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The effects of climate change on alpine skiing tourism a European approach

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Abstract: In this paper we consider the effects of climate change for alpine skiing in Europe. For the analysis we propose a new model where we can take substitution effects between different areas and different behavioral adaptation strategies of tourists under changed climate into account. A result of the modeling is that the south western regions of the Alps are more strongly affected by climate change than the north eastern part of the Alps or Scandinavia**.**

Keywords: alpine skiing, winter tourism demand, overnight stays, climate change, behavior tourists

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Introduction

Tourism is an industry that is highly dependent on weather conditions. In this paper we consider a type of tourism that is especially dependent on weather namely alpine skiing. With climate change it is expected that snow reliability of ski areas will be deteriorating. The aim of this paper is to discuss possible implications of climate change on the distribution of alpine skiing tourists across Europe. The main focus is on analyzing possible substitution between different alpine skiing areas and the effect of different behavioral adaptation strategies of tourists. We call this type of analysis, with an associated tool-box and data base for weather or climate sensitivities Weather Driven Demand Analysis (WEDDA). In this paper, in which we are interested, how the distribution of tourists among the different European destinations will evolve due to climate change, we use the WEDDA-Regional Distribution Model (RDM) described below. The WEDDA-RDM is a multi-destination and multi origin model for the estimation of shifts in overnight stays under a changed climate. WEDDA-RDM is used in (summer paper) to study the effects of climate change on beach tourism.

Effects of climate change on alpine skiing tourism are already studied in several papers, but most papers do not take substitution effects between different ski areas into account. We can distinguish between papers that only consider the physical effects of climate change and studies that consider the effects on climate change on demand.

Papers that consider the physical effects of climate change usually use a measure for snow reliability that is then projected into the future. Beside papers that consider natural snow reliability only (e.g. König and Abegg (1997) or Moen and Fredman (2007), Tranos and Davoudi (2014)), other papers include artificial snow making in the evaluation of future snow reliability, (e.g. Scott et al. (2003); Hennessy et al. (2003); Scott, et al, (2006); Scott et al. (2007), Steiger and Mayer (2008); Bark et al. (2010); Teich et al. (2007) and Steiger and Abegg (2013)). There are some common conclusions of these studies: while natural snow reliability is predicted to deteriorate significantly in the future, for most areas artificial snow making might still be feasible in the next decades, but cost of artificial snow making will increase significantly which might be the main limitation of artificial snow making as an adaptation strategy.

Beside the effects of climate change on snow reliability also the implications on demand are important. An important question is how tourists will behave under a changed climate. Behringer et al (2000), Unbehaun et al (2008), and Pütz et al. (2011) for example use interviews with skiers to identify future possible behaviors. Although these studies do not use the same questionnaire, we can come to the conclusion that a majority of skiers would not abandon skiing but would change location and to a lesser extent also timing to more snow reliable destinations and times respectively. This suggests that when conditions for alpine skiing worsen in most areas, areas that can still provide acceptable conditions for skiing might profit from a warming climate.

Another approach is to consider the empirical connection between snow or more generally weather conditions and demand in ski areas. For demand basically two types of indicators are used: overnight stays in areas related to ski areas and skier days in a ski area. In the literature it is often stated that the influence of weather on skier days is higher than for overnight stays, since day tourists can easily react to changed weather conditions while booked ski holidays might not be canceled without costs (e.g. Steiger (2011)). Nevertheless if we think about the change in skier days as a proxy for the change in attractiveness for alpine skiing, we might conclude that in the long run the effects on a change in climatic conditions to overnight stays will be similar to the change in skier days for the short run, since tourists can react over time to the new conditions.

To evaluate the effects of a single extreme year as the proxy of future climate, the analog approach is used in Dawson et al. (2009) and Steiger (2011). Steiger (2011) shows that a snow scarce winter can significantly reduce overnight stays and skier days for low lying ski areas as well as for ski areas not equipped with sufficiently snow making facilities, while there is relative small or even positive impact for ski areas that can still provide acceptable snow cover. Further impacts for the entire province are significantly smaller than for an individual ski area. This supports the results of Unbehaun et al (2008) who predict that the first option for skiers is to search for more snow reliable areas.

Beside the analog approach there is a series of papers that consider time series models or panel data models to study the effects of climate on demand in ski areas (e.g. Fukushima et al., 2002, Moeltner and Englin, 2004, Hamilton et al. (2007), Similarly, Shih et al. (2009), Falk (2013), Klingmair (2011), Gonseth 2013, Töglhofer et al. 2011, Damm et al. (2014), Falk (2015)). The papers differ in location and used data while some papers concentrate on skier days others concentrate on monthly or seasonal overnight stays further different weather indices are considered in the models. Results on the elasticity of demand can change significantly between the different studies. A common feature is that the studies are concentrated on single areas or groups of areas, but no substitution effects are taken into account, i.e tourists abandon areas with insufficient snow conditions for areas with better conditions

A paper that takes this consideration into account is Pons-Pons-et al. (2012), where agent based methods are used to model daily visitations to different ski areas in Andorra. In the model skiers that face a closed ski area can decide if they would like to change to an open ski area or stop skiing; this leads to a redistribution of skiers in years with bad snow conditions.

In this paper we want to add a new approach to the estimation of effects of climate change on alpine skiing tourism. We want to use the different climatic conditions of different month to investigate the impact of different climatic conditions on overnight stays. These impacts are than used in the WEDDA RDM to estimate the shift in tourism demand for different destination regions. Note that while this method is not used for alpine skiing tourism, similar methods are used for tourism in general or summer tourism (e.g. Hamilton et al. 2005, Hein et al 2010 or Amelung and Moreno 2012). In this paper we further want to compare the effects of different adaptation strategies of tourists on the shift of overnight stays, especially we want to consider two adaptation strategies: First alpine skiing tourists can adapt to climate change by changing to more reliable ski areas. Second alpine skiing tourists can change from skiing to other activities. The method to implement the adaptation strategy in WEDDA-RDM is similar to Amelung and Moreno (2012).

In section 2 we provide description of our model as well as remarks on the estimation and usage. Further we provide details on the used data. In section 3 we show how well our model fits the data. In section 4 we provide results concerning future distribution of tourists. In section 5 we discuss the model and compare our results with results from other papers. Finally in section 6 we provide concluding remarks.

1 The used data and model

The ideas behind the model

1.1 MODEL DESCRIPTION

In this paper we want to predict the effects of a changed climate on overnight stays related to alpine skiing tourism. We want to predict the effects of a changed climate on overnight stays related to alpine skiing. Instead of the often used time series approach, that relates the history of individual ski areas to weather data, we use a more climate oriented method. Instead of comparing the effects of a year to year change of weather we want to compare effects of different climatic conditions in different months. The advantage of using different month is that we can observe the effects of different climate conditions on one ski area and on an average season. Further we will use the data from several ski areas to get impact function of climate on alpine skiing tourism. While it seems that this approach is not common for analyzing alpine skiing tourism there exist papers that use similar approaches to analyze the effects of climate change on tourism demand e.g. Hamilton et al (2005) for worldwide yearly overnight stays, Hein et al. (2010) for tourism in Spain, Amelung and Moreno (2012) for general tourism in Europe. Nevertheless to our knowledge this is the first paper that applies this methodology to alpine skiing tourism. Further, note that WEDDA-RDM is used in (summer paper) to predict the effects of climate change on summer beach tourism. Nevertheless, to keep the paper self-contained, we will repeat in this paper the general definition of WEDDA-RDM, but with a focus on alpine skiing tourism.

1.1.1 WEDDA-RDM

For a set of destination regions I, a set of months M and a set of origin countries O, the WEDDA-RDM predicts the shifts of overnight stays from a set of current climate indices C to a new climate index $\hat{C}$, where the number of overnight stays $ov_{i,m,o} = ov_{i,m,o}(C)$ are known under current climate C. The model is based on climate utility functions $RT_{i,m,o}(C)$ that depend on the destination country i, the month m and the country of origin o. In the model it is assumed that the probability that a tourist of origin country o spends an overnight stay in a region i and month m conditioned that it spends the overnight stay in a region out of the set of regions I and a month out of the set of month M is given by

$$p_{i,m,o}(C) = \frac{\exp(RT_{i,m,o}(C))}{\sum_{j\in I}\sum_{n\in M}\exp(RT_{j,n,o}(C))}.$$

Under a changed climate $\hat{C}$ the WEDDA-RDM predicts that overnight stays from origin country o are distributed according to $p_{i,m,o}(\hat{C})$ among the chosen set of destination regions I and months M, i.e

$$ov_{i,m,o}(\hat{C}) = \frac{p_{i,m,o}(\hat{C})}{p_{(i,m,o)}(C)} \cdot ov_{i,m,o}(C).$$

The utility function in the model is defined as

$$RT_{i,m,o}(C) = g_{i,m}(C) + \epsilon_{i,m,o} + N_{i,o},$$

where $\epsilon_{i,m,o}$ is a parameter that describes the attractiveness of a specific month m for the destination region i for tourists of origin o, $N_{i,o}$ is the attractiveness of the region for tourists of origin country o.

$g_{i,m}(\cdot)$ is the climate dependent part of the utility which will be explained later in more detail, and is referred to as impact function. While $g_{i,m}(\cdot)$ can be seen as external variable, $\epsilon_{i,m,o}$ and $N_{i,o}$ are chosen such that the probability that a tourist of origin country o spends an overnight stay in a region i and month m conditioned that it spends the overnight stay in a region out of the set of regions I and a month out of the set of month M is the share of overnight stays of observed overnight stays for the destination region and month, i.e.

$$p_{i,m,o}(C) = \frac{ov_{i,m,o}}{\sum_{j\in I}\sum_{n\in M} ov_{j,n,o}}.$$

Note that shifting from climate C to $\hat{C}$ the utility changes by $RT_{i,m,o}(\hat{C}) - RT_{i,m,o}(C) = g_{i,m}(\hat{C}) - g_{i,m}(C)$.

1.1.2 The climate dependence

The WEDDA-RDM uses different impact functions $g_{i,m}(C)$ for different types of destination regions and season. Currently the WEDDA-RDM uses four types of destinations regions: city regions, beach regions, ski regions and other regions (details on how the regions are allocated to the different destination types are given in section 1.2). Further the model distinguishes between the summer season (May to October) and the winter season (November to April). In this paper we concentrate on alpine skiing tourism, hence we will only apply the model for the winter season.

For ski regions in the winter season WEDDA-RDM Model uses the impact function $g_{i,m}(C) = g_{i,m}(SI_{i,m}, TI_{i,m}) = s_S(SI_{i,m}) + s_T(TI_{i,m})$, where $s_S(\cdot)$ and $s_T(\cdot)$ are continuous functions. SI respectively TI denote a snow respectively temperature index described below in more detail. (see section 1.2 for an exact definition). The functions $s_S(\cdot)$ and $s_T(\cdot)$ are estimated from a set of estimation regions $\tilde{I}$ and the month of the winter season $\widetilde{M}$ (November - April). We use a set of estimation regions $\tilde{I}$ and not all ski regions for the estimation of the parameter since not for all ski regions all overnight stays can be related to alpine skiing. The data was obtained from the corresponding National Statistical Institutes, this also means that the exact definition of overnight stays differs between different regions; further the size of the considered regions can vary significantly. This means that the absolute number of overnight stays of different regions is not directly comparable. Hence we decided to use only the share of overnight stays in a month $s_m^i = \frac{ov_{i,m}}{\sum_{n\in\widetilde{M}} ov_{i,n}}$ compared to other month in the season for the estimation of the impact function, i.e. we assume that

$$s_m^i \approx \frac{\exp(s_S(SI_{i,m}) + s_T(TI_{i,m}) + \epsilon_{i,m})}{\sum_{n\in\widetilde{M}} \exp(s_S(SI_{i,m}) + s_T(TI_{i,m}) + \epsilon_{i,n})}$$

Note that $\epsilon_{i,m}$ is not known. If we set $\epsilon_{i,m} = 0$ for the estimation, we would assume that there are no common patterns in the distribution of overnight stays for all destination regions. This might not be true, since for a given origin country there might be preferences to make holidays in a certain month independent of the climate in the destination regions (e.g Christmas). In the estimation of $s_S(\cdot)$ and $s_T(\cdot)$ we compensate for these effects by replacing $\epsilon_{i,m}$ with the term $A \cdot log(ROV_{i,m})$ where A is a parameter and $ROV_{i,m}$ is an index that relates to the attractiveness of the month for holidays (see section 0 for more details). For estimation of A, $s_S(\cdot)$ and $s_T(\cdot)$ we maximize the likelihood function of a multinomial logit model when $N_{i,o} = \epsilon_{i,m,o} = 0$ i.e we choose A, $s_S(\cdot)$ and $s_T(\cdot)$ to maximize.

$$\sum_{i \in I} \prod_{m \in \widetilde{M}} \left(s_m^i\right)^{\frac{\exp\left(A \cdot log\left(ROV_{i,m}\right) + s_S\left(SI_{i,m}\right) + \left(TI_{i,m}\right)\right)}{\sum_{n \in \widetilde{M}} \exp\left(A \cdot log\left(ROV_{i,n}\right) + s_S\left(SI_{i,m}\right) + \left(TI_{i,m}\right)\right)}}.$$

This defines the impact function. To estimate the continuous function we first generate basis function and write the continuous function as linear combination of the basis function. We extract the basis function from a general additive model with (basis function with 5 degree of freedoms) and quasipoisson link function were s_m^i is the dependent variable and the model formula is given by $s_m^i \sim A \cdot \log(ROV_{i,m}) + s_S(SI_{i,m}) + s_T(TI_{i,m})$.

For other types of regions and seasons we use the same method with the exception that we replace $g_{i,m} = s_S(SI_{i,m}) + (TI_{i,m})$ by $g_{i,m} = B \cdot CI_{i,m}$, where $CI_{i,m}$ is a climate index that is indented to describe the effects of light outdoor activities and B depends on type of the destination region. The climate index $CI_{i,m}$ consists of two sub-indices (scores).

- Temperature score: The temperature score depends on the temperature it is monotone increasing until a point 25.3 ° C and monotone decreasing afterwards (see Figure 1). The score is estimated with the help of visitor numbers of an Austrian cable car (that is not used for alpine skiing). It can be seen as an estimate for the suitability of a climate for light outdoor activities.
- Sunshine score: The sunshine score evaluates to 100 when cloud cover is less than 25% and then decreases linearly to 0 (100% at cloud cover) (compare Rutty 2009).

The climate index is $25 + 0.5 \times$ temperature score $+ 0.25 \times$ sunshine score.

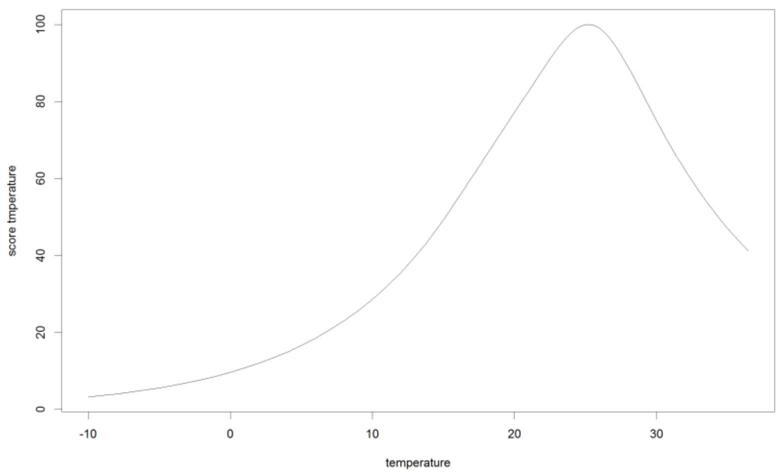

Figure 1 temperature score used in the climate index for regions that are not ski regions.

Application of the model

To apply the WEDDA-RDM we have to choose a set of origin countries O, a set of destination region I and a set of month M.

As origin countries we use the countries AT, BE, BG, CH, CY, CZ, DE, DK, EE, EL, ES, FI, FR, HU, IE, IS, IT, LT, LU, LV, MT, NL, NO, PL, PT, RO, SE, SI, SK, UK, RU, US, CN and JP. In the results section we will only present the total number of overnight stays, therefore we assume that the relative change in total number of overnight stays is the same as for the sum of overnight stays from the considered origin countries.

The actual choice of sets I and M determines how we assume that tourists behave under a changed climate, or in other word determines how the tourists adapt to a changed climate in the model. So the choice of sets I and M can also be interpreted as adaptation strategy of tourists towards a changed climate. In general the set I will consist of a set of comparison region and the considered region. Note that with this method we can also provide changes to regions that are not in I.

We have the following options to choose the set of destination regions I:

- We can choose I as only the considered region, meaning that tourists do not change the destination region (location conservatives).
- We can choose I as the regions with the same type this means that tourists might change the destination but will not change the type of their holidays, e.g. alpine skiing is not exchanged with city trips (activity conservatives).
- We can choose I to consist of regions of any type, this means that when climate condition change tourists might also consider changing the type of their holidays, e.g from city to beach (type flexible).

For choosing the set of month M we have the following options:

- We can choose as M only the considered month m. This means that tourists will not consider to change the timing of their holidays (time conservatives).
- We can choose M as the considered season, meaning that tourists consider shifting their holidays inside the season but do not for example consider to change from summer holidays to winter holidays (season conservatives).
- We can choose M as all month of the year (time flexible)

In this paper we will not present results for all possible sets I and M we will rather concentrate on two different sets.

We only want to consider regions as comparison regions that can also be associated with tourism. These regions we will call touristic regions (for an exact definition see section 1.2). Using touristic regions as comparison regions, means that tourists, when changing location only consider regions where there is already a certain amount of tourism. As comparison regions we use either the set of touristic regions that are also ski regions or the set of touristic regions of any type (see Figure 1.2). When we use ski regions that area also touristic regions as comparison regions, then the total number of overnight stays in ski regions is the same as in a world without climate change. Hence we are only comparing ski regions amongst each other and there will be ski regions that gain overnight stays while others will lose them. As set of month we use the winter season, i.e we assume that tourists might change to month with better conditions but do not change, for example to the summer season.

This means that we assume that tourists adapt to a changed climate by either changing to destination region (or time) where conditions for alpine skiing still acceptable or in the second case that they might also change do different type of tourism, e.g. city tourism.

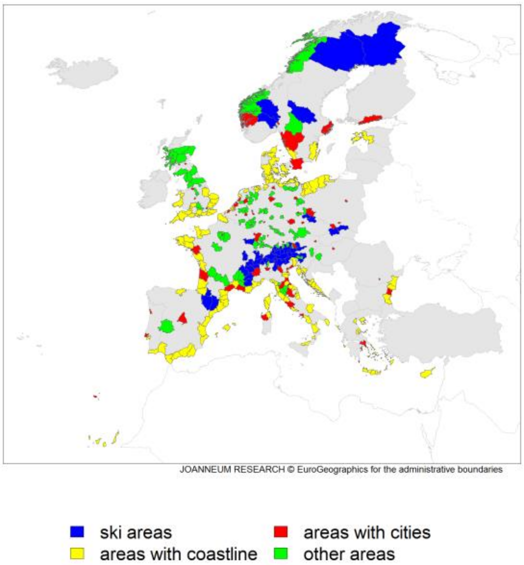

Figure 1.2 The set of regions I that are used for the estimation of the effects of climate change for alpine ski tourism. Blue ski regions, red city regions, yellow beach regions, green other regions.

1.2 DATA

Climate data

The used climate data for the calibration for ski regions as well as for the forecast of climatic effects for all regions were taken from the FP7-Project IMPACT2C. We will only provide a short description of the data. More details on the used climate data can be obtained from Damm et al (2015). The data on temperature is taken from E-OBS (Haylock et al. 2008) version 9 with an elevation adjustment applied. For values of SWE E-OBS data was used to force the hydrological model VIC (Liang et al. 1994) to evaluate SWE at different elevation bands and the band next to the minimal elevation of the ski area was used in the calculations.

For the climate change periods data was taken from 11 GCM/RCP combinations (2 combinations for RCP2.6, 5 combinations for RCP4.5 and 4 combinations for RCP8.5). The output of the models was adjusted to the E-OBS observation, and SWE and Temperature were obtained in the same way as for the base period. From the climate models we use the relative change between the indices in the base period (1979-2009) to the climate change period (2035-2065). Since the used snow index for the calibration is derived from other observations and not directly observed, there are uncertainties in the values of the index.

For describing the climate condition we will use two climate indices. The first index SI is the percentage of days with a natural snow cover of more than 120 mm snow water equivalent (SWE) at the minimal elevation of the ski area. This approximately corresponds to 30 cm of snow depth, a snow depth that is often used as minimum snow depth to make skiing possible (e.g. Damm et al. 2014). This index provides the percentage of days that can be used for skiing under natural conditions. Note that nowadays artificial snow making is widely used and hence the index should be seen as an aesthetical index (snow cover also beside the slopes). An interesting observation is that for a majority of ski areas the SI index is higher in April than in January but overnight stays are higher in January than in April. On a first glance this would mean that better snow conditions measured by SI lead to less overnight stays. Explanations why there are less overnight stays in April although SI is better than in January might be: Although there is less natural snow in January artificial snow making can compensate for marginal snow cover; because of lower temperatures snow quality might be better in January than in April; there might be effects of competitions, meaning that when temperatures get warmer other activities get more attractive and reduce the demand for skiing; a further explanation is, that after a season of skiing tourists are already saturated with skiing or the budget for skiing is used up. Therefore we add a second climate index TI to capture some of these effects. TI is the sum of mean daily temperatures above 0°C in a month measured at the minimal elevation of the ski area. This index is roughly proportional to the amount of snowmelt for the considered month (compare Steiger and Mayer 2008). This index is a proxy for the needed amount of artificial snow, but also an indicator for snow quality since snow characteristics heavily depend on temperature. Both indices are calculated for individual ski areas and then aggregated to NUTS3 regions, where ski slope length is used to weight ski areas.

We should note that the used indices TI and SI are not the only possible climate variables to estimate the effects described above therefor we also tested similar indices. For SI we also considered percentage of days with SWE of at least 120 SWE and percentage of days with SWE of at least 4 mm SWE at the minimal, maximal and mean elevation of the ski area. For TI we considered the sum of main daily temperatures above 0°C in a month and days with temperature below -2 °C (a proxy for the number of days where snowmaking is possible compare (Steiger and Mayer 2008) at the minimal, maximal and mean elevation of the ski area. From all this combinations of SI's and TI's we took the one that minimized the residual mean squared error of the model.

For the calibration for regions that are not ski regions we use temperature, humidity, cloud cover from ERA-interim reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) (a global re-analysis product). We use the values for 12:00 UTC. With this index we calculated the daily CI and aggregated it to monthly values. For the calibration of the model parameters we use the average for the period 1990 to 2011. We use the period 1990-2011 since ERA-interim data is only available to us for the time span 1990 to 2013 and we did not consider the years 2012 and 2013 for the calibration since data of overnights stays were only available to us up to the year 2011 for a reasonable set of origin countries. For the application of the model we use the average monthly cloud cover (since cloud cover was not available from the data) for each region and temperature from the climate models (for temperatures below 26.7 this corresponds to the heat index).

Also for regions that are not ski regions we tested other indices namely a variant of the TCI of Mieczkowski (1985) and a version of the TCI and the used climate index where the weighted average is replaced by a weighted geometric average. The multiplicative structure of the geometric average implies that overriding effects are taken into account i.e. a cloudy day can override otherwise nice temperature conditions. For the three considered type of areas the considered climate index CI worked best.

Socio economic data

For the calibration of the model we need data for s_m^i. To get a plausible model special care is taken in the selection of NUTS3 regions on which the model is calibrated. In a first step we select the NUTS3 regions that contain ski areas with an overall slope length of at least 70km. From this regions we remove the regions AT323 (Salzburg und Umgebung), FR623 (Haute-Garonne, Toulouse), ITC11 (Torino), NO011 (Oslo) and NO051 (Hordaland, Bergen), which contain lager cities. Further we manually subtract NUTS3 regions which do not seem to have the typical guest structure of winter tourism, i.e. a peak in the winter season and a decline after the end of the winter season in April or May. With this method we have selected 48 NUTS3 regions depicted in Figure 1.3. We obtained monthly overnight stays for the selected NUTS3 regions from the corresponding National Statistic Institutes of Austria, Czech Republic, Finland, France, Germany (only for Bavaria and Baden-Württemberg), Italy, Norway, Slovakia, Slovenia, Spain, Sweden and Switzerland. We should note that the exact definition of overnight stays varies between the different countries. From these areas we calculate the average monthly number of overnight stays for the years with data (ranging from 9 years for Italy do 40 years for Austria). From this overnight stays we then calculated s_m^i as the relative share of tourists in month m compared to the months November-April.

Figure 1.3 4 Regions $\tilde{I}$ that are used for estimating the impact function $g_{i,m}(C)$ for ski regions and the winter season.

For the application of the model we need the number of overnight stays for each considered region i, month m and origin country o. Since this data is not available to us, we combine data from different sources to get an estimate of the number of overnight stays in a NUTS3 region and month with origin information. We combine data from three sources: From Eurostat we use monthly number of overnight stays with origin information for countries, yearly number of overnight stays for NUTS2 regions, and yearly number of beds for NUTS3 regions. From UNWTO we use yearly number of overnight stays with origin information. Further we use the data from the National Statistic Institutes. Details of the procedure are in the appendix of (summer paper). We derive the number of overnight stays for the years 1996 to 2011. Note that also Amelung and Moreno (2012) combine data from different spatial levels to get monthly distribution of tourists for NUTS2 regions.

Type of regions and other derived quantities

WEDDA-RDM uses different types of destination regions. We use the following procedure to identify the destination type of a NUTS3 region. A city region, is a region where more than 60 % of overnights are reported in cities or if there is no data on overnight stays for the cities in the region if at least 60 % of population lives in cities. For the overnight stays in cities we use URBAN audit data from Eurostat and for the number of overnights in the region we use the combined data as described above.

Beach regions are all NUTS3 regions that have a coastline, except for the following regions:

- city regions
- regions which have ski areas of at least 70 km combined slope length and are located in Finland, Norway, Sweden or United Kingdom
- regions where the maximal sea temperature (at 12 UTC) between 1990 and 2013 does not exceed 16°C. 16 °C is the lower bound for "neither warm nor cold bathing water temperature" in Table 1 of (Morgan et al. (2000))
- regions that lie too far north, i.e. in the NUTS2 regions Northern and Eastern Finland (FI1D), North Sweden (SE3),UK North East (UKC),UK North West (UKD), or Scotland (UKM).

Ski regions are regions which include ski areas of at least 70 km cumulative slope length and are not beach regions or city regions

Other regions are regions that are neither ski regions, beach regions nor city regions.

We say that a NUTS3 region is a touristic region if two out of the following three criteria are fulfilled:

- The region has more tourists than the average NUTS3 region.
- The region has more overnight stays per inhabitant than Europe.
- The region has more tourists than the average region in the same country.

For regions that are not NUTS3 regions we say that the region is a touristic region, respectively of a specific type, if the majority of beds in NUTS3 regions associated with the region are in a touristic region, respectively in a NUTS3 region of the specific type.

For the estimation of the impact function $g_{i,m}(C)$ we use an index $ROV_{i,m}$, that is a measure of the attractiveness of a month independent of climatic factors in the destination region. The idea behind $ROV_{i,m}$ is that if for example the sum of overnight stays in all destination regions is higher in December than in November, than we expect that for tourists from the considered origin country it is more attractive to make holidays in December than in November. As $ROV_{i,m}$ we use the share of domestic overnight stays for a month compared to the winter season (November – April).

Finally, to get an estimate for the number of future overnight stays from a given origin country, we use the above derived data to calculate the yearly number of overnight stays per inhabitant for the years 2000-2011. We relate this data to GDP per capita of a country. Since with a growing number of overnight stays per inhabitant the rate of growth of overnight stays might slow down, we assumed that the elasticity of overnight stays (per inhabitant) with respect to GDP (per capita) is decreasing with the number of overnight stays per inhabitant. With projections of GDP and population taken from the IIASA Database on SSP, we forecast future number of overnight stays for a given country. The increase in overnight stays is than distributed evenly among all regions and months, i.e. all regions are multiplied with the same factor, providing us with an estimate for the number of overnight stays under current climate.

In this paper we are interested in relative results, i.e. the change in overnight stays compared to a world without climate change. While the estimation of $N_{i,o}$, $\epsilon_{i,m,o}$ and the future number of overnight stays have significant impact on the absolute values of future overnights stays in a given region or month, the influence on relative results are significantly smaller, i.e. they only influence the weights of different regions and months in the comparison to each other. So the actual values of $N_{i,o}$, $\epsilon_{i,m,o}$ and the future number of overnight stays will have less influence on the results in this paper than the changes in the climate indices.

2 Results of calibration

After calibrating WEDDA-RDM we basically obtain the functions $s_S(\cdot)$ and $s_T(\cdot)$ that relate the climate indices to overnight stays (Figure 2.1). We can observe that the effect of the snow index ($s_S(\cdot)$) between 100% and 60% is linearly decreasing. The decline of utility between a value of 100% of snow cover and 60% is approximately 0.27 corresponding to approximately 31 % of decline in overnight stays. From an index of 60% to 30% the effect of the snow index on overnight stays is less which means that tourists seem to be indifferent for conditions in this region. Further overnight stays steeply decline when less than 30% percent of ski areas have a snow water equivalent of more than 120mm snow a decline from 30% to 0% is about 0.68 which corresponds to a loss of overnight stays of 50%. Further we can observe a nearly linear behave of the effects of the temperature index ($s_T(\cdot)$) on overnight stays it basically suggests that days with positive temperature are bad for skiing.

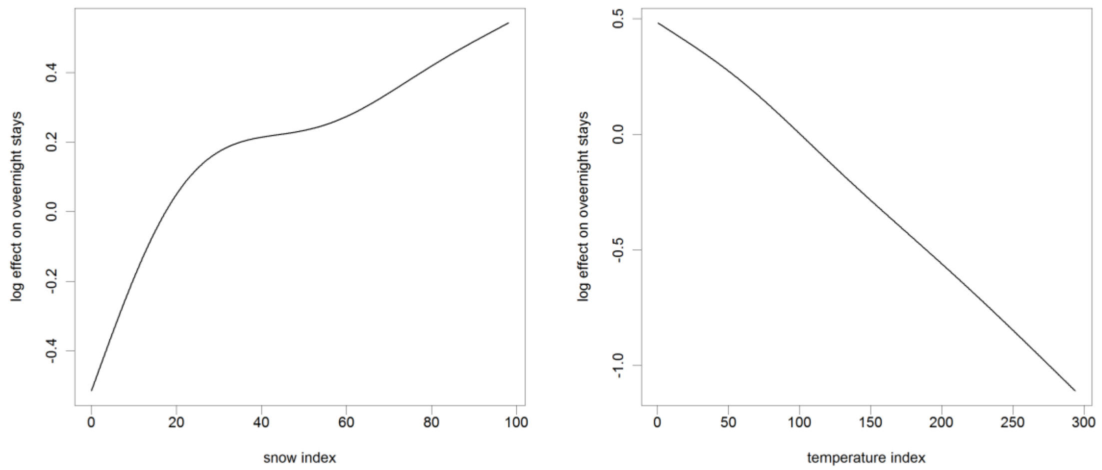

Figure 2.1 Effects of snow index on overnight stays ($s_S(SI)$) (left) and effects of temperature index on overnight stays ($s_T(TI)$) (right).

We want to provide some information on how well our model captures the observed overnight stays. The mean square error of the estimated shares over the variance of the observed shares i.e.

$$\frac{\sum_{i\in\tilde{I},m\in\tilde{M}}\left(\frac{\exp\left(A\cdot log\left(ROV_{i,m}\right)+s_S\left(SI_{i,m}\right)+s_T\left(TI_{i,m}\right)\right)}{\sum_{n\in\tilde{M}}\exp\left(A\cdot log\left(ROV_{i,n}\right)+s_S\left(SI_{i,n}\right)+s_T\left(TI_{i,n}\right)\right)}-s_m^i\right)^2}{Var\left(s_m^i\right)}.$$

This measure corresponds to the R^2 in classical regression models and evaluates to 0.82

Finally in Figure 2.2 we provide a plot of the share of overnight stays predicted by the model for each ski region in the Alps compared to the actual share of tourists. We considered to restrict to the Alps since for example the Scandinavian ski regions might have better snow conditions but they are not as good reachable for most skiing tourists as the regions in the Alps. Note that we have not included factors like size of NUTS3 regions reachability, quality of ski resorts and other non-climatic factors. In Figure 2.2 the triangles correspond to the NUTS3 regions (AT223 (Östliche Obersteiermark), AT226 (Westliche Obersteiermark), AT321 (Lungau), CH051 (Glarus), CH064 (Obwalden)), which are either relatively small or no classical touristic regions. On the other side plus stands for the NUTS3 regions: AT322 (Pinzgau-Pongau), AT335 (Tiroler Unterland), ITH10 (Bolzano-Bozen) and ITH20 (Trento). The area with the worst predicted share of these regions is AT335, considering the big gap between estimated and real share of overnights stays, it might be possible that for this region the quality of the snow cover data is insufficient. So if we subtract the 5 smallest and 4 biggest region we get a quite well explanation of the overnight stays related to climate variables.

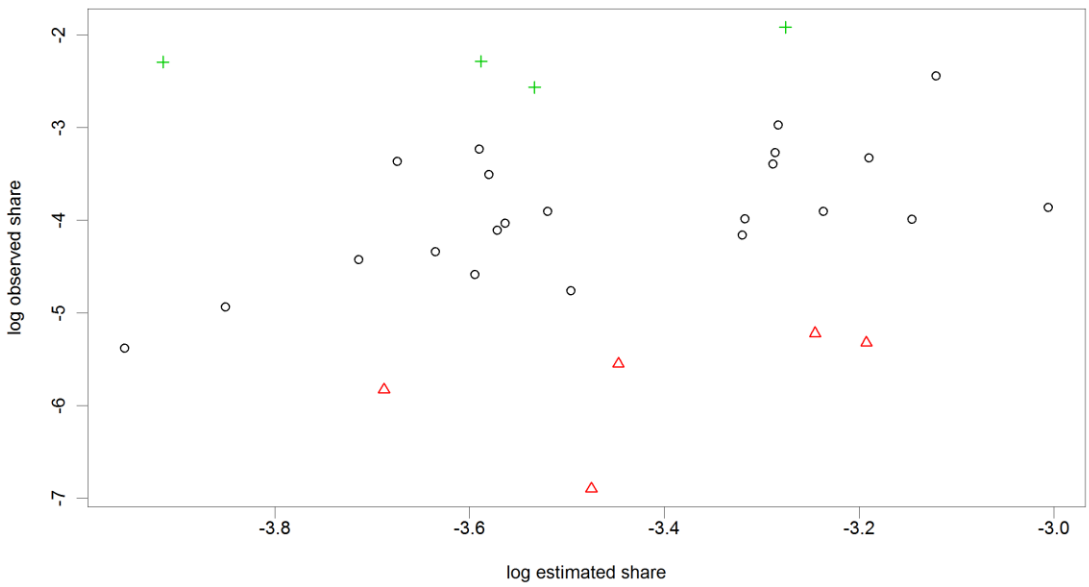

Figure 2.2 Observed share of overnight stays against estimated share of overnight stays in the log scale

3 Results

We will consider the period 2035-2065 and three RCP/SSP combinations namely RCP2.6/SSP1, RCP4.5/SSP4 and RCP8.5/SSP5 compare ToPDAd deliverable 2.1 for reason why we have chosen this RCP/SSP combination. In this paper we will consider the difference of a climate change scenario to a baseline scenario. i.e socio economic change for the period 2035-2065 with climate from the base period 1979-2009. We consider areas with a ski pist length of at least 70 km. Note that unlike for the estimation process we also include areas where overnight stays do not depend entierly on skiing. The results for these areas should be seen as the results of overnight stays for overnight stays associated with skiing.

To describe the climate potential of an area with respect to alpine skiing we use the exponential of the diference of optimal climatic conditions with respect to our model and observed climatic conditions, i.e.

$$\text{climate potential} = \exp[\mathrm{s_S(SI)} + \mathrm{s_T}(TI) - (s_S(100) + s_T(0))].$$

In Figure 2.1 we provide the avearge climatic potential for the month January to March and different countries, where results for Scandinavia and eastern Europe are aggregated. The errorbars indicate the range from different climate models. We can observe that under current climate the best conditions can be found in Scandinavia. With the exception of Germany, having worse conditions, and Spain having better conditions, the other regions have compareble conditions to each other. With climate change this general observation does not change. Losses in potential are between 10% and 24% for RCP2.6, 13% and 36% for RCP4.5 and 21% and 45% for RCP8.5 where genaerally losses are smallest for the scandinavian countries and highest for France, Italy and Spain. Further there is a significant uncertenty that comes from the use of different climate models.

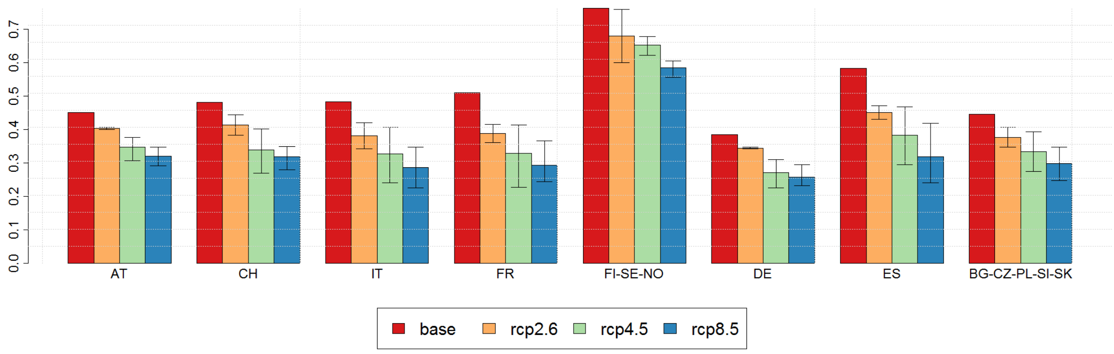

Figure 3.1 Average climate potential for the month January-March for the period 2035-2065 and the base period 1979-2009 average over climate models. (error bars indicate climate model uncertainty)

To discuss the effects of climate change on overnight stays in ski regions we only consider two extreme adaptation strategies of tourists. The first strategy is that tourists do not abandon alpine skiing, i.e. the number of overnight stays in ski regions is the same as without climate change. The second strategy is that the tourists also consider destinations that do not provide alpine skiing but stay inside the winter season. In Figure 3.2 we provide the results for the first strategy. The error bars again indicate the range of different climate models. In this case we can observe that especially France and Spain loose overnight stays while Austria Scandinavia and the eastern European countries win overnight stays. Results are between -6.2% and 2.4% for RCP2.5, -5.7% and 5.2% for RCP4.5 and -7.4% and 4.9% for RCP8.5. Interestingly for Spain and Scandinavia RCP2.6 is less favourable than the other RCP's with higher forcing. A possible explanation is that under RCP2.6 other regions are less affected than under the other RCP's and hence Scandinavia cannot gain as much from other regions, and similarly Spain loses more tourists to the other regions.

In Figure 3.3 we provide the results for the second strategy. In this case we can observe that all areas are losing overnights stays. An explanation is that with rising temperatures and reduced snow cover areas associated with alpine skiing lose attractiveness, while areas providing other touristic activities might not be negatively affected by a warming climate. Results are between -10.1% and 26.5% for RCP2.6, -14.2% and -34.6% for RCP4.5, and -22.5% and -44.2% for RCP8.5.

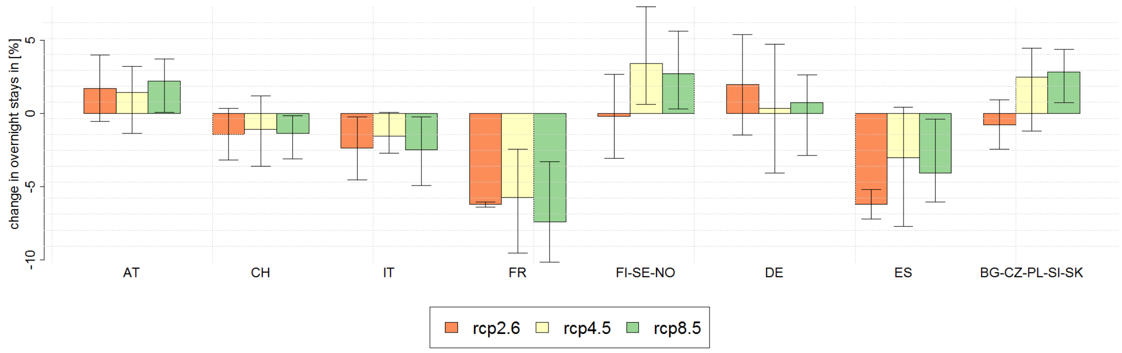

Figure 3.2 Change in winter overnight stays in [%] (2035-2065 vs. baseline) in skiing dominated regions when tourists stick to skiing; average over all climate models (error bars indicate the range of climate scenarios)

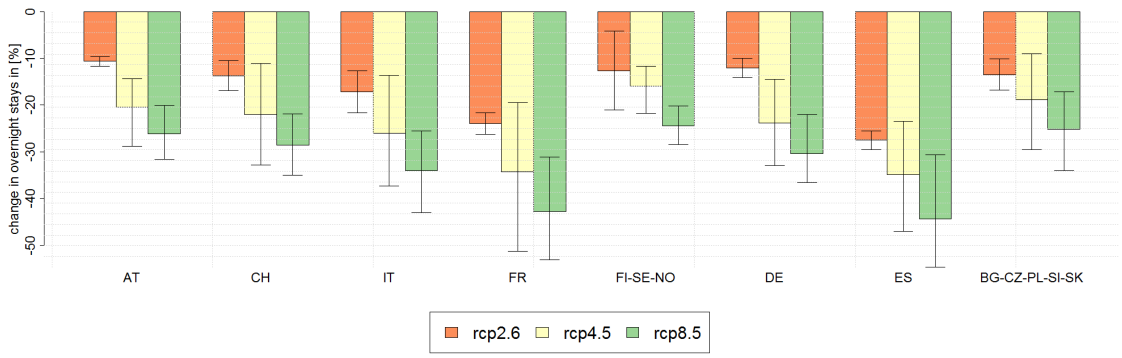

Figure 3.3 Change in winter overnight stays in [%] (2035-2065 vs. baseline) in skiing dominated regions when tourists do not stick to skiing; average over all climate models (error bars indicate the range of climate scenarios)

In Figure 4.4 we provide results for individual NUTS3 regions. Since results for different RCP/SSP combinations are qualitatively similar, we only present results for RCP4.5/SSP4 and period 2035-2065. The average over the used climate models is presented. When we consider the case that tourists do not abandon alpine skiing, in Scandinavia only two regions might lose overnights stays namely the areas NO034 (Telemark) and NO051 (Hordaland). Considering the alpine ark than the model predicts that south western regions are more affected than the north eastern regions. when we consider the case that tourists can change the holidays type than we can observe in Figure 4.4 right that all regions loose overnights stays.

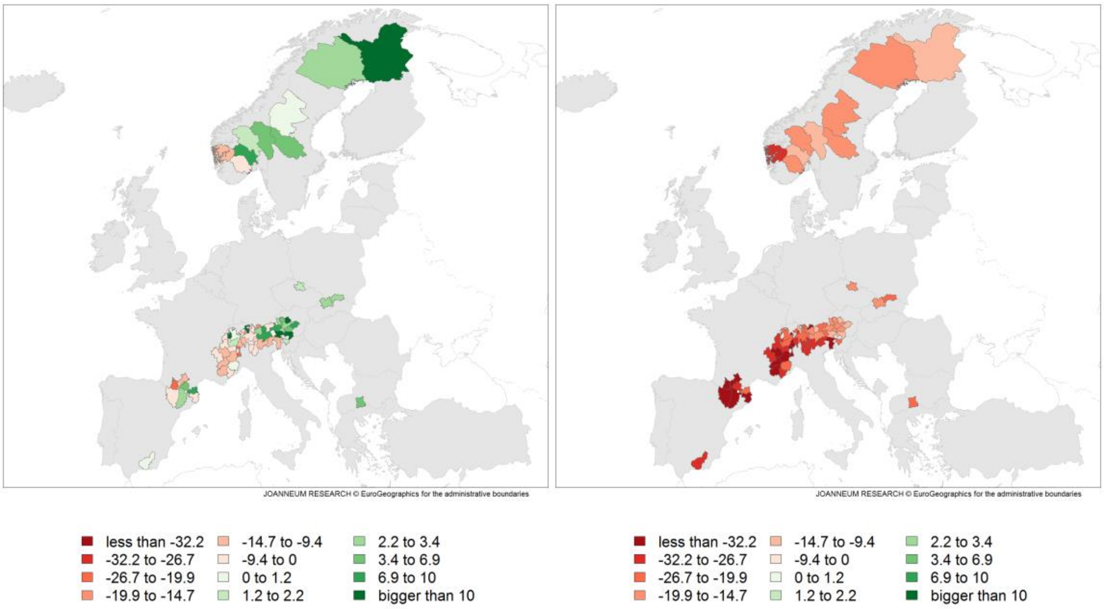

Figure 3.4 Change in winter overnight stays in [%] (2035-2065 vs. baseline) in ski regions for RCP4.5/SSP4, when tourists stick to skiing (left) or do not stick to skiing (right); average over all climate models.

4 Discussion

Since we provide a fairly new method we want to compare our results to results from other papers, that consider a similar area. Note that different papers use different climate data as well as demand side data to model the effects of climate change on skiing and hence results are not completely comparable. Falk (2013) considers overnight stays for the winter season for 28 Austrian ski areas. The results show that a 10% change of snow depth leads to a 0.7% change of overnight stays. Further rising temperature have a positive effect in the long run. (Falk 2010) uses a similar data set and comes to similar conclusions. Töglhofer et al. (2011) consider seasonal overnight stays for 185 Austrian municipalities; it is shown that a 1 standard deviation change in snow condition leads to 0.6% to 1.9% of change in overnight stays. In this study different snow indices are considered. Damm et al (2014) consider the effects of skier days for a Styrian ski resort. It is shown that for the season 2049/2050 under a A1B scenarios a reduction of 6%-28% has to be expected when taking artificial snowmaking into account and by 22%-64% when artificial snow making is not taken into account.

For Switzerland (Gonseth 2013) uses number of skiable days in a season combined with artificial snowmaking to predict the number of visits to 70 ski areas it is shown that a change in one skiable day relates to 0.41 %. to 0.25% change in skier visits, depending on the amount of artificial snow making.

Falk (2015) considers skier visits to six (high elevation) ski areas in France and shows that snow depth at a station outside the ski areas is a significant predictor for demand with a long run elasticity of 0.034. With the exception of Damm et al (2014) our model provides significant more impact of climate change on tourism than the other papers. There might be different reasons for the different outcome of the models. For example we use the same snow dependencies for all regions, which means that for some regions we might over or underestimate the effects of snow conditions. Maybe the biggest difference is the type of data that we use to explain the behaviour of ski tourists under changed climate. The cited studies with the exception of Damm et al.(2014), use the seasonal variation of overnight stays for calibrating the effects of climate change while we use the inter seasonal variation for the calibration. Hence our model explains the difference in overnight stays for different month e.g. the drop before and after the core season while the other models explain the fluctuation between the different years.

Finally we want do discuss some of the limitation of the used model. We have used NUTS3 regions for the calibration of the model. This is problematic since most considered NUTS3 regions contain different ski areas that have a different degree of snow reliability. Hence effects are only the average over different ski areas which might lead to an overestimation of effects of snow conditions on demand for snow reliable areas and an underestimation for not snow reliable areas. Further not all overnight stays in a NUTS3 region can be associated with alpine skiing. This can lead to an underestimation of the impact of insufficient snow conditions, i.e the model would predict a positive number of overnight stays, even if skiing is not be possible. To overcome these two problems one could use data on municipality level, where one uses only municipalities that can be related to a specific ski area or use directly data on ski ticket sales from different ski areas. For both methods data on European level is not available to us.

In our modeling approach we used the same connection between demand and climate models for all considered region. The idea behind this assumption is that when conditions are bad for skiing it does not dependent on the place. Nevertheless the actual used snow index (percentage of days with SWE bigger than 120 mm) is location dependent since the amount of needed snow depends on the ski area. In this respect it would be better to use a snow index that includes the percentage of usable ski slopes as well as the quality of the snow for skiing. Ideally this index would also include artificial snow making. Unfortunately we did not have this kind of data for our modeling, and it might get hard to obtain such data for a significant set of areas. Further one has to predict such an index under climate change conditions. Beside a snow index one should also include aesthetical (e.g. sunshine hours, snow beside the slope) and thermal (eg, wind chill, temperature) aspects of weather (compare de Freitas (2008)).

A week point in our model is that we do not consider the effects of artificial snow making in more detail. Töglhofer et al (2011) show that the dependence between natural snow cover and overnight stays decreased over time, which is attributed to artificial snow making, similar Gonseth (2013) shows that the amount of artificial snow making in a ski area influences the dependence between snow depth and overnight stays. We can see that although our model does not directly account for artificial snow making, it influences the model parameters via the data. Nevertheless the model could be improved by including artificial snow making already in the snow parameter (e.g. Damm et al (2014)).

5 Conclusion

In this paper we presented the first model that considers the demand for alpine skiing in Europe when taking substitution effects between different areas into account. We have seen that the regions in the south eastern parts of the Alps are more affected than the north western regions of the Alps. Our model shows that the future touristic demand for skiing areas heavily dependents on the adaptation strategy of tourists towards climate change. If the tourists do not stick to alpine skiing most areas will lose overnight stays were for some areas losses can exceed 40% compared do a world without climate change. If on the other hand tourists stick do skiing the negative effect of overnight stays might be reduced, and for larger areas losses might be bounded by 10%. The reality might be somewhere in between this two extreme cases.

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