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Does artificial snow production pay under future climate conditions? – A case study for a vulnerable ski area in Austria

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HIGHLIGHTS

- We carry out a cost–revenue analysis of snowmaking under future climate conditions.
- Snow pack and skiing demand simulations form the basis of annuity calculations.
- Results reveal that rising electricity prices will challenge ski area operators.
- Ski visitor numbers are projected to decline due to decreasing overall snow depths.
- Annual real ticket price changes are inevitable to keep skiing operations profitable.

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ABSTRACT

The prospects of increasing temperatures, a growing frequency of snow scarce winter seasons and rising energy prices raise questions about the future profitability of snowmaking. Therefore, we carry out a cost–revenue analysis of snowmaking based on projected daily snowmaking hours and visitor numbers until 2050 for a case study site in Austria. The results show that ski area operators are at risk of facing a substantial increase in total energy costs due to expected rising electricity costs, although the total amount of snowmaking hours is projected to slightly decrease because of shrinking feasible time for snowmaking (considering current snowmaking infrastructure). In the long run ski visitor numbers are projected to decline due to decreasing overall snow depths. Overall, the profitability analysis of skiing operations reveals that price increases in ski lift tickets, slightly higher than observed in the recent past, will be inevitable in order to keep skiing operations profitable in future.

1. Introduction

Alpine winter tourism plays a fundamental role in the Austrian economy. According to Arbesser, Grohall, Helmenstein, and Kleissner (2010) "winter sports", which covers several industries (mainly accommodation and food service activities, transportation, arts, entertainment and recreation, and retail trade), annually generates almost 7.4 billion EUR in direct value added, which represents about 3.16% of the gross domestic product (GDP). The annual contribution to the GDP amounts to more than 11.4 billion EUR, if multiplicative effects, i.e. indirect economic effects due to inter-industrial relations, are taken into account as well. The economically important winter tourism industry, however, is increasingly challenged to deal with rising temperatures and snow poor winter seasons. Changing natural snow reliability influences tourism demand (Fukuskima, Kureha, Ozaki, Fukimori, & Harasawa, 2003; Hamilton, Brown, & Keim, 2007; Shih, Nicholls, & Holecek, 2009; Töglhofer, Eigner, & Prettenthaler, 2011) and ski area operators are faced with an enhanced need for artificial snow production.

Ski resorts have long been dealing with variability in seasonal temperature and natural snowfall leading to early adaptive interventions (Dawson & Scott, 2013). Falk (2013) shows a significant relationship between the early adoption of snowmaking and the economic viability of ski area operators. Nowadays, snowmaking is a widely used adaptation strategy to sustain longer and more snow-reliable ski seasons. In Austria, currently around two thirds of ski slopes are equipped with snowmaking facilities (Professional Association of the Austrian Cable Cars, 2011).

The use of snowmaking involves high investment and operating costs. Between 2000 and 2011 the Austrian cableway enterprises,

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supplying around 25,400 ha of ski slopes with average annual ski lift ticket sales of around 1 billion EUR, invested a total of approximately 6 billion EUR in quality, security and snowmaking infrastructure. In the financial year 2011 the sum of investments reached almost 500 million EUR, whereof around 102 million EUR were invested in snowmaking technologies (Professional Association of the Austrian Cable Cars, 2011). In the literature, investment costs range between 25,000 to 150,000 EUR per ha (Abegg, Agrawala, Crick, & Montfalcon, 2007; Breiling, Charamza, & Feilmayr, 2008; Hahn, 2004). The annual snowmaking operating costs are estimated to be between 10,000 and 30,000 EUR per ha (Breiling et al., 2008).

The costs of snowmaking are discussed in several studies (Abegg et al., 2007; Breiling et al., 2008; Gonseth, 2008; Hahn, 2004; Lang, 2009; Teich et al., 2007), but the economic limits of snowmaking are still poorly understood. Limiting factors of snowmaking are not only increasing temperatures and decreasing efficiency of snow production, but also potential increases in energy prices owing to higher taxes and/or shortage of fossil fuel, which would affect the profitability of snowmaking (Steiger, 2010).

This paper addresses the gap of knowledge concerning the economic profitability of snowmaking, taking prospective snowmaking requirements under future climate scenarios into account. We carry out a detailed cost–revenue analysis of snowmaking under current and future climate conditions until 2050 for a case study site in Styria, Austria, using the annuity method. Projected daily snowmaking hours (as an output of a physically based snow model) and projected daily visitor numbers (based on an econometric skiing demand model), as well as different energy price, ski lift ticket price and discount rate scenarios are considered in the cost–revenue analysis to draw conclusions about the viability of ski area operators under changing climate conditions. Furthermore, we determine the minimum average annual ski lift ticket price increase ski tourists can expect in future subject to different assumed levels of price elasticities of demand.

The paper is structured as follows: Section 2 gives an overview of the existing literature in the field of ski tourism and climate change, starting from a natural science perspective, since these results are often the basis for further economic analyses. Then, the economic aspects of snowmaking as discussed in the literature are delineated. In Section 3 we describe the methodological framework of the cost–revenue analysis of snowmaking comprising the determinants of cost and revenue components and the underlying data basis. The results in Section 4 are structured so as to firstly present details on the projected development of cost and revenue components, before coming to the annuity results of the investment models. Finally, we show the determined minimum average annual ski lift ticket price increase ski tourists have to expect. In Section 5 we discuss the results and conclude.

2. Snow conditions and skiing operations under a changing climate: previous findings

A variety of studies deal with the impacts of changing climate conditions on ski tourism. The major part of these studies investigates the impacts from a natural science perspective. The ‘first generation’ of studies in this field mainly focused on the impacts of temperature rise on ski season length and the natural snow reliability of ski areas, without regarding snowmaking as an adaptation strategy. König and Abegg (1997) came to the result that under current climate conditions the line of snow reliability, where at least 100 skiing days per winter season with a snow depth of at least 30 cm are ensured, lies at 1200 m above sea level. The line would rise to a minimum altitude of 1500 m by a warming of 2 °C, inducing a drop in the number of snow reliable ski areas in Switzerland from 85% to 63%. Abegg et al. (2007) compared the snow reliability of ski areas in Austria, France, Germany, Italy, and Switzerland under present and future climate conditions (+1 °C, +2 °C, and +4 °C) by applying the 100-days rule and found that currently, around 91% of the 666 operating ski areas can be considered as snow reliable. While under a +1 °C scenario only 75% of the ski areas would still be snow reliable, this proportion drops to 61% and 30% under a +2 °C and +4 °C scenario, respectively.

In the outlined ‘first generation’ climate impact studies on ski tourism, several shortcomings have been identified. First, local climate conditions are not incorporated in those studies which solely rely on some general altitude criteria for determining snow reliability. Second, snowmaking which has become an important adaptation strategy and is already standard in many ski areas has not been considered in those studies and the potential future climate impacts on the ski tourism industry are likely overestimated. Scott, McBoyle, and Mills (2003) were the first to incorporate a snowmaking module in their analysis and found that the projected shortening of the ski season in central Ontario, Canada, was significantly less severe than in preceding studies. Further studies considering snowmaking in their climate change impact analyses followed (e.g. Hennessy et al. 2003; Scott, McBoyle, & Minogue, 2007; Scott, McBoyle, Minogue, & Mills, 2006; Steiger & Mayer, 2008; Teich et al., 2007). For Austria, Steiger and Mayer (2008) used a rather simple degree-day model to assess the suitability of snowmaking as an adaptation strategy for ski areas in Tyrol (Austria) and also in the Bavarian Alps (Germany). The required number of snowmaking days is determined by calculating daily snow melt and producing the same amount of artificial snow. Using this approach, Steiger and Mayer (2008) analysed elevations suitable for snowmaking by using three climate stations in Tyrol. Under present climate conditions, the line of technical snow reliability was found to be at 1000 m. In a +2 °C climate scenario current snowmaking intensity will not be sufficient below 1500 m–1600 m. According to Steiger and Mayer (2008) snowmaking is not primarily limited to climatic conditions, at least not with a temperature rise of 2 °C, but the ski area operators will be faced with the challenge of rising costs of snow production.

These studies first incorporating snowmaking, however, do not account for temperature decreases that occur with increasing elevations suggesting that impacts may in some cases still be overestimated especially for ski areas at higher elevations. Steiger (2010) attempted to meet this limitation and refined the SkiSim model of Scott et al. (2003) to simulate snow pack and snowmaking requirements at 100 m altitudinal bands at each ski area. The model was applied on three ski areas in Tyrol (Austria) concerning climate change scenarios under two different greenhouse gas emission scenarios (A1B, B1). Taking snowmaking into account, all three ski areas remain snow reliable until the 2040s or 2050s. By then, the technical limits are reached regarding currently available snowmaking technologies. The required artificial snow volume is projected to increase by 330% by the end of the century.

To better understand climate change effects and the boundary conditions for artificial snow production, Olefs, Fischer, and Lang (2010) analysed past trends using meteorological data of 14 Austrian climate stations. Technical specifications of snow guns were used to define a wet-bulb temperature threshold value of −2 °C for snowmaking and a relationship between wet-bulb temperature and snowmaking capacity. The number of snowmaking days per season decreased by 20–34 days for half of the stations in the period between 1979 and 2003.

Not many studies can be found dealing with the economic impacts of climate change on ski area operators in very much detail. While snowmaking potentials and requirements have been studied from a technical point of view, economic limits of snowmaking are