2011) showing that environmental quality, the role of agriculture and the degree of tourism specialization of regions strongly correlate. Conversely, a weakening of tourism and the regional economy, especially the less profitable alpine agriculture, can have far-reaching consequences for the environment (e.g. a loss of biodiversity on abandoned agricultural areas; Schirpke et al., 2018; Schirpke et al., 2019).

If all destinations are affected by deteriorating snow conditions, total demand reduces by 12% if snow reliability is low but still experiences are good and by 64% if also snow experiences are bad. If these conditions and effects are limited to the beginning (including Christmas) and the end of the ski season (April), demand losses of 18% are still substantial, but should be manageable, e.g. by limiting ski operations to the core season. To the best of our knowledge, such high market-wide losses have not been observed so far in any market in the world. A potential explanation is that most markets consist of ski areas with different snow reliability (e.g. because of altitudinal differences and/or more favorable climate) always offering skiers potential substitute ski areas with higher snow reliability. The potential magnitude of impact can be assessed by looking at climate change impact assessments and the share of snow reliable ski areas: Steiger and Scott (2020) estimate that about 15% of ski areas in Austria are going to have medium snow reliability by the 2030s and up to another 22% will already be considered as not snow reliable. By the 2050s, 20% of ski areas are estimated to have medium snow reliability and up to 48% not being snow reliable anymore.

Based on time series analysis, climatic changes in the last decades were found to have affected the economic situation of ski areas in New England (Beaudin and Huang, 2014). Large ski areas turned out to be more capable of coping with these changes. Both findings are in line with our results. One possibility to adapt to changing climate conditions is snowmaking. Falk and Vanat (2016) have shown that this strategy has been successful in the past, but only for higher altitude ski areas. In this paper, we follow a different approach: instead of analyzing observed demand indicators of the last years, we focus on tourists' preferences. Our resulting stylized facts are consistent with previous studies based on completely different methods (Beaudin and Huang, 2014; Falk and Vanat, 2016), this is an important robustness check for our results. Investigating preferences offers the advantage to be able to consider compensation measures (i.e. price, size, additional non-snow activities) for marginal snow conditions. Smith et al. (2016) also follow this approach and use their results for a market segmentation. In contrast to Smith et al. (2016) who only found a very moderate impact of climate change on winter outdoor activities, our results suggest a huge impact. One possible explanation is that they investigate a broad portfolio of activities, while the present study focuses on alpine skiing.

Our results show that marginal snow conditions and declining snow reliability cannot be compensated by offering more non-snow activities. This suggests that people for whom skiing is the main activity in their winter holiday (which is the case in our sample, as the survey was carried out while the interviewees had breaks from skiing) are unwilling to renounce skiing in favor of other non-snow activities and are rather looking for alternative destinations with better snow conditions. Measures that enhance price performance ratio, i.e. lowering lift ticket

Table 5
Simulation 2, snow conditions change in all destinations.

	Reference scenario	Simulated demand changes with					
		No reaction in SKI2			Price discounts, additional non-snow activities in SKI2		
		Snow scenarios					
Ski areas		S1a	S2a	S3a	S1b	S2b	S3b
SKI1 (large, mid-priced)	53%	53%	46%	21%	51%	47%	26%
SKI2 (medium size, mid-priced)	32%	32%	29%	9%	31%	28%	9%
SKI3 (small, mid-priced)	8%	8%	7%	4%	8%	8%	4%
SKI4 (large, high-priced)	6%	6%	5%	2%	9%	8%	3%
Stay at home	1%	1%	12%	64%	0%	9%	57%

prices and avoiding crowding, turned out to be the most suitable compensation. However, the potential for compensation by price discounts appears smaller in the choice experiment than in the survey. An explanation is that in the choice experiment each attribute was further defined with different levels describing the destination characteristic in more detail than in the survey. As consequence, price turned out to be an effective compensation only for ski areas that are in the highest price category. This saturation effect in the price attribute also reveals a limitation of our study, as we only had a rough price differentiation included in the CBC. Therefore, price should be modeled as continuous variable in future CBC applications. Considering individual data instead of sample averages as in the CBC results, price discounts appear as an effective measure in the less severe snow scenario not only for ski areas in the highest price category. This highlights the importance of using individual data in addition or instead of sample averages especially when the variance is high as in our case.

Sub-optimal snow conditions and lower snow reliability can in part be tackled with price discounts. To date pricing is mainly based on the seasonality of demand, most pronounced in the accommodation sector. Price structuring of ski lift tickets, at least in Europe, is usually not very differentiated (Pellinen, 2003; Malasevska and Haugom, 2018) throughout the season and very rarely dependent on snow conditions. A more dynamic pricing would enable ski areas and other tourism service providers to increase occupancy rates (Malasevska and Haugom, 2018), which is very important in sectors with high proportion of fixed costs, as e.g. ski areas and accommodation. On the other hand, higher prices on peak days might provide opportunities to increase revenue and potentially avoid crowding on the ski slopes and lifts. This kind of yield management has been introduced in the last years in a few ski areas in Switzerland (e.g. St. Moritz, Andermatt; Pröbstl-Haider and Flaig, 2019). Demand models including e.g. calendar and weather/snow effects for better yield management could not only be used by ski area operators, but also by accommodation owners. This would allow the tourism sector to react more systematically to these changing conditions.

Ski areas with climatic advantages, providing better snow reliability (e.g. higher altitude) and/or favorable conditions for snowmaking, might benefit from more frequent marginal snow conditions when snow is increasingly becoming a scarce commodity. Ski areas with a high frequency of bad snow conditions (i.e. low snow reliability) seem to have fewer opportunities to prevent or reduce demand losses during the winter season, at least according to our results. Therefore, the short-term challenge for these ski areas and tourism regions is to be financially able to cope with the projected demand losses and to search for opportunities provided by climate change. As the winter season will be shortened, the summer season will be prolonged. Although there is also strong seasonality of demand in the summer half year and gained days for this season are usually in low demand periods (e.g. April or October/November), it nevertheless represents an opportunity especially for ski destinations that already have a robust summer season. In the medium-term, the potential for non-snow related tourism activities and relevant tourist segments needs to be evaluated in order to become less dependent on ski tourism demand.

These results show that considering seasonality of demand and snow conditions is crucial in order to provide more sophisticated impact assessments. If seasonality is neglected, projections of demand losses are likely to overestimate the impact. Nevertheless, it should be considered that changing snow reliability and snow experience does not only affect demand during periods with bad snow conditions, but might affect winter demand throughout the season and beyond by damaging the destination's reputation. To adequately prepare ski tourism for deteriorating climatic conditions, it is necessary to know how specific snow conditions are perceived and affect behavioral changes: 1) it is not unlikely that demand responses will not change proportionally to changing climatic conditions but could change abruptly once certain thresholds are reached (Gössling and Hall, 2006); and 2) information on critical thresholds would make it possible to identify time horizons where climatic conditions will significantly affect demand for ski tourism.

6. Conclusions

In this study we have investigated the impact of climate change on winter tourism demand by using results of a choice experiment for simulation. The originality of our approach is that we used individual data thus considering the heterogeneity of preferences and reaction to marginal snow conditions. We also show that simulated demand changes differ significantly on the local (i.e. ski area) and the market level (i.e. Austria). Including seasonality in the estimation of demand losses was found to significantly reduce the impact, while the effectiveness of compensation measures is limited.

For winter tourism dependent regional economies, the following conclusions can be drawn from our results: 1) The effect of a deterioration of snow reliability from high to medium is economically bearable for ski area operators and destinations. 2) The effects do depend on the frequency of occurrence of marginal snow conditions. An important question is whether tourists will perceive marginal snow conditions as unusual or normal when marginal snow condition becomes the new average in the future and how that influences decisions. 3) As long as substitute destinations with high snow reliability exist, demand losses in ski areas with low snow reliability are severe. This is a more likely scenario than uniformly bad snow reliability across the Alps. The simulated demand loss of almost 60% in our reference destination (without adaptation) has the potential to destabilize winter tourism dependent regional economies. Again, the frequency of occurrence will determine the severity of effects. Destinations with a high probability of marginal snow conditions might be forced to give up skiing tourism and develop alternative tourism products. Destinations with a mixture of good and bad snow years might become more resilient through intelligent product development, e.g. introducing yield management with dynamic pricing for the entire tourism product, or by valorizing the extension of the summer season. 4) The analysis of how these differently affected destinations are distributed and consequently which regions are more affected requires both higher resolution climate models and a better understanding of customer reaction to marginal snow conditions. We have contributed to the latter and demonstrated the importance of considering heterogeneity in the demand decision process. This heterogeneity of preferences and ski areas (snow reliable vs. non-snow reliable) together with high seasonality of demand and snow calls for further investigations on that topic.

Funding

This research was gratefully funded by the Austrian Climate Research Programme (grant number KR14AC7K11929). The funding source was not involved in study design, collection, analysis, interpretation of data or in the decision to submit the article.

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.

Appendix 1

Response rate.

Respondents filling out the in-situ questionnaire	9190
E-Mails collected	5910
Final sample (after cleaning of the sample)	3673

Appendix 2

Online questionnaire.

No.	Question & answer options
1	Have you been skiing/snowboarding in Austria at least once in the last 5 years? (y, n)
2	I am on the slope most of the time with… (skis, snowboard, telemark, other)
3	How do you collect most skiing days in general? (single-day, 1–2 night trips, trips with 3 or more nights)
4	Please rate your skiing skills (beginner, intermediate, advanced, expert)
5	On which runs do you feel the most comfortable? (blue, red, black, off-piste, fun-park)
6	Please rate the following statement: skiing/snowboarding is very important for me (scale of 5)
7	How many years have you been skiing/snowboarding? (0–5, 6–10, 11–15, > 15 years)
8	Please choose the five most important factors for ski destination choice.
a. .	Altitude of skiing area
b. .	Prominence of skiing area
c. .	Possibility of artificial snow making
d. .	Snow conditions
e. .	Additional non-snow related activities/facilities (e.g. shopping, spas)
f. .	Low waiting times at lifts
g. .	Size of skiing area
h. .	Good price/performance ratio
i. .	Uncrowded ski slopes
j. .	Landscape, mountains, nature
k. .	Diverse offer of runs
l. .	Proximity to my place of residence
9	Please rank the five selected factors according to their importance
10	How many hours are you generally willing to travel for each type of ski/snowboard trip? (please check the maximum number of hours you are willing to travel)
a. .	Day trip
b. .	Weekend/multi day trip (1–2 nights)
c. .	Holiday (3 or more nights)
11	What mode of transport do you use to go to the skiing area for a…
a. .	Day trip (car, public transport, airplane, other)
b. .	Weekend/multi day trip (1–2 nights) (car, public transport, airplane, other)
c. .	Holiday (3 or more nights) (car, public transport, airplane, other)
12	How many days do you ski during single-day trips each winter? (open question)
13	How many days do you ski during multi-day trips (1–2 nights) each winter? (open question)
14	How many days do you ski during holidays (3 or more nights) in Austria? (open question)
15	When do you usually go skiing? (Oct, Nov, Dec before Christmas, Dec during Christmas holiday, Jan, Feb, March (except Easter), April (except Easter), Easter)
16	Do you go skiing if… (yes – maybe – no)
a. .	… 25% of slopes are open.
b. .	… 50% of slopes are closed.
c. .	… the valley run is closed.
d. .	… the slopes have artificial snow but little natural snow.
17	What do you understand of snow reliability?
a. .	Proportion of slopes with artificial snow making
b. .	Length of the season in the past
c. .	Average values of cumulative snowfall per season
d. .	Altitude of ski area
e. .	No idea
18	Please rate the following statement: “Skiing/snowboarding has a central role in my life” (5-scale)
19	How many people are living in your household including yourself? (1, 2, 3, 4, 5 or more)
20	Do you have kids (0–12 years)? (no, yes - > how many?)
21	How often do you children (0–12 years) ski with you? (never, rarely, sometimes, often, always)
22	What is your average household net income per month? (< €500, €500–1999, €2000–2999, €3000–4999, €5000 and more)
23	Where is your current place of residence? (Germany, Austria, Switzerland, Liechtenstein, Italy, Other)
24	Zip code (open question)
25	Sex (female, male)
26	Age

Appendix 3

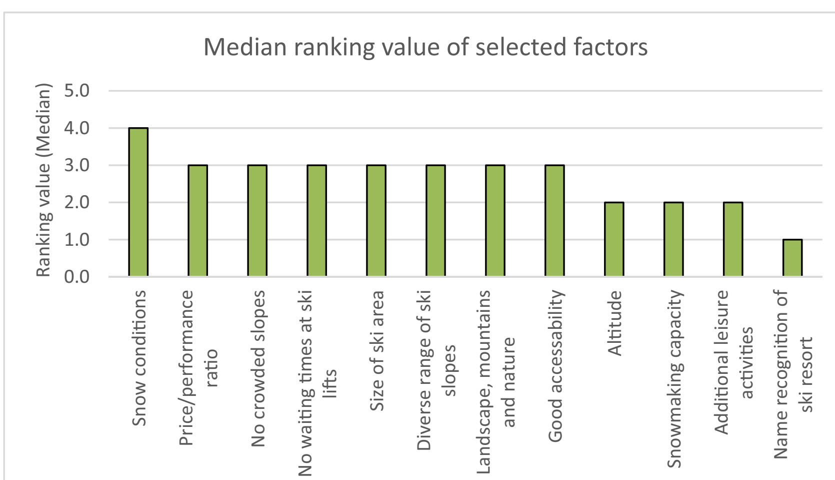
Descriptive statistics of selected variables.

Category	n	%
Q2: Most of the time I am on the slopes with…		
Skis	1716	87.7
Snowboard	230	11.8
Telemark	2	0.1

Other	9	0.5
Q4: Please rate your skiing skills		
Beginner-intermediate	543	27.7
Advanced	1025	52.4
Expert	389	19.9
Q20: Do you have kids (0–12 years)?		
No	1391	71.1
Yes	566	28.9
Q22: What is your average household net income per month?		
< 500 €	127	6.5
500–1999 €	321	16.4
2000–2999 €	328	16.8
3000–4999 €	484	24.7
≥ 5000 €	298	15.2
No answer	390	19.9
Q23: Where is your current place of residence?		
Austria	178	9.1
Germany	1522	77.8
Switzerland	46	2.4
Liechtenstein	1	0.1
Italy	1	0.1
Other	186	9.5
No answer	23	1.2
Q25: Sex		
Female	894	45.7
Male	1056	54.0
No answer	7	0.4
Q26: Age		
18–24	358	18.3
25–34	439	22.4
35–44	432	22.1
45–54	503	25.7
≥ 55	208	10.6
No answer	17	0.9

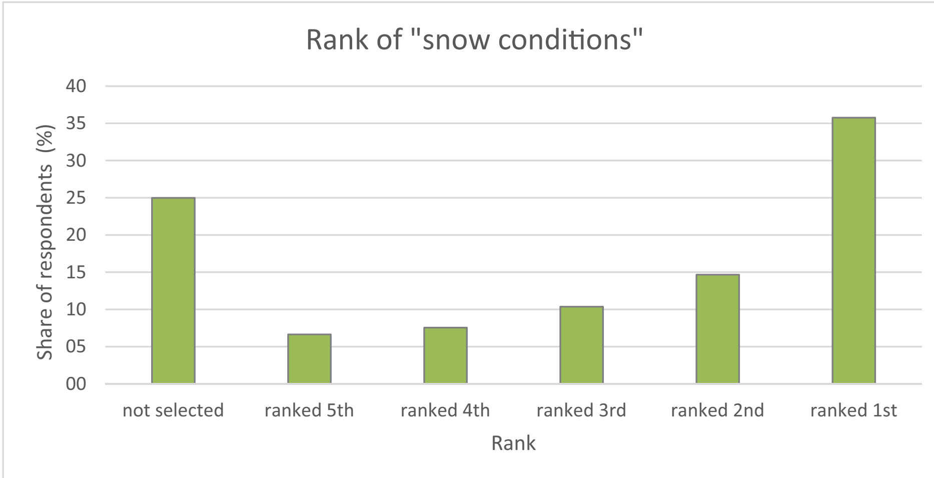
Appendix 4

Ranking of selected factors.



Appendix 5

Rank of snow conditions.



References

Abegg, B., 1996. Klimaänderung und Tourismus. Klimafolgenforschung am Beispiel des Wintertourismus in den Schweizer Alpen. vdf Zurich, Zurich.
Adams, D., 2019. Management Accounting for the Hospitality, Tourism and Leisure Industries, 3rd ed. Goodfellow Publishers Limited, Oxford.
Arnberger, A., Haider, W., 2005. Social effects on crowding preferences of urban forest visitors. Urban For. Urban Green. 3 (3), 125–136. https://doi.org/10.1016/j.ufug.2005.04.002.
ASTAT, 2018. Tourismus in einigen Alpengebieten. Landesinstitut für Statistikhttps://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwjfvN_h4IvjAhVRmIsKHSAlAPUQFjABegQIBBAC&url=https%3A%2F%2Fastat.provinz.bz.it%2Fde%2Faktuelles-publikationen-info.asp%3Fnews_action%3D300%26news_image_id%3D1006432&usg=AOvVaw3BDzhnxDuCtdNrgMUy4Rsu.
BAKBasel, 2018. Benchmarking du tourisme -Le secteur Suisse du tourisme en comparaison internationale, Basel. https://www.bak-economics.com/fileadmin/documents/reports/bak_economics_rapport_tourisme_benchmarking_2018.pdf.
Beaudin, L., Huang, J.-C., 2014. Weather conditions and outdoor recreation: a study of New England ski areas. Ecol. Econ. 106, 56–68. https://doi.org/10.1016/j.ecolecon.2014.07.011.
Bédiová, M., Ryglová, K., 2015. The main factors influencing the destination choice, satisfaction and the loyalty of ski resorts customers in the context of different research approaches. Acta Universitatis Agriculturae et Silviculturae mendelianae brunensis 63, 499–505.
Beniston, M., 2007. Entering into the “greenhouse century”: recent record temperatures in Switzerland are comparable to the upper temperature quantiles in a greenhouse climate. Geophys. Res. Lett. 34. https://doi.org/10.1029/2007GL030144.
Carmichael, B., 1992. Using conjoint modelling to measure tourist image and analyse ski resort choice. In: Johnson, P., Thomas, B. (Eds.), Choice and Demand in Tourism. Mansell Publishing Limited, London, pp. 93–106.
Castillo, V., Figal Garone, L., Maffioli, A., Salazar, L., 2017. The causal effects of regional industrial policies on employment: a synthetic control approach. Reg. Sci. Urban Econ. 67, 25–41. https://doi.org/10.1016/j.regsciurbeco.2017.08.003.
Damm, A., Greuell, W., Landgren, O., Prettenthaler, F., 2017. Impacts of +2°C global warming on winter tourism demand in Europe. Climate Services 7, 31–46. https://doi.org/10.1016/j.cliser.2016.07.003.
Dawson, J., Scott, D., 2013. Managing for climate change in the alpine ski sector. Tour. Manag. 35, 244–254. https://doi.org/10.1016/j.tourman.2012.07.009.
Dawson, J., Scott, D., McBoyle, G., 2009. Climate change analogue analysis of ski tourism in the northeastern USA. Clim. Res. 39, 1), 1–9.
Dawson, J., Scott, D., Havitz, M., 2013. Skier demand and behavioural adaptation to climate change in the US northeast. Leisure/Loisir 37 (2), 127–143. https://doi.org/10.1080/14927713.2013.805037.
Desarbo, W.S., Ramaswamy, V., Cohen, S.H., 1995. Market segmentation with choice-based conjoint analysis. Mark. Lett. 6 (2), 137–147. https://doi.org/10.1007/BF00994929.
Dickson, T., Faulks, P., 2007. Exploring overseas Snowsport participation by Australian skiers and snowboarders. Tour. Rev. 62 (3+4), 7–15.
Falk, M., 2015. The demand for winter sports: empirical evidence for the largest French ski-lift operator. Tour. Econ. 21 (3), 561–580.
Falk, M., Hagsten, E., 2016. Importance of early snowfall for Swedish ski resorts: evidence based on monthly data. Tour. Manag. 53, 61–73. https://doi.org/10.1016/j.tourman.2015.09.002.
Falk, M., Steiger, R., 2019. Size facilitates profitable ski lift operations. Tour. Econ. https://doi.org/10.1177/1354816619868117. (1354816619868117).
Falk, M., Vanat, L., 2016. Gains from investments in snowmaking facilities. Ecol. Econ. 130, 339–349. https://doi.org/10.1016/j.ecolecon.2016.08.003.
Falk, M., Vieru, M., 2016. Demand for downhill skiing in subarctic climates. Scand. J. Hosp. Tour. 1–18. https://doi.org/10.1080/15022250.2016.1238780.
Gilbert, D., Hudson, S., 2000. Tourism demand constraints: a skiing participation. Ann. Tour. Res. 27 (4), 906–925. https://doi.org/10.1016/S0160-7383(99)00110-3.
Gobiet, A., Kotlarski, S., Beniston, M., Heinrich, G., Rajczak, J., Stoffel, M., 2014. 21st century climate change in the European Alps–a review. Sci. Total Environ. 493, 1138–1151. https://doi.org/10.1016/j.scitotenv.2013.07.050.
Godfrey, K.B., 1999. Attributes of destination choice: British skiing in Canada. J. Vacat. Mark. 5 (1), 18–30. https://doi.org/10.1177/135676679900500103.
Gössling, S., Hall, M.C., 2006. Uncertainties in predicting tourist flows under scenarios of climate change. Clim. Chang. 79, 163–173. https://doi.org/10.1007/s10584-006-9081-y.
Gössling, S., Scott, D., Hall, C.M., Ceron, J.-P., Dubois, G., 2012. Consumer behaviour and demand response of tourists to climate change. Ann. Tour. Res. 39 (1), 36–58. https://doi.org/10.1016/j.annals.2011.11.002.
Hamilton, L.C., Brown, C., Keim, B.D., 2007. Ski areas, weather and climate: time series models for New England case studies. Int. J. Climatol. 27, 2113–2124.
Hartl, L., Fischer, A., Olefs, M., 2018. Analysis of past changes in wet bulb temperature in relation to snow making conditions based on long term observations Austria and Germany. Glob. Planet. Chang. 167, 123–136. https://doi.org/10.1016/j.gloplacha.2018.05.011.
IPCC, 2014. Climate change 2014: Synthesis report. In: Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva.
IPCC, 2018. Global warming of 1.5°C. In: AnIPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty, . https://www.ipcc.ch/sr15/.
Joppe, M., Elliot, S., Durand, L., 2013. From ski market to ski traveller: a multi-dimensional segmentation approach. Anatolia 24 (1), 40–51. https://doi.org/10.1080/13032917.2012.762316.
Klein, G., Vitasse, Y., Rixen, C., Marty, C., Rebetez, M., 2016. Shorter snow cover duration since 1970 in the Swiss Alps due to earlier snowmelt more than to later snow onset. Clim. Chang. 1–13. https://doi.org/10.1007/s10584-016-1806-y.
Klenosky, D.B., Gengler, C.E., Mulvey, M.S., 1993. Understanding the factors influencing ski destination choice: a means-end analytic approach. J. Leis. Res. 25 (4), 362–379.
König, U., 1998. Tourism in a Warmer World: Implications of Climate Change Due to Enhanced Greenhouse Effect for the Ski Industry in the Australian Alps. University of Zurich, Zurich.
Konu, H., Laukkanen, T., Komppula, R., 2011. Using ski destination choice criteria to segment Finnish ski resort customers. Tour. Manag. 32 (5), 1096–1105. https://doi.org/10.1016/j.tourman.2010.09.010.
Landauer, M., Pröbstl, U., Haider, W., 2012. Managing cross-country skiing destinations under the conditions of climate change - scenarios for destinations in Austria and Finland. Tour. Manag. 33, 741–751. https://doi.org/10.1016/j.tourman.2011.08.007.
Landauer, M., Haider, W., Pröbstl-Haider, U., 2013. The influence of culture on climate change adaptation strategies. J. Travel Res. 53 (1), 96–110. https://doi.org/10.1177/0047287513481276.
Lenk, P.J., Desarbo, W.S., Green, P.E., Young, M.R., 1996. Hierarchical Bayes conjoint analysis: recovery of Partworth heterogeneity from reduced experimental designs. Mark. Sci. 15 (2), 173–191. https://doi.org/10.1287/mksc.15.2.173.
Lindberg, K., Fredman, P., 2005. Using choice experiments to evaluate destination attributes: the case of snowmobilers and cross-country skiers. Tourism (Zagreb) 53 (2), 127–140.
Luterbacher, J., Liniger, M.A., Menzel, A., Estrella, N., Della-Marta, P.M., Pfister, C., Rutishauser, T., Xoplaki, E., 2007. Exceptional European warmth of autumn 2006 and winter 2007: historical context, the underlying dynamics, and its phenological

impacts. Geophys. Res. Lett. 34, L12704.
Ma, S., Kirilenko, A.P., 2019. Climate change and tourism in English-language newspaper publications. J. Travel Res. https://doi.org/10.1177/0047287519839157. (0047287519839157).
Malasevska, I., Haugom, E., 2018. Optimal prices for alpine ski passes. Tour. Manag. 64, 291–302. https://doi.org/10.1016/j.tourman.2017.09.006.
Marty, C., Tilg, A.-M., Jonas, T., 2017. Recent evidence of large-scale receding snow water equivalents in the European Alps. J. Hydrometeorol. 18 (4), 1021–1031. https://doi.org/10.1175/JHM-D-16-0188.1.
Matzler, K., Teichmann, K., Strobl, A., Partel, M., 2019. The effect of price on word of mouth: first time versus heavy repeat visitors. Tour. Manag. 70, 453–459. https://doi.org/10.1016/j.tourman.2018.09.013.
Mayer, M., Kraus, F., Job, H., 2011. Tourismus – Treiber des Wandels oder Bewahrer alpiner Kultur und Landschaft? Mitteilungen der Österreichischen Geographischen Gesellschaft 153, 31–74. https://doi.org/10.1553/moegg153s31.
Olefs, M., Fischer, A., Lang, J., 2010. Boundary conditions for artificial snow production in the Austrian Alps. Journal of Applied Meteorology & Climatology 49 (6), 1096–1113. https://doi.org/10.1175/2010JAMC2251.1.
Österreich Werbung, 2018. Österreich-Urlauber im Winter 2017/18. https://www.austriatourism.com/tourismusforschung/studien-und-berichte/oesterreich-urlauber-im-winter-201718/.
Pellinen, J., 2003. Making price decisions in tourism enterprises. Int. J. Hosp. Manag. 22 (2), 217–235. https://doi.org/10.1016/S0278-4319(03)00019-7.
Permanent Secretariat of the Alpine Convention, 2010. The Alps. People and pressures in the mountains, the facts at a glance. http://www.alpconv.org/en/publications/alpine/Documents/Vademecum_web.pdf.
Phillips, J., Brunt, P., 2013. Tourist differentiation: developing a typology for the winter sports market. Tourism: An International Interdisciplinary Journal 61 (3), 219–243.
Pickering, C.M., 2011. Changes in demand for tourism with climate change: a case study of visitation patterns to six ski resorts in Australia. J. Sustain. Tour. 19 (6), 767–781. https://doi.org/10.1080/09669582.2010.544741.
Pickering, C.M., Castley, J.G., Burtt, M., 2010. Skiing less often in a warmer world: attitudes of tourists to climate change in an Australian ski resort. Geogr. Res. 48 (2), 137–147. https://doi.org/10.1111/j.1745-5871.2009.00614.x.
Pröbstl-Haider, U., Flaig, R., 2019. The knockout deal – pricing strategies in alpine ski resorts. In: Pröbstl-Haider, U., Richins, H., Türk, S. (Eds.), Winter Tourism. Trends and Challenges. CABI Publications, Wallingford, pp. 116–137.
Pröbstl-Haider, U., Haider, W., Wirth, V., Beardmore, B., 2015. Will climate change increase the attractiveness of summer destinations in the European Alps? A survey of German tourists. J. Outdoor Recreat. Tour. 11, 44–57. https://doi.org/10.1016/j.jort.2015.07.003.
Pütz, M., Gallati, D., Kytzia, S., Elsasser, H., Lardelli, C., Teich, M., Waltert, F., Rixen, C., 2011. Winter tourism, climate change, and snowmaking in the Swiss Alps: tourists' attitudes and regional economic impacts. Mt. Res. Dev. 31 (4), 357–362.
Rao, V.R., 2014. Applied Conjoint Analysis. Springer, Berlin, Heidelberg.
Richards, G., 1996. Skilled consumption and UK ski holidays. Tour. Manag. 17 (1), 25–34. https://doi.org/10.1016/0261-5177(96)00097-0.
Riddington, G., Sinclair, C., Milne, N., 2000. Modelling choice and switching behaviour between Scottish ski centres. Appl. Econ. 32 (8), 1011–1018. https://doi.org/10.1080/000368400322066.
Rutty, M., Scott, D., Johnson, P., Jover, E., Pons, M., Steiger, R., 2015a. Behavioural adaptation of skiers to climatic variability and change in Ontario, Canada. J. Outdoor Recreat. Tour. 11, 13–21. https://doi.org/10.1016/j.jort.2015.07.002.
Rutty, M., Scott, D., Johnson, P., Jover, E., Pons, M., Steiger, R., 2015b. The geography of skier adaptation to adverse conditions in the Ontario ski market. The Canadian Geographer/Le Géographe canadien 59 (4), 391–403. https://doi.org/10.1111/cag.12220.
Rutty, M., Scott, D., Johnson, P., Pons, M., Steiger, R., Vilella, M., 2017. Using ski industry response to climatic variability to assess climate change risk: an analogue study in eastern Canada. Tour. Manag. 58, 196–204. https://doi.org/10.1016/j.tourman.2016.10.020.
Salvati, L., Carlucci, M., 2011. The economic and environmental performances of rural districts in Italy: are competitiveness and sustainability compatible targets? Ecol. Econ. 70 (12), 2446–2453. https://doi.org/10.1016/j.ecolecon.2011.07.030.
Sawtooth Software, 2009. The CBC/HB module for hierarchical Bayes estimation. Technical paper. https://www.sawtoothsoftware.com/support/technical-papers/hierarchical-bayes-estimation/cbc-hb-technical-paper-2009, Accessed date: 29 May 2019.
Sawtooth Software, 2013. The CBC system for choice-based conjoint analysis. Version 8. https://pdfs.semanticscholar.org/0aa2/5fd7ba782197138d9ca5c5cb04d0534f22e0.pdf.
Schirpke, U., Meisch, C., Marsoner, T., Tappeiner, U., 2018. Revealing spatial and temporal patterns of outdoor recreation in the European Alps and their surroundings. Ecosystem Services 31, 336–350. https://doi.org/10.1016/j.ecoser.2017.11.017.
Schirpke, U., Altzinger, A., Leitinger, G., Tasser, E., 2019. Change from agricultural to touristic use: effects on the aesthetic value of landscapes over the last 150 years. Landsc. Urban Plan. 187, 23–35. https://doi.org/10.1016/j.landurbplan.2019.03.004.
Schöner, W., Koch, R., Matulla, C., Marty, C., Tilg, A.-M., 2019. Spatiotemporal patterns of snow depth within the Swiss-Austrian Alps for the past half century (1961 to 2012) and linkages to climate change. Int. J. Climatol. 39 (3), 1589–1603. https://doi.org/10.1002/joc.5902.
Scott, D., 2006. Global environmental change and mountain tourism. In: Gössling, S., Hall, M.C. (Eds.), Tourism and Global Environmental Change. Routledge, London, New York, pp. 54–75.
Scott, D., Dawson, J., Jones, B., 2008. Climate change vulnerability of the US northeast winter recreation– tourism sector. Mitig. Adapt. Strateg. Glob. Chang. 13, 577–596. https://doi.org/10.1007/s11027-007-9136-z.
Scott, D., Hall, C.M., Gössling, S., 2012. Tourism and Climate Change. Impacts, Adaptation & Mitigation, 1st ed. Routledge, London and New York.
Scott, D., Steiger, R., Knowles, N., Fang, Y., 2019. Regional ski tourism risk to climate change: an inter-comparison of eastern Canada and US northeast markets. J. Sustain. Tour. 1–19. https://doi.org/10.1080/09669582.2019.1684932.
Shih, C., Nicholls, S., Holecek, D.F., 2009. Impact of weather on downhill ski lift ticket sales. J. Travel Res. 47 (3), 359–372. https://doi.org/10.1177/0047287508321207.
Simma, A., Schlich, R., Axhausen, K.W., 2001. Destination Choice of Leisure Trips: The Case of Switzerland. Institut für Verkehrsplanung und Transporttechnik, Strassen- und Eisenbahnbau; ETH Zürich, Zürich.
Smith, J.W., Seekamp, E., McCreary, A., Davenport, M., Kanazawa, M., Holmberg, K., Wilson, B., Nieber, J., 2016. Shifting demand for winter outdoor recreation along the North Shore of Lake Superior under variable rates of climate change: a finite-mixture modeling approach. Ecol. Econ. 123, 1–13. https://doi.org/10.1016/j.ecolecon.2015.12.010.
Sorice, M.G., Oh, C.-O., Ditton, R.B., 2007. Managing scuba divers to meet ecological goals for coral reef conservation. AMBIO 36 (4), 316–322.
Spandre, P., François, H., Morin, S., George-Marcelpoil, E., 2015. Snowmaking in the French Alps. Climatic context, existing facilities and outlook. Journal of alpine research 103 (2). https://doi.org/10.4000/rga.2913.
Steiger, R., 2010. The impact of climate change on ski season length and snowmaking requirements. Clim. Res. 43 (3), 251–262.
Steiger, R., 2011a. The impact of climate change on ski touristic demand using an analogue approach. In: Weiermair, K., Pechlahner, H., Strobl, A., Elmi, M., Schuckert, M. (Eds.), Coping With Global Climate Change. Strategies, Policies and Measures for the Tourism Industry. Innsbruck University Press, Innsbruck, pp. 247–256.
Steiger, R., 2011b. The impact of snow scarcity on ski tourism. An analysis of the record warm season 2006/07 in Tyrol (Austria). Tour. Rev. 66 (3), 4–15.
Steiger, R., Abegg, B., 2013. The sensitivity of Austrian ski areas to climate change. Tourism Planning & Development 10 (4), 480–493. https://doi.org/10.1080/21568316.2013.804431.
Steiger, R., Abegg, B., 2018. Ski areas' competitiveness in the light of climate change: comparative analysis in the eastern Alps. In: Müller, D., Więckowski, M. (Eds.), Tourism in Transition, Recovering from Decline and Managing Change. Springer International Publishing, Basel, pp. 187–199.
Steiger, R., Mayer, M., 2008. Snowmaking and climate change. Future options for snow production in Tyrolean ski resorts. Mt. Res. Dev. 28 (3/4), 292–298. https://doi.org/10.1659/mrd.0978.
Steiger, R., Scott, D., 2020. Ski tourism in a warmer world: increased adaptation and regional economic impacts in Austria. Tour. Manag. 77, 104032. https://doi.org/10.1016/j.tourman.2019.104032.
Steiger, R., Scott, D., Abegg, B., Pons, M., Aall, C., 2019. A critical review of climate change risk for ski tourism. Curr. Issue Tour. 22 (11), 1343–1379. https://doi.org/10.1080/13683500.2017.1410110.
Tappeiner, U., Borsdorf, A., Tasser, E., 2008. Alpenatlas. Spektrum Akademischer Verlag, Heidelberg.
Train, K.E., 2009. Discrete Choice Methods With Simulation, 2nd ed. Cambridge University Press, Cambridge.
Unbehaun, W., Pröbstl, U., Haider, W., 2008. Trends in winter sport tourism: challenges for the future. Tour. Rev. 63 (1), 36–47. https://doi.org/10.1108/16605370810861035.
Won, D., Bang, H., Shonk, D.J., 2008. Relative importance of factors involved in choosing a regional ski destination: influence of consumption situation and recreation specialization. Journal of Sport & Tourism 13 (4), 249–271. https://doi.org/10.1080/14775080802577185.