Impacts of weather variability and climate change on tourism in Austria

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Abstract

This paper aims at quantifying the potential impacts of climate change on winter and summer tourism in Austria, using a two-step approach. Firstly, the historical weather sensitivity of tourism demand is quantified by means of dynamic, multiple regression models. Secondly, the estimated sensitivities are used to simulate a future baseline of tourism demand under constant climatic conditions and scenarios of tourism demand under four different climate change scenarios until 2050. A comparison to the baseline suggests negative impacts of climate change on winter tourism, whereas impacts on summer tourism are less clear in their direction and smaller in their extent.

Keywords: climate change, weather, tourism, Austria, impact

1 Introduction and literature review

This paper aims at modeling the impact of weather variability and climate change on tourism in Austria. By combining detailed estimations on the sensitivity of regional tourism demand to weather in the winter and summer season with a range of climate scenarios, this modelling can be seen as an important step towards closing the gap between climatological studies and studies on the macroeconomic effects of climate change.[1]

For winter tourism in Alpine countries, numerous studies have focused on understanding the overwhelmingly negative effects of winter temperature and precipitation patterns on the length of ski seasons, snow reliability and snow making conditions (e. g. König & Abegg 1997; Breiling & Charamza 1999; Abegg et al. 2007; Steiger & Mayer 2008). Some recent studies have also quantified the relationship between past weather conditions and the economic performance of ski areas (e. g. Hamilton et al. 2007; Dawson et al. 2009; Shih et al. 2009; Töglhofer et al. 2011) and found a clear (expected) relationship between snow or temperature conditions and the economic indicators examined.

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[1] Since the analyses outlined within this paper are part of the research project Adapt at funded by the Austrian Climate Research Program ACRP (see also http://www wegcenter at/econclim) some methodological decisions are owed to the task of quantifying climate change impacts on tourism in such a way that they become applicable in macroeconomic models (more specifically in computable general equilibrium models) and feedback effects on other sectors can be taken into account as well

For summer tourism research either focuses on the construction of indices which holistically deal with all the essential facets of tourism climate (e.g. Matzarakis et al. 2007; de Freitas et al. 2008) or on the impact of one or several climate elements on tourism demand (e.g. Hamilton et al. 2005; Agnew & Palutikof 2006; Serquet & Rebetez 2011). While it is proposed that hot summer temperatures could lead to a spatial shift of tourists to destinations located further north or at higher altitudes in Europe (IPCC 2007) and that Alpine countries could profit from that, there is no clear cut evidence of the size and direction of the total effect. In fact, even within a country gains in summer months, e.g. in Alpine regions, could be outweighed by negative effects, e.g. for urban areas.

This paper contributes to the mentioned literature by introducing a methodology and first results for estimating the total effects of climate change on different types of tourism on a regional scale. The remainder is structured as follows: In chapter 2 the used methods and data are separately discussed for (1) the identification of tourism region types, (2) the generation of region- and season-specific impact functions and (3) the estimation of climate change impacts. Following the same structure, results are then presented in chapter 3, while chapter 4 discusses the robustness of the approach and concludes.

2 Data and methodology[2]

2.1 Identification of tourism region types

As a hypothesis, specific tourism forms rely on different weather or climatic conditions, and they do so to a different extent. E.g. while a hot and dry summer might be good for lake tourism, this weather condition might be bad for urban or thermal spa tourism. Thus, climate change impacts are supposed to vary from tourism type to tourism type. Since Austria shows strong regional differences both, in the mix of prevailing tourism types and in climatic conditions, a mere analysis on net effects for the Austrian tourism sector could not account for these differences. On the other hand, an analysis with a too high spatial resolution, such as municipalities[3], cannot account for the fact that negative and positive impacts within a region can cancel out each other not only statistically but also due the interconnectedness of the regional economy, i.e. the hedging effect of common regional labor markets. With a correct analysis of the ensuing macroeconomic effects from climate change impacts as a focus, which is indeed one of the objectives of the above mentioned Adapt.at project, the NUTS 3 level[4] was chosen as the appropriate starting level for aggregating effects. This insures that counteracting impacts in municipalities that are

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[2] All calculations are carried out either by using the software packages SPSS or R

[3] For a clustering of Austria's municipalities according to their tourism characteristics see Prettenthaler & Formayer (2011)

[4] The NUTS classification is a hierarchical system introduced by Eurostat that divides up the economic territory of the EU (Eurostat 2011)

sufficiently linked in regional economic terms are only taken into account as a net effect that is relevant in macroeconomic terms. But this also grants enough differentiation according to the regional specialization of tourism types in Austrian regions. Therefore, Austria's 35 NUTS 3 regions are classified into groups as homogenous as possible with respect to regional tourism characteristics, such as tourism intensity and dependency, seasonal focus, feasible types of touristic utilization, relative importance of alpine skiing, and relative shares of the 4–5 stars segment[5]. This classification procedure is carried out by means of hierarchical cluster analysis (see e.g. Backhaus et al. 2003), using the squared Euclidian distance as proximity measure along with Ward's clustering algorithm. To avoid unintended unequal weighting of variables due to the high correlations observed within our dataset, the method of Principal Component Analysis (PCA) is used for pre-processing the original data. Furthermore, we make use of the "single linkage" clustering algorithm to identify eventual outliers.

2.2 Impact functions

Direction and extent of climate change impacts on tourism demand in a particular region depend on two factors: (i) the weather sensitivity of tourism demand in the considered region described by the impact function and (ii) the region's exposure to changes in the climate. Starting with the first of these two factors, we use past meteorological and tourism data to analyze the weather sensitivity of tourism demand for each of the tourism region types identified by cluster analysis. Since weather sensitive tourism forms related to the winter season (e.g. skiing tourism) generally require and benefit from completely different weather and climatic conditions than weather sensitive tourism forms related to the summer season (e.g. lake tourism), we analyze the weather sensitivity of tourism demand for winter season (November–April) and summer season (May–October) separately. Analyses concerning the winter half year are carried out on a seasonal basis, whereas investigations related to the summer season are done for each month separately since we expect the weather sensitivity of tourism demand to differ significantly between the single summer months.

In order to determine the region- and season-specific weather sensitivity of tourism demand, we make use of partial adjustment models – a special form of the general Autoregressive Distributed Lag (ADL) model (see e.g. Song et al. 2009) – where the dependent variable is explained by lagged endogenous variables as well as simultaneous exogenous variables. The usage of models including dynamic effects – such as the partial adjustment model – is generally preferred to static models when modeling tourism demand, since the former are less prone to spurious regression (Song et al. 2009). Within the analysis at hand the dependent variable is represented by the natural logarithm of overnight stays in the considered tourism region type during the winter season or a particular summer month, whereas one of the weather indices listed in Table 1 enters the model as independent variable. In order to prevent multi-

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[5] For a detailed description of the indicators used to represent the listed tourism characteristics see Köberl et al (2010)

Table 1: Tested weather indices.

Abbr.	Explanation
Weather indices used within winter season analysis:	
S_{mean}	mean depth of natural snow (in the region's ski areas) during the winter season [cm]
S_{day1}	days with at least 1 cm natural snow depth (in the region's ski areas) [days/winter season]
S_{day30}	days with at least 30 cm natural snow depth (in the region's ski areas) [days/winter season]
Weather indices used within summer season analysis:	
T_{mean}	monthly average of the air temperature (2 m above the ground) [°C]
R_{days1}	days with at least 1 mm precipitation [days/month]
R_{days10}	days with at least 10 mm precipitation [days/month]
R_{sum}	sum of precipitation [mm/month]

collinearity, only one weather index – a snow index in case of winter season analysis and a temperature or precipitation index in case of summer season analyses - enters the region- and season-specific regression model at a time.

Besides different weather indices also various model specifications are tested, differing in the number of considered lags of the dependent variable (between one and three periods) and the inclusion of a trend variable. Equations 1 and 2 illustrate the most parsimonious and the most extensive model specification tested for each tourism cluster in each considered season and for each considered weather index:

$$\ln(nights_{it}) = \beta_{i0} + \phi_{i1} \ln(nights_{t-1}) + \beta_{i1} W_{jit} / \mathrm{sd}(W_{j}) + \varepsilon_{t} \tag{1}$$

$$\ln(nights_{it}) = \beta_{i0} + \sum_{j=1}^{3} \phi_{j} \ln(nights_{t-j}) + \gamma_{i1} trend + \beta_{i1} W_{jit} / \mathrm{sd}(W_{j}) + \varepsilon_{t} \tag{2}$$

where ln(*nights*$_{it}$) describes the natural logarithm of overnight stays in tourism region type *i* at time *t*, WI_{jit}/sd(WI_{ji}) denotes weather index *j* in tourism region type *i* at time *t* divided by its standard deviation (i.e. the standardized weather index), β_{i0}, β_{i1}, $\o_{i1}$, $\o_{i2}$, $\o_{i3}$, and γ_{i1} represent the parameters for tourism region type *i*, and ε_{it} indicates the error term.

To select the most adequate model specification and the most appropriate weather index per considered region and season, the following two criteria are applied:

1. A model passes diagnostic tests (i.e. on the absence of residual autocorrelation and heteroscedasticity, the absence of functional form misspecification and the normal distribution of the residuals) at a 5% level of significance.
2. A model shows the smallest Bayesian Information Criterion (BIC)-value (see e.g. Verbeek 2008) of all tested models that fulfill the first criterion.

The methodology described above is applied on observational data[6] covering the periods 1973 to 2006 (winter season analysis) and 1977 to 2006 (summer season analysis). Original data on overnight stays (Statistics Austria) and on meteorological parameters (ZAMG) are partly available on a finer regional and temporal resolution than required for the analysis described above and are thus transformed to tourism region type level and monthly (in case of summer season analyses) or seasonal (in case of winter season analysis) scale.

The original snow data, which stems from a snow cover model developed by the ZAMG (see also footnote 8), is e.g. available for 550 selected ski area coordinates[7] (1 × 1 km grid cells) on a monthly scale. To translate the original snow data from grid cell level to tourism region type level and from a monthly to a seasonal base we proceed in three steps. The first step comprises the translation from grid cell level to ski area level by averaging snow data from coordinates belonging to the same ski area (see also Töglhofer 2011). Within the second step, the snow data is aggregated from ski area level to tourism region type level by forming the weighted average, where overnight stays in communities with a ski resort averaged over the winter seasons 2000 to 2005 serve as weighting factor. In a third step, the monthly snow data at tourism region type level is summed (in case of S_{day1} and S_{day30}) or averaged (in case of S_{mean}) over the months of the winter season.

Temperature and precipitation indices employed within summer season analysis are originally supplied on a monthly scale and at municipal level, which means that the meteorological conditions are reported for the centers of the communities, or in other words for those points, where the bulk of economic activities takes place. The aggregation of the original data from the municipal to the tourism cluster level is done by forming the weighted average, where the communal overnight stays averaged over the summer seasons 2000 to 2005 serve as weighting factor.[8]

2.3 Climate change impacts

In order to quantify the potential region- and season-specific impacts of climate change on tourism demand we proceed in three steps:

1. Generation of (future) baseline scenarios: The calibrated region- and season-specific impact functions are used to simulate how overnight stays could potentially evolve until 2050 if the climatic conditions remained the same as in the recent

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[6] Actually, the snow indices are not directly derived from observational station data, but from data generated by ZAMG with a simple snow cover model which uses daily mean temperature and precipitation sum to compute the snow water equivalent during snow accumulation and snow melt Snow height is a diagnostic output quantity applying a varying snow density in the course of the year (see Beck et al 2009) Note that for the sake of simplicity, snow indices are nevertheless labeled "observational" in this context, since they are calculated by means of observational data In contrast, we label snow data as "scenario data", when it results from running the snow cover model with scenario data on temperature and precipitation

[7] The classification of ski areas applied within the paper at hand follows that of Töglhofer (2011), who takes all areas with more than five transport facilities or at least one cable car into account and results in a total of 202 ski areas

[8] For more details on the original data and their transformation to the required regional and temporal resolution see Köberl et al (2011)

past. For this purpose, a climate baseline scenario, which exhibits the same mean and variability as observed in the climate normal period 1971–2000, is simulated for the scenario period 2007 to 2050 for each weather index finally selected to enter one of the impact functions. This is done by randomly drawing 44 times (without replacement) from the respective weather index. Mean and standard deviation of the resulting time series are then adjusted to the ones observed for the period 1971–2000[9].

2. *Generation of climate change scenarios:* Again the calibrated region- and season-specific impact functions are applied to simulate how overnight stays could potentially evolve until 2050. However, this time meteorological scenario data, generated by four different regional climate models (see below), are employed.
3. *Generation of impact scenarios:* In a final step, the deviation of overnight stays as simulated according to each of the climate change scenarios from overnight stays as simulated according to the future baseline scenario is calculated. Long-term averages of these deviations, e. g. over 30 or 40 years, represent the potential impacts of climate change on overnight stays.

Regarding the meteorological scenario data applied within the second step of the procedure described above, we draw on the outcomes of the EU FP6 Integrated Project ENSEMBLES (http://www.ensembles-eu.org), where a set of 19 high resolution regional climate model (RCM) simulations with a horizontal grid spacing of about 25 km and driven by eight different global climate models (GCMs) was produced (van der Linden & Mitchell 2009)[10]. Déqué et al. (2011) showed that both the choice of the GCM and RCM are major sources of uncertainty. To account for this uncertainty, we selected four RCMs, namely CNRM-RM4.5, ETHZ-CLM, ICTP-REGCM3, and SMHI-RCA, which are forced by four distinct GCMs, accounting adequately for uncertainty in boundary conditions and RCM model formulation[11]. Furthermore, in order to correct for errors of RCM simulations, a quantile based error correction approach (Quantile Mapping; QM) as proposed by Themeßl et al. (2010) is applied based on a 1 km interpolated observational grid for Austria (see Beck et al. 2009).

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[9] Note that, besides the meteorological data representing the climatic conditions of the recent past, these simulations of region- and season-specific overnight stays are solely based on the functional relationships and evolutions observed within the calibration period and describe one of a countless number of possible developments

[10] Since the choice of the GHG emission scenario is less important until the mid of the 21st century (Prein et al 2011), only the A1B emission scenario (Nakicenovic et al 2000), which is characterized by rapid economic growth and a balanced emphasis on all energy sources, was used to force the simulations

[11] The model selection is based on climate change signals for air temperature (2 m above ground) and precipitation amount between 1961–1990 and 2021–2050 over Austria, calculated separately for the summer and winter season The aim was to choose one model of each quadrant spanned by the median of the 19 air temperature and precipitation changes, in order to appropriately sub-sample the model-ensemble, considering warmer/drier, warmer/wetter, colder/drier and colder/wetter conditions than the ensemble median

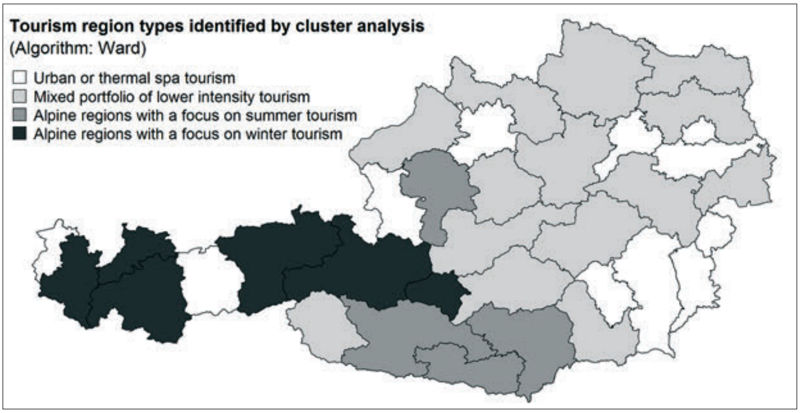

Figure 1: Cluster analysis result.

3 Results

3.1 Identification of tourism region types

Figure 1 illustrates the four tourism region types resulting from cluster analysis. The *Urban or thermal spa tourism* cluster includes nearly all NUTS 3 regions with federal capitals as well as some important thermal spa regions and is characterized by a high share of the 4–5 stars segment. The *Mixed portfolio of lower intensity tourism* cluster encompasses the by far largest number of NUTS 3 regions, but only accounts for about 14% of yearly overnight stays. The cluster labelled *Alpine regions with a focus on summer tourism* includes some typical lake tourism regions. Despite the clear summer focus, alpine skiing is of high importance for overnight stays during the winter season. The fourth tourism region type, *Alpine regions with a focus on winter tourism*, is characterized by the highest tourism intensity. Consisting of only six NUTS 3 regions it accounts for about 50% of yearly overnight stays.

3.2 Impact functions

The modeling and selection procedure outlined in chapter 2.2 results in 28 region- and season-specific impact functions[12]. Summarizing the results, Table 2 illustrates the weather sensitivity of overnight stays per tourism region type, which indicates

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[12] Since the focus is on the weather sensitivity of tourism demand, i e the relationship between overnight stays and the considered weather index, parameter estimates of control variables (lagged dependent variables and trend variable) are not pointed out explicitly in Table 2 Altogether, results show that 82% of the finally selected model specifications just include a one-period lag of the dependent variable, whereas the remaining 18% also consider a two-period lag Moreover, half of the region- and season-specific impact functions encompass a trend variable Region-specific impact functions for the winter season exhibit an adjusted R^2 of at least 0 9 Regarding the single summer months, 71% of the region-specific impact functions exhibit an adjusted R^2 of at least 0 7 (with 37% exceeding 0 9), whereas 25% show an adjusted R^2 below 0 5 This suggests that estimations for the summer season are less reliable than those for the winter season

Table 2: Weather sensitivity of overnight stays according to the region- and season-specific impact function.

	Urban/thermal spa			Mixed portfolio			Focus summer			Focus winter		
Nov-Apr	0.70	(S_{mean})	√	0.61	(S_{mean})	√	**2.82*****	(S_{mean})	√	**1.60****	(S_{mean})	√
May	**−2.00****	(T_{mean})	×	−1.07	(T_{mean})	×	−2.65	(R_{day10})	√	−2.33	(T_{mean})	×
Jun	**2.20****	(R_{day1})	×	1.37	(R_{day10})	×	1.01	(T_{mean})	√	2.14	(R_{day10})	×
Jul	−1.09	(R_{day10})	√	0.33	(R_{day10})	×	0.58	(T_{mean})	√	1.30	(R_{day1})	×
Aug	−0.58	(R_{day1})	√	**−2.01****	(R_{day10})	√	**−1.88***	(R_{day1})	√	**−2.99*****	(R_{day10})	√
Sep	−1.06	(R_{day10})	√	**−1.35****	(R_{day1})	√	−1.20	(R_{sum})	√	−1.44	(R_{day10})	√
Oct	−0.96	(R_{day1})	√	**−2.25*****	(R_{day10})	√	**−2.41***	(R_{sum})	√	1.60	(T_{mean})	√

*Significance codes: *** … 0.01, ** … 0.05, * … 0.1*

√ … *estimated weather index coefficient shows the at first sight expected sign*

× … *estimated weather index coefficient does not show the at first sight expected sign*

the percentage change in the regions' overnight stays due to an increase in the considered weather index by its standard deviation. In addition, the statistical significance of the weather index coefficient is pointed out along with the weather index finally selected to enter the region- and season-specific impact function and a symbol (√ or ×) indicating whether the estimated weather index coefficient shows the expected sign.

Region-specific weather sensitivities of overnight stays during the winter season show the expected (positive) sign – the better the natural snow conditions in a region's ski resorts during the winter season the higher the number of winter overnight stays. Statistically significant snow dependencies of winter overnight stays are only found in the cluster *Alpine regions with a focus on summer tourism* and the cluster *Alpine regions with a focus on winter tourism*, whereby results suggest winter overnight stays in the first-mentioned cluster, i. e. the *Alpine regions with a focus on summer tourism*, to show a higher snow sensitivity. This result is quite intuitive. While both tourism region types show a relative high importance of skiing tourism for winter overnight stays, the first mentioned cluster exhibits ski areas averagely typically located at lower altitudes, which tend to be more sensitive to snow conditions (see also Töglhofer et al. 2011).

Measured in terms of the number of region-specific impact functions that exhibit statistically significant weather index coefficients, results for the single months of the summer season suggest overnight stays to be most weather sensitive during August, followed by October (see Table 2). In the majority of cases, precipitation indices are chosen by the selection procedure to finally enter the region-specific impact functions of the single summer months. In particular, it is remarkable that all tourism region types (except the *Urban or thermal spa tourism* cluster) show some form of significant negative impact from rain starting with August, which might be well explained by the peaking hiking season during these months. Apart from two exceptions[13], all statistically significant weather index coefficients within the analyses of the summer months show the sign expected at first sight, i. e. a positive correlation in case of the temperature index and a negative correlation in case of a precipitation index. To conclude, there are two strong results: cold and rainy weather is good for the *Urban or thermal spa tourism* cluster especially in early summer season. The same weather is bad for more nature oriented forms of tourism at lakes and on mountains in the later summer season. And in between the two clear effects there is a rather indeterminate weather impact in July.

3.3 Climate change impacts

Figure 2 illustrates the third modeling step (section 2.3) by indicating the average seasonal deviation of overnight stays over the period 2011 to 2050 under the considered climate change scenario in the respective.

As illustrated in Figure 2a each of the four considered climate change scenarios indicates negative climatic effects on winter tourism demand in all four tourism region types. Measured in relative terms, winter overnight stays in the *Alpine regions with a focus on summer tourism* show the highest reductions due to potential climate change, whereas absolute decreases are the highest in the *Alpine regions with a focus on winter tourism*. From a statistical point of view, for these two clusters changes are significant, while this is not the case for the *Urban and thermal spa tourism* cluster and the *Mixed portfolio of lower intensity tourism* cluster. Compared to the winter season, results for the summer season (see Figure 2b) suggest the extent of potential climate change impacts to be smaller and in no case statistically significant. Indeed, for some tourism region types only the choice of the regional climate change scenario affects the direction of the reported impacts. Altogether this means that impact directions are less clear in the summer season than in the winter season.

4 Discussion and conclusions

In using a dynamic time series regression model and doing analyses for a comparatively long observational period, the present paper produces relatively robust estimates of the weather sensitivity of Austrian tourism, e. g. in comparison with frequently used static regression or correlation approaches. Furthermore, in order to account for the uncertainties related to climate change, four error-corrected regional climate model simulations which represent different levels of air temperature and precipitation changes are considered. Modelling clearly reveals that negative effects during the winter season dominate potential positive effects during the summer sea-

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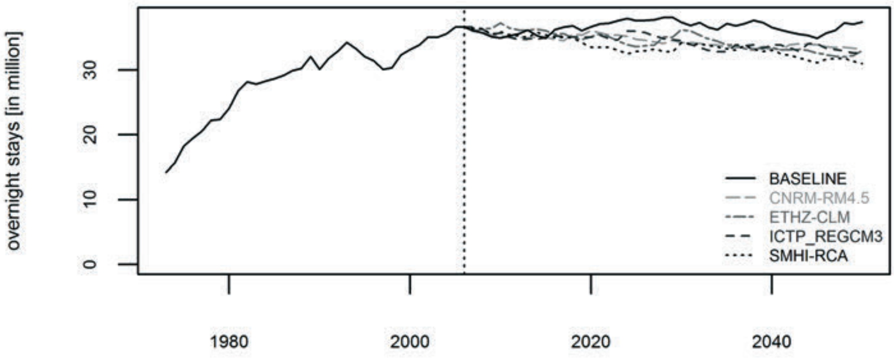
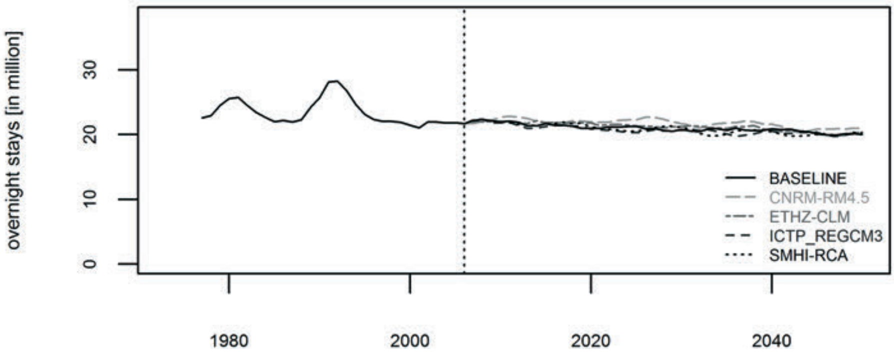
[13] But actually, there is some reasonable explanation for the two exceptions observed for the Urban or thermal spa tourism cluster In both cases, the considered weather index is highly correlated to the figures reported for the other three tourism region types As we expect vacations in the Urban or thermal spa tourism cluster to become more attractive relative to the other tourism region types when weather conditions in all tourism region types get less suitable for outdoor activities, the mentioned correlation might explain the – at first sight – unexpected signs



a) Winter season



b) Summer season

Figure 2: 40-year-averages (2011–2050) with respect to the deviations of overnight stays simulated under a climate change scenario from overnight stays simulated under a future baseline scenario; Average deviations from future baseline overnight stays are pointed out in absolute (left hand-side) and relative (right hand-side) terms.

son. Depending on the considered climate change scenario and the tourism region type, annual overnight stays during the period 2011 to 2050 are expected to be on average 0.75% to 16.55% lower than they would be if the climatic conditions remained the same as in the recent past.

Looking for practical implications of these results, we would argue that they are able to point out the macroeconomic pertinence of climate change for winter tourism in Austria and show that also the *Alpine regions with a focus on summer tourism* have to expect an important backlash from the negative impact during the winter season. Because of the aggregative, macroeconomic approach starting from the mesoscale of NUTS 3 regions, these results are not intended to inform decision making on the regional level like other studies (Prettenthaler & Formayer 2011 or Strasser et al. 2011). While these results do show the relative importance of the different impacts on the four characteristic tourism region types found for Austria, too strong implications should not be drawn for the following reasons:

There is some room for improvement in the statistical modelling approach (e.g. rethinking the equal treatment of statistically significant and not statistically significant weather index coefficients; using a more objective approach for the simulation of future baseline scenarios) and in particular in the inclusion of more elaborated weather indices. Indeed the choice and construction of adequate weather indices influences the accuracy of regression results.

Furthermore, it needs to be examined to what extent estimated weather sensitivities are representative under future climatic conditions, or in other words to what extent past sensitivities can be extrapolated to the future. While estimated weather sensitivities consider some degree of adaptation, namely the average level observed within the calibration period, especially for winter tourism there is some evidence that the weather sensitivity has decreased in recent years (see Töglhofer et al. 2011). Therefore, it seems that relatively sudden changes in adaptation levels (e.g. due to the massive introduction of artificial snow production in Austrian winter tourism in the 1990s, but also due to any kind of behavioural adaptations) need to be quantified for climate change impact assessment. This is statistically challenging and might be limited by data availability. In this respect, for an economic evaluation of climate change impact and adaptation it seems more straightforward and promising to incorporate changes in adaptation levels and respective changes in the weather sensitivity by a deterministic approach. Such an approach will have to be based on profound empirical data and needs to jointly investigate the cost and economic benefits of adaptation measures as well as their effect on the weather sensitivity of tourism.

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Artikel/Article: Impacts of weather variability and climate change on tourism in Austria 319-331