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A dynamic panel data analysis of snow depth and winter tourism

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ABSTRACT

This paper analyses the relationship between the number of overnight stays and different measures of snow depth based on panel data covering 28 Austrian ski resorts for the period 1986/87–2005/06. Using the dynamic heterogeneous panel data technique of Pesaran, Shin, and Smith (1999), we found a long-run relationship between the number of overnight stays, amount of snow depth, weighted real GDP per capita of the major countries of visitor origin, and price index of accommodation services. The long-run elasticity of overnight stays with respect to snow depth was 0.10. However, for high-elevation resorts the evolution of the number of overnight stays was independent of variations in snow depth. Furthermore, the long-run elasticity of the number of overnight stays with respect to weighted real GDP per capita of the country's visitors was much greater for high-elevation resorts than for low-elevation resorts. Finally, early Easter holidays were significantly and positively related to winter tourism demand.

1. Introduction

In Austria, much of winter sport focuses on snow-dependent activities such as alpine skiing, snowboarding and cross-country skiing. Snow is the primary input required for these winter sport activities, and a lack of snow due to high temperatures and/or low precipitation is seen as a great challenge for winter tourism in the Alps. An Intergovernmental Panel on Climate Change (IPCC) report (2007) revealed that average temperatures in alpine areas have been rising since the mid-20th century; this trend is likely to continue well into the future. The Organization for Economic Co-operation and Development (OECD) (2007) suggested that many ski resorts at lower elevations will face serious problems if the projected climate change scenarios are realised.

The potential impact of climate change on snow depth and cover and the resulting effects on winter travel flows have long been a concern for snow-dependent industries, since they are likely to suffer some of the largest negative impacts of climate change. Ski resorts at low elevations, such as in the Kitzbühel Alps, are particularly concerned about the effects of climate change.[1] During the exceptionally warm winter of 2006/07 the number of overnight stays at the 50 major ski resorts in Austria decreased by 2.5 per cent compared to the previous season. For some low-elevation ski resorts the decrease in ski demand was much more pronounced: The Kitzbühel area recorded a decrease of 10 per cent, while for Saalbach/Hinterglemm/Leogang the decrease was 4.5 per cent.[2] Anecdotal evidence suggests that for low-elevation resorts Austrian banks have become increasingly reluctant to provide loans for investments in hotels, buildings and apartment houses.[3] Tourism operators and ski lift operators have recognised the importance of snow conditions by providing weather and climate information in their tourism brochures (Gómez Martín, 2005).

Winter tourism demand depends not only on snowfall but also on a number of other factors, such as domestic and foreign income, prices, transportation costs and the timing of the Easter holiday. This paper analyses the relationship between the number of overnight stays and different measures of snow depth—controlling for other factors—using a panel of 28 Austrian ski resorts for the period of 1986/87–2005/06. Using a panel error correction model we investigated the number of overnight stays as a function of snow depth, real GDP per capita of visitor countries, prices of accommodation services and the early Easter holiday effect. The main advantage of panel data is that unobserved individual effects (such as mountain scenery and reputation) can be controlled. Another advantage is that it usually results in a large number of

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[1] The Kitzbühel Alps are located in the state of Tyrol in the western part of Austria.

[2] Saalbach is also part of the Kitzbühel Alps.

[3] For instance in the area of SkiWelt Wilder Kaiser-Brixental with slopes ranging between 600 and 1800 m above sea level.

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observations, increasing the precision of the estimates and reducing potential multicollinearity problems (see Baltagi, 2005; Wooldridge, 2002).

This paper contributes to the literature on tourism demand in several ways. Firstly, this was, to my knowledge, the first study using a dynamic, heterogeneous panel data technique to investigate the relationship between winter tourism demand and snow depth. As Song and Li (2008) suggested, panel data has rarely been applied to tourism demand.[4] Secondly, this dataset was much more detailed than that of previous studies with respect to the time span and the number of resorts included. Note that the sample represented almost 50 per cent of all overnight stays in the winter season in western Austria. Thirdly, we also tested for parameter stability of the relationship between tourism demand and snow accumulation.

There have been a number of studies related to this topic. One important strand of the literature focused on the supply side of the ski tourism industry by examining the implications of various projected climate change scenarios (based on the IPCC) regarding snow cover, snow depth, length of ski season and number of skiable days (see e.g. Scott, Dawson, & Jones, (2008); Scott, McBoyle, Mills, & Minogue, 2006, for the US; Breiling & Charamza, 1999, for Austria; Fukushima, Kureha, Ozaki, Fujimori, & Harasawa, 2003, for Japan; Koenig & Abegg, 1997, and Elsasser & Bürki, 2002, for Switzerland; Moen & Fredman, 2007, for Sweden; and OECD, 2007, for all alpine countries). These studies have found negative effects on alpine skiing, such as reduced season lengths and more erratic ski seasons, upward shifts in snowline elevation, reductions in snow-covered area, reduced snow depth, increased annual variability in snowfall, and fewer potential snowmaking days, with more pronounced effects at low-elevation resorts. The OECD (2007) suggested that for the European Alps the reliable line of natural snow will rise by 150 m on average for every 1 °C increase in temperature.[5] For Austria the OECD (2007) projected that a 1 °C rise in temperature would lead to a 23 per cent decline in the number of ski resorts with reliable snow cover. There is also expected to be a significant shift in travel demand from ski locations with low snow reliability to regions with higher snow reliability. Another result of these studies is that snowmaking is seen as a solution to offset the negative impact of climate change (Scott et al., 2008, for the US, Wolfsegger, Gössling, & Scott, 2008, for Austria).

Another strand of the literature focused on the demand side, i.e. how tourist flows respond to changing climate and weather conditions. In particular, these studies examined the impact of weather and climate factors on tourism flows or skiing demand while controlling for travel costs, prices and income of the visitor countries at different levels of aggregation, namely cross-country data and individual or resort-level data (see e.g. Englin & Moeltner, 2004; Fukushima et al., 2003; Hamilton, Brown, & Keim, 2007; Harrison, Winterbottom, & Sheppard, 1999; Lise & Tol, 2002; Maddison, 2001; Moeltner & Englin, 2004; Shih, Nicholls, & Holecek, 2009).

Using daily data on seven ski resorts in Japan, Fukushima et al. (2003) found that the annual number of skier visits was significantly and positively related to snow depth, but the correlation was significant at the 5 per cent level for only two resorts. Using daily data on weather conditions and ski lift ticket sales for two Michigan ski resorts for the period 1996–2002, Shih et al. (2009) found a positive and significant impact of snow depth on downhill ski lift ticket sales, while temperatures were significantly and negatively related to lift ticket sales. Using count data models on ski trips, Englin and Moeltner (2004) investigated the impact of snowfall and temperatures on the travel demand of skiers and snowboarders, controlling for participant income, prices and other factors. The authors found ski demand increased with amount of snow, with a diminishing effect. Furthermore, demand for ski trips was more responsive to changes in price than to changes in snow depth. The authors also found that an increase in temperature had a negative effect on the travel demand of skiers and snowboarders. The data were based on 131 college students visiting the Lake Tahoe area of Nevada and California for the year 1998. Based on a similar dataset, Moeltner and Englin (2004) showed that a skier's trip history and snow conditions (measured as cumulative water content of snowfall) had a significant and positive effect on ski resort choice based on a survey of individual skiers and snowboarders in the US. Average daily temperatures, however, did not appear to be a significant determinant of skier visits.

Using annual data for Scottish ski resorts for the period 1972–96, Harrison et al. (1999) found that total length of season showed an average decline of more than 10 per cent during the period, with more negative effects for the lower-elevation slopes. Hamilton et al. (2007) investigated the relationship between skier attendance and weather conditions (e.g. daily snow depth, snowfall and temperature) based on daily observations of two New Hampshire ski resorts covering seven ski seasons from 1999/2000 to 2005/06. Using dynamic time-series models, the authors found that visits to the ski areas were more influenced by snowfall in large population centres (Boston) than at the ski resorts themselves. In particular, the regression results showed that a one-centimetre increase in the previous day's snow depth at Bethlehem (near Cannon, New Hampshire) increased attendance by 11 skiers/snowboarders, while a one-centimetre increase in the previous day's snow depth in Boston increased predicted attendance by 18 skiers/snowboarders. Based on a survey of ski lift operators, Wolfsegger et al. (2008) found that snowmaking was the most preferred climate adaptation strategy of Austrian ski area managers. Furthermore, the authors found that the majority of the lift operators believed that further installations and adaptations of snowmaking facilities would enable them to maintain their ski business until 2050, regardless of the magnitude of climatic change. For a selection of Swiss ski resorts, Abegg and Froesch (1994) found that unfavourable snow conditions led to a substantial decline in the number of skier visits and overnight stays. For instance, in the Berner Oberland region in the winter of 1989/90, the number of overnight stays dropped 12 per cent compared to the preceding period (Abegg & Froesch, 1994). Butsic, Hanak, and Valletta (2008) assessed the impact of projected warming at ski resorts in western North America on house prices. The authors did not find an impact of snowfall accumulation on house prices.

A common feature in the literature was the finding of a nonlinear effect between weather conditions and tourism flows (see Englin & Moeltner, 2004, Maddison, 2001). Gössling and Hall (2006) pointed out that the assumption of a linear relationship was not appropriate in assessing the relation between weather conditions and/or climate change on travel flows.

The structure of this study is as follows. Section 2 introduces the empirical model, while Section 3 presents the data and descriptive statistics. Section 4 presents the empirical results and Section 5 concludes.

2. Empirical model

The number of overnights stays in the winter season depends not only on snow conditions, but also on a number of other factors.

[4] For recent exceptions in applications of dynamic panel models in the previous literature of tourism demand, see Kuo, Chen, Tseng, Ju, and Huang (2008), Garín-Muñoz (2006), Garín-Muñoz and Montero-Martín (2007) and Narayan (2004).

[5] Keep in mind that this is only a general estimate and does not refer to a specific period.

The independent variables commonly used are prices and income of the visitor countries (Crouch, 1992, 1995; Lim, 1997). Other explanatory variables are exchange rates, transportation costs (often proxied by the real price of oil), marketing expenditures and special events (Lim, 1997). Indicators of annual snow accumulation were the key variable in this study. Snow accumulation was measured as average snow depth during the winter season covering the period November–March. Timing of snowfall is also important to the performance of resorts. Breiling and Charamza (1999) suggested that adequate snow depth and conditions over the Christmas holidays and in February were essential for a good winter season. In order to account for early snow, one can also use average snow depth covering the period November–January. Econometric models relating tourism demand to weather conditions often include temperature as the most important weather parameter. Gómez Martín (2005) suggested that most skiers prefer sunny weather and pleasant temperatures. However, average temperatures were not significant in any of the regressions and were therefore not included in our final specification.

Empirical evidence for summer tourism showed that tourism demand was heavily dependent on GDP per capita in visitors' origin countries and on the relative costs of living at their destination (Garín-Muñoz & Montero-Martín, 2007). Economic theory states that people are more willing to travel and spend more nights as per capita income rises. The other variable is price. Prices have often been used relative to respective country of origin or the destination country's competitors, which in Austria's case are Italy and Switzerland. However, accommodation prices in South Tyrol (Italy) or Switzerland were not available. Note that the focus of this paper was not to assess price effects. Exchange rates were not considered as an explanatory variable because about 90 per cent of the visitors were from the Euro zone. Tourism demand also depends on the timing of the Easter holidays. Early Easter school holidays may stimulate winter tourism since alternative destinations on the Mediterranean Sea are usually cold and less attractive than winter destinations during such periods. In addition, early Easter holidays increase the chance of good snow conditions and sunny weather and thereby the number of overnight stays.[6]

The number of visitors is also determined by other factors, such as a resort's quality of infrastructure and accommodation, mountain scenery, attractiveness of a nearby old town centre and availability of après-ski options. These factors are difficult to measure and are generally not available. The panel nature of our data allowed us to control for some of these factors when they were time-invariant. Given the discussion above, the static demand model can be written as:

$$\ln Y_{it} = \beta_1 \ln \mathrm{SHX}_{it} + \beta_2 \ln \mathrm{GDP}_{it} + \beta_3 \ln P_{it} + \beta_4 D_t + \lambda t + \eta_i + u_{it},$$

where subscript i refers to the ski resort, ln represents the natural logarithm and t denotes the time trend. Y represents output, measured as the number of domestic and international overnight stays of visitors during the winter season. As an alternative dependent variable we used capacity utilization measured as the ratio of observed to potential overnight stays in per cent.[7] SHX is a measure of snow accumulation; and GDP is GDP per capita in constant purchasing power parities (ppp), weighted by the share of overnight stays of the 13 major countries of origin. P is the price index of accommodation prices and D is a dummy variable used to capture the early Easter holiday effect, taking the value 1 when the Easter school days in the main origin markets (Germany, Netherlands, Austria) start early in March and 0 otherwise. The parameters β_1 and β_2 are the elasticities of demand with respect to snow depth and real GDP per capita of the major visitor countries, respectively. u_{it} is the error term that is assumed to be independently and identically distributed with $N(0,\sigma^2)$, η_i are individual resort effects and t denotes the linear time trend.[8]

Following the literature we used a dynamic model to investigate the demand for winter tourism, measured as the number of overnight stays. It is well known that skiers tend to adjust their travel behaviour based on past snow conditions (Koenig & Abegg, 1997). Similarly, adjustment in the number of overnight stays to changes in real GDP per capita of the visitor countries is not likely to be instantaneous and may only partially adjust. In order to determine the lag order we applied a restricted-version simple ARDL (Autoregessive Distributed Lags) model because of the small number of time-series observations. The error correction reparameterisation of the ARDL model can be written as:

$$\begin{aligned}\Delta \ln y_{it} = {} & \alpha_i \Big(Y_{it-1} - \tilde{\tilde{\beta}}_1 \ln \mathrm{SHX}_{it} - \tilde{\tilde{\beta}}_2 \ln \mathrm{GDP}_{it} - \tilde{\tilde{\beta}}_3 \ln P_{it} \\ & -\tilde{\tilde{\beta}}_4 D_t - \lambda t \Big) + c_{1i} \Delta \ln \mathrm{SHX}_{it} + c_{2i} \Delta \ln \mathrm{GDP}_{it} \\ & + c_{3i} \Delta \ln P_{it} + \tilde{u}_{it} + \tilde{\eta}_i,\end{aligned}$$

where $\tilde{\beta}_1$ is the long-run elasticity of the number of overnight stays with respect to snow depth and α is the error correction coefficient measuring the speed of adjustment towards long-run equilibrium. If a long-run relationship exists, then the error correction term will significantly differ from zero. The intercepts and the short-run coefficients are allowed to vary across groups, but the long-run coefficients are constrained to be the same. A positive sign of the long-run elasticity is expected for GDP per capita, while a negative sign is expected for prices. In the empirical tradition of demand analysis a good is called a luxury if its income elasticity is greater than one. Because winter sport activities have a luxury character one can expect the corresponding income elasticity to be greater than one, especially for high-elevation resorts which often charge higher lift ticket prices. The key parameter of interest is the significance and level of snow depth. Note that we used various measures of snow depth. Since maximum snow depth is a function of time and the timing of snow is also important, we also calculated the average maximum snow depth for the months of November–March and November–January.

The relationship between overnight stays and snow depth can be expected to differ across ski resorts, reflecting differences in size, elevation and snowmaking capacity. We explicitly addressed the issue of heterogeneity by using two different dynamic panel estimation techniques, namely the mean group (MG) and the pooled mean group (PMG) estimators. The mean group estimator estimates separate regressions for each ski resort and calculates averages of the resort-specific coefficients. While consistent, this estimator is likely to be inefficient in small samples. More

[6] Another peak season is Carnival week, which also shifts according to the date of Easter in a given year. However, it is not possible to investigate the effect of the dates of Carnival week since Carnival is connected to Easter. Furthermore, Carnival week is in February or at the beginning of March, when snow conditions are usually excellent.

[7] I would like to thank an anonymous contributor for this suggestion.

[8] Time-specific effects can be captured by a time trend (linear or quadratic) or time dummies. In this application we included a time trend rather than time dummies since the number of individuals was relatively small compared to the number of time periods.

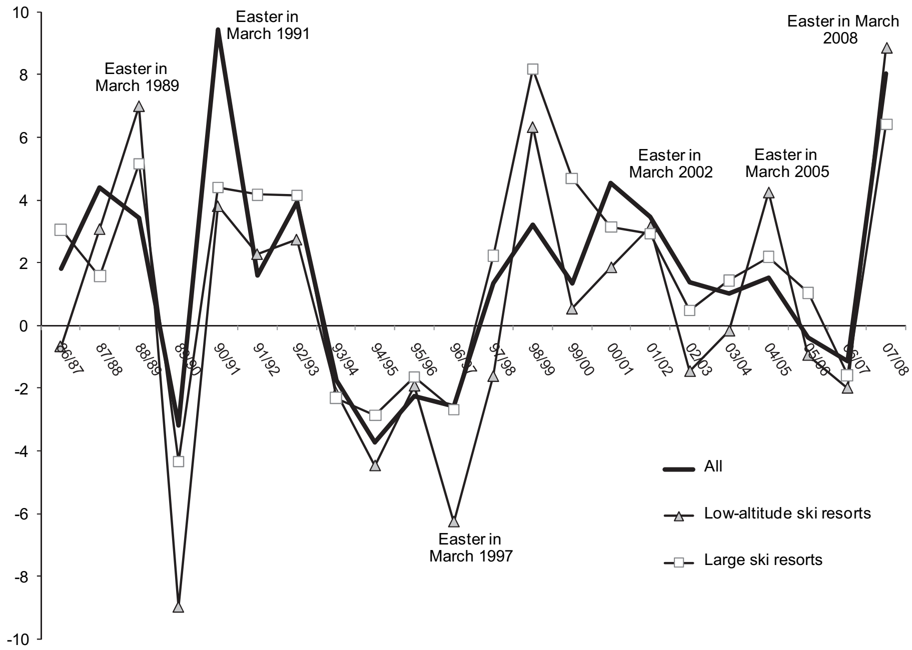
Table 1
Evolution of the number of overnight stays, weighted GDP per capita of the visitor countries, accommodation prices and measures of snow depth.

	# of overnight stays in 1000s	Capacity utilization in per cent, aggregated	Weighted real GDP of the main visitor countries (1986 = 100)	Price index of accommodation services (86/87 = 100)	Max. monthly snow depth	Average max. snow depth Nov.–Mar.	Av. max. snow depth Nov–Jan.	Easter holiday in March (yes = 1, 0 otherwise)
	Sum		Unweighted mean		(Unweighted) mean in cm			
85/86	17,563	42.6	100.0	n.a.	n.a.	n.a.	n.a.	1
86/87	17,876	37.5	101.6	100.0	115	74	60	0
87/88	18,244	41.2	105.0	102.1	151	72	39	0
88/89	19,222	41.1	109.1	105.5	76	50	43	1
89/90	18,098	41.1	114.2	109.1	73	39	22	0
90/91	19,033	40.2	118.6	116.1	76	50	47	1
91/92	19,635	43.6	120.7	121.6	116	78	68	0
92/93	20,422	43.8	120.3	132.4	81	53	43	0
93/94	19,967	43.1	123.6	140.8	81	55	49	0
94/95	19,284	42.3	126.3	148.2	102	60	46	0
95/96	18,919	39.1	128.3	150.8	59	43	37	0
96/97	18,204	37.0	131.4	155.2	79	56	57	1
97/98	18,499	39.1	134.7	156.8	64	37	33	0
98/99	19,726	40.0	138.2	157.3	148	86	56	0
99/00	20,377	41.4	143.1	159.8	118	84	71	0
00/01	21,032	43.3	145.1	163.2	86	49	31	0
01/02	21,659	44.9	145.7	166.1	66	47	44	1
02/03	21,722	43.6	146.0	168.9	79	42	30	0
03/04	21,988	45.4	148.1	171.2	99	67	51	0
04/05	22,556	44.0	150.6	175.3	108	65	41	1
05/06	22,624	44.4	155.5	178.1	124	86	69	0
06/07	22,225	43.7	159.8	181.2	n.a.	n.a.	n.a.	0
07/08	23,789	46.0	162.3	187.2	n.a.	n.a.	n.a.	1

Source: STAT Austria, Central Institute for Meteorology and Geodynamics Austria, author's own calculations. The number of ski resorts was 28, whereas the number of weather stations was 19. Data on weighted real GDP per capita of the major visitor countries referred to the respective calendar year.

importantly, simply taking the averages of the long-run parameters would increase the potential influence of outliers (Pesaran et al., 1999).

The PMG estimator allows for specific individual short-term adjustments and adjustment speeds while imposing cross-country homogeneity restrictions only on the long-run coefficients. If the long-run coefficients are equal across ski resorts the PMG will be consistent and efficient, whereas the MG estimator will only be consistent. If slope homogeneity does not exist, the PMG will be inconsistent and estimates will be biased downwards. The Hausman test can be used to test whether the PMG is consistent. Since low-elevation ski resorts are most vulnerable to climate change we provided separate estimates for low and high-elevation ski resorts. As the ski resorts differ greatly with respect to elevation,



Graph 1. Evolution of the number of overnight stays. Notes: The change in the number of overnights stays was measured as the unweighted percentage change as compared to the previous year. Source: see Table 1.

Table 2
Correlation coefficients between change in snow depth and change in overnight stays (*p*-value in parentheses).

	Total sample			Subsample: large ski resorts		
	Annual percentage change			Annual percentage change		
Annual percentage change in:	Overnight stays	Max. monthly snow depth	Average max. snow depth Nov.–Mar.	Overnight stays	Max. monthly snow depth	Average max. snow depth Nov.–Mar.
Max. monthly snow depth	0.089** (0.041)			0.130* (0.059)		
Average max. snow depth Nov.–Mar.	0.159*** (0.000)	0.864*** (0.000)		0.205*** (0.003)	0.872*** (0.000)	
Average max. snow depth Nov.–Nov.	0.246*** (0.000)	0.494*** (0.000)	0.772*** (0.000)	0.216*** (0.002)	0.519*** (0.000)	0.801*** (0.000)
# of obs.	532			209		
	Subsample: high-elevation ski resorts			Subsample: low–elevation ski resorts		
	Annual percentage change			Annual percentage change		
Annual percentage change in:	Overnight stays	Max. monthly snow depth	Average max. snow depth Nov.–Mar.	Overnight stays	Max. monthly snow depth	Average max. snow depth Nov.–Mar.
Max. monthly snow depth	0.068 (0.244)			0.134** (0.030)		
Average max. snow depth Nov.–Mar.	0.169*** (0.006)	0.886*** (0.000)		0.175*** (0.004)	0.849*** (0.000)	
Average max. snow depth Nov.–November	0.380*** (0.000)	0.584*** (0.000)	0.815*** (0.000)	0.196*** (0.001)	0.433*** (0.000)	0.741*** (0.000)
# of obs.	266			266		

Note :*p*-values in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

topography and solar exposure, we ran separate regressions for low and high-elevation ski resorts.

Before presenting the results of the panel error correction model, we will apply the panel unit root tests proposed by Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (2003) in order to find whether the series are nonstationary. In the next step, panel cointegration tests are applied.

3. Data

This study used annual panel data on 28 Austrian ski resorts for the period 1986/87–2005/06 resulting in 532 observations. The dependent variable was the number of overnight stays published by Statistics Austria. The number of overnight stays referred to the winter season (November–April) and covered hotels and similar establishments, private accommodation and apartments. In order to account for the fact that some ski resorts were connected to one other (either by bus or by lift) and shared the same lift pass, I aggregated the number of overnight stays across the individual resorts.[9] As an alternative dependent variable one could use capacity utilization measured as the ratio of observed to potential overnight stays and expressed as a percentage, whereas the latter is measured as the number of beds multiplied by the days of operation. However, the capacity measure was found to be quite noisy and showed an unexpectedly high degree of variability over time compared to the number of overnight stays. To reduce the noise in the data, smoothing was done by calculating the long-run trend in capacity.

The selection of ski resorts was based on their proximity to weather stations in terms of elevation, distance and data availability. The selected resorts were located in four Austrian provinces—Tyrol, Styria, Vorarlberg and Salzburg—and made up 46 per cent of the total overnight stays in this part of the country for the 2005/06 winter season. At 26 of the 28 ski resorts, alpine skiing was the most popular winter sport, while winter tourism at the remaining two resorts (i.e. Seefeld and Ramsau) depended mainly on cross-country skiing.

Data on overnight stays at the resort level were matched with weather data. The weather stations were selected based on their location at elevations close to the ski areas, and especially on their proximity to the base elevation of the ski stations because slopes at the lower resort elevations will be most affected by climate change. Some ski resorts were located several kilometres from the respective weather station (see Table A3 in the appendix for the weather stations and the corresponding ski resorts). The weather stations were located in the valleys and at elevations of 766 m and above, with the exception of the weather station at Rudolfshütte (2300 m). The ski resorts' data were matched with data from 19 weather stations.

Data on monthly snow depth and monthly mean temperatures were drawn from the annual yearbook of the Central Institute for Meteorology and Geodynamics (ZAMG Austria). Data on monthly snow depth from 19 weather stations were averaged from November to April. An alternative measure of snow depth was the average of the period November through January, which captured the effects of the timing of snow.

Real GDP per capita was measured as GDP in constant purchasing power parities per capita and was drawn from the OECD Economic Outlook database and the New Cronos database for the new EU member states. Weighted real GDP per capita was calculated as the weighted average of domestic real GDP per capita of the 13 most important visitor countries. The underlying weights were defined as the respective share of the sum of overnight stays for 13 visitor countries, measured as the sample midpoint value (1996). Table A2 in the appendix shows that German tourists had the highest share of overnight stays (58 per cent) based on the unweighted average across resorts, followed by Austrian (18 per cent), Dutch (11 per cent) and Swiss (4 per cent) visitors. The remaining countries (i.e. Belgium, Denmark, Finland, France, Hungary, Sweden, United Kingdom and the United States) accounted for 10 per cent of the overnight stays of the 13 major visitor countries. Finally, accommodation prices were drawn from Statistics Austria.

[9] Multi-resort areas include: Arlberg area, Gasteiner Valley, Kitzbühel, Lundgau area, Sportwelt ski resorts in the province of Salzburg, Schladming area, Ziller valley and Serfaus-Fiss-Ladis (see Table A1 in the appendix for the definition of the multi-resort areas).

Table 3
Panel error correction estimates of the determinants of number of overnight stays.

	(i)		(ii)		(iii)	
	coeff.	*z*-value	coeff.	*z*-value	coeff.	*z*-value
Mean group estimates						
Error correction term	−0.714***	−14.85	−0.700***	−14.69	−0.650***	−13.55
Ln max. snow depth Nov.–Mar., in cm	0.070***	2.81				
Ln average max. snow depth Nov.–Mar., in cm			0.050**	2.31		
Ln average max. snow depth Nov.–Jan., in cm					0.047**	2.21
Ln weighted GDP per capita at 2000 ppp	1.060***	5.21	1.088***	5.31	1.308***	6.12
Ln price index accommodation	−0.488***	−5.32	−0.516***	−5.47	−0.673***	−6.59
Dummy variable, early Easter holiday	0.017*	1.94	0.019**	2.29	0.019*	1.87
Short-run coefficients	Yes		Yes		Yes	
Constant	7.130***	8.75	7.032***	8.91	6.272***	8.57
Hausman test (*p*-value)	(0.00)		(0.00)		(0.04)	
# of obs. (# of ski resorts)	532 (28)		532 (28)		532 (28)	
Pooled mean group estimates						
Error correction term	−0.407***	−10.33	−0.371***	−10.45	−0.357***	−8.13
Ln max. snow depth Nov.–Mar., in cm	0.122***	8.07				
Ln average max. snow depth Nov.–Mar., in cm			0.100***	6.19		
Ln average max. snow depth Nov.–Jan., in cm					0.059***	3.97
Ln weighted GDP per capita at 2000 ppp	0.957***	6.57	1.056***	6.26	0.827***	5.18
Ln price index accommodation	−0.659***	−6.75	−0.813***	−7.13	−0.882***	−7.68
Dummy variable, early Easter holiday	0.044***	4.01	0.049***	3.93	0.021**	2.03
Short-run coefficients	Yes		Yes		Yes	
Constant	4.372***	10.1	4.111***	10.4	4.488***	8.57

Notes :***, ** and * denote significance at the 1, 5 and 10 per cent levels, respectively. The dependent variable is the logarithmic change in the number of overnight stays. The short-run coefficients have not been reported in order to save space.

Table 1 reports the evolution of the number of overnight stays aggregated across the selected resorts, average weighted real GDP per capita of the major visitor countries, the price index of accommodation services and different measures of snow depth. The total number of overnight stays of the resorts included in the sample increased from 17.6 million in the 1985/86 winter season to 23.8 million in the 2007/08 winter season. Similarly, capacity utilization increased from 42.6 per cent in the 1985/86 season to 46.0 per cent in 2007/08. However, the increase in the number of overnight stays is uneven over the sample period. Winter tourism demand increased from 1986/87 to 1991/92, with the exception of the 1990/91 season. From 1991/92 to 1997/98 one could observe a decline followed by a remarkable recovery until the extraordinarily warm 2006/07 winter season, when the number of overnight stays dropped by 1.8 per cent as compared to the previous year.

The number of overnight stays increased by 1.6 per cent per year on average for the sample period (see Table A1 in the

Table 4
Panel error correction estimates of the determinants of number of overnight stays for low and high-elevation resorts.

	Low-elevation resorts		High-elevation resorts	
	coeff.	*z*-value	coeff.	*z*-value
Mean group estimates				
Error correction term	−0.701***	−11.45	−0.699***	−9.27
Ln average max. snow depth Nov.–Mar., in cm	0.095***	3.79	0.006	0.17
Ln weighed GDP per capita at 2000 ppp	0.546***	3.05	1.631***	5.24
Ln price index accommodation	−0.533***	−4.38	−0.500***	−3.35
Dummy variable, early Easter	0.037***	6.76	0.002	0.13
Short-run coefficients	Yes		Yes	
Constant	8.796***	9.61	5.268***	4.67
Hausman test (*p*-value)	0.03		0.00	
# of obs. (resorts)	266 (14)		266 (14)	
Pooled group estimates				
Error correction term	−0.462***	−8.59	−0.413***	−5.52
Ln average max. snow depth Nov.–Mar., in cm	0.104***	6.04	0.025	0.92
Ln weighed GDP per capita at 2000 ppp	0.456***	2.71	2.582***	11.29
Ln price index accommodation	−0.667***	−5.85	−0.910***	−6.13
Dummy variable, early Easter	0.039***	3.24	−0.024*	−1.80
Short-run coefficients	Yes		Yes***	
Constant	6.167***	8.39	1.666***	5.17

Notes :***, ** and * denote significance at the 1, 5 and 10 per cent levels, respectively. Groups were selected based on the elevation of their highest slope. Ski resorts with slopes at 2000 m or higher were Gastein Valley, Galtür, Ischgl, Kappl, See, Kals, Matrei, Ziller valley, Soelden, Obergurgl, Kaprun, Sillian, Arlberg, Serfaus, Fiss & Ladis, St. Jakob St. Jakob/Defereggen valley and Warth. Low-elevation ski resorts included Bad Mitterndorf, Bad Aussee, Ehrwald, Lermoos & Berwang, Kitzbühel, Klösterle, Salzburg Sportwelt, Ramsau, Rauris, Schladming area, Saalbach, Hinterglemm & Leogang, Damuels, Mellau & Schoppernau, Seefeld, Lundgau area and Zell am See.

Table 5
Panel error correction estimates of the determinants of number of overnight stays for small and large ski resorts.

	Small ski resorts		Large ski resorts	
	Coeff.	*z*-value	Coeff.	*z*-value
Mean group estimates				
Error correction term	−0.750***	−11.51	−0.622***	−9.71
Ln average max. snow depth Nov.–Mar., in cm	0.016	0.62	0.103***	3.05
Ln weighed GDP per capita at 2000 ppp	0.784***	3.37	1.560***	4.53
Ln price index accommodation	−0.414***	−3.49	−0.674***	−4.51
Dummy variable, early Easter	0.017**	2.18	0.022	1.22
Short-run coefficients	Yes		Yes	
Constant	7.650***	7.59	6.077***	4.77
Hausman test (*p*-value)	0.07		0.55	
# of obs. (resorts)	323 (17)		209 (11)	
Pooled group estimates				
Error correction term	−0.451***	−7.17	−0.340***	−5.95
Ln average max. snow depth Nov.–Mar., in cm	0.061***	3.82	0.113***	4.41
Ln weighed GDP per capita at 2000 ppp	0.414**	2.40	1.464***	6.85
Ln price index accommodation	−0.600***	−4.91	−0.902***	−6.32
Dummy variable, early Easter	0.022*	1.96	0.052***	2.91
Short-run coefficients	Yes		Yes	
Constant	5.769***	7.28	3.600***	6.04

Notes: The group of large ski resorts included Gasteiner Valley, Ischgl, Ziller Valley, Soelden including Obergurgl, Arlberg region, Serfaus, Fiss & Ladis, Kitzbühel, Salzburg Sportwelt, Schladming area, Saalbach, Hinterglemm & Leogang and Zell am See.

appendix). As expected, the increase was more pronounced for high-elevation resorts, with an average growth rate of 2.2 per cent (unweighted averages), than for low-elevation ski resorts (0.4 per cent). This was consistent with the OECD's finding that there was a shift in overnight stays from regions with low snow reliability to higher regions. Graph 1 shows that the evolution in the number of overnight stays depended on the timing of the Easter holiday. There was some evidence that an early Easter holiday (i.e. starting in March) was associated with higher winter tourism demand (in particular in 1988/89, 1990/91, 2004/05 and 2007/08).

It seems obvious that part of the decline in the number of overnight stays was caused by snow deficiency during some seasons. For instance, the decline in tourism demand was most severe in the warm, snow-deficient winter of 1989/90, when demand dropped by 5.8 per cent as compared to the previous period. Note that the winter of 1989/90 was one of the seasons with the lowest snow depth, in particular for the third measure, namely average maximum snow depth between November and January (see Table 1). In contrast, the winters of 1998/99 and 2005/06 were associated with heavy snowfall. However, the snow depth number differed greatly depending on the definition of snow depth, i.e. on the number of months included in the calculation of average snow depth. During the record winter of 1998/99 the amount of snow depth was only slightly above the average when measured as averages for the months of November–January (unweighted average of 56 cm), since snow arrived late in February. However, the maximum snow depth over the period reached 148 cm on average.

Graphs A1 and A2 in the appendix show the evolution of the number of overnight stays and average snow depths (November–March) for three selected ski resorts (namely Kitzbühel, Saalbach-Hinterglemm and St. Anton am Arlberg). One can observe a decline in overnight stays during the three snow-deficient winters at the end of the 1980s and also in the 2006/07 season. However, other factors also seem to be important in explaining winter tourism demand over time.

In order to provide some initial evidence on the relationship between the number of overnight stays and snow depth, we provided pairwise correlation coefficients for both the total sample and for three subsamples (see Table 2). As expected, the annual growth rate in the number of overnight stays was strongly correlated with the change in snow depth. However, the magnitude of the correlations depended on how snow depth was measured. The correlation between the change in average snow depth in the first half of the winter (November–January) and the change in the number of overnight stays was higher than that of other measures of snow depth.

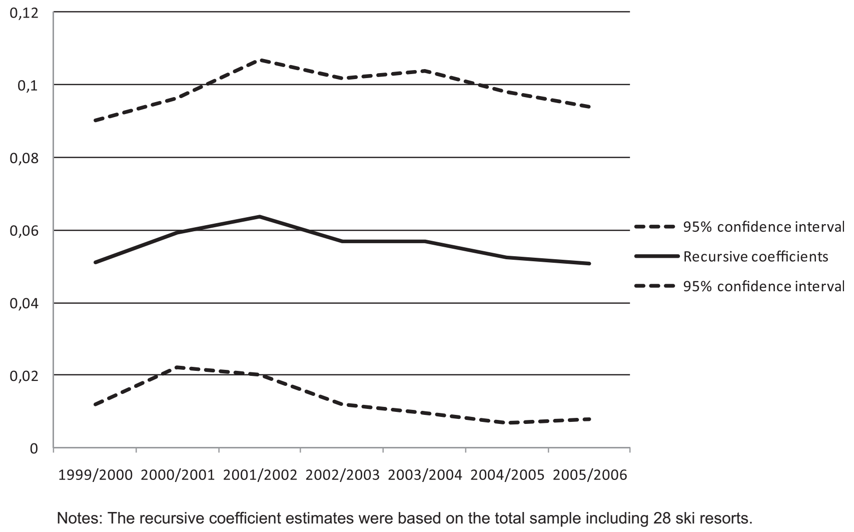
Furthermore, the degree of correlation was higher in the samples covering large lift-linked resorts and in those including low-elevation resorts. Note that the significance of the simple correlation coefficients tells us nothing about causal relationships between variables. In fact, regression analysis is the proper tool for estimating the partial effects.

4. Estimation results

Before reporting the estimation results, we applied panel unit root tests to the four variables. The results of the panel unit root tests of Im et al. (2003) and Levin et al. (2002) showed that weighted real GDP per capita, number of overnight stays and the consumer price index for accommodation services turned out to be integrated at the order of one (i.e. nonstationary with a unit root) in most of the cases, while snow depth was stationary.[10] However, snow depth was still included in the final specification because, according to Pesaran et al. (1999), both the PMG and MG approaches yielded consistent and asymptotically normal estimates of the long-run coefficients, even when one of the underlying explanatory variables was stationary.

After having found that all variables except snow depth appeared to be nonstationary, it was necessary to test the existence of a cointegrating relationship. Since the presence of a cointegrating relationship implied that the error correction term was negative and significant, a *t*-test could be used to test for no cointegration (Banerjee, Dolado, & Mestre, 1998; Kremers, Ericsson, & Dolado, 1992). In all cases we found that the

[10] These results are available upon request.



Graph 2. Recursive coefficient estimates of snow depth (MG estimates). Notes: The recursive coefficient estimates were based on the total sample including 28 ski resorts.

adjustment coefficient of the error correction term had a negative sign and was highly significant. This strongly indicated the presence of a cointegrating relationship between overnight stays, weighted GDP per capita, accommodation prices and snow depth. The estimated values of the error correction coefficient ranged between −0.65 and −0.71 based on the mean group (MG) estimator, which meant that the adjustment was complete after about one and a half years. We concluded that the adjustment speed was high. In addition, the residual-based panel cointegration test by Kao (1999) also clearly rejected the null hypothesis of no cointegration.[11]

Table 3 lists the results of the mean group and pooled mean group estimators. The Hausman test rejected the null hypothesis of homogeneity of the long-run parameters with *p*-values below 0.05 in all three specifications. Although the PMG estimates were rejected, we still included the results because the pooled mean group estimates were more robust with respect to outliers. The long-run coefficients of the weighted real GDP per capita of the major visitor countries and snow depth were positive and significant at the 5 per cent level using both the PMG and MG estimates. The long-run elasticity of overnight stays with respect to GDP per capita ranged between 0.83 and 1.31 depending on the estimation method and the specification. For the preferred specification (ii) and the MG estimator the long-run elasticity was 1.09. Using the MG estimator, the long-run elasticity of overnight stays with respect to snow depth ranged between 0.05 and 0.07 depending on the measure of snow depth (maximum monthly snow depth, average monthly snow depth), with 0.05 for the preferred specification. The latter finding indicated that an increase in snow depth of 10 per cent led to an increase of 0.5 per cent in the number of overnight stays.

In order to provide an indication of the magnitude of the effects, one could also calculate the effect of a one-standard-error increase in both variables. An increase of one standard deviation in the log snow depth led to an increase of about 1.6 per cent in the log number of overnight stays, while an increase of one standard deviation in log real GDP per capita led to an increase of 8.9 per cent. This implied that variations in real income were much more important than snow depth in determining the evolution of overnight stays.

Furthermore, the early Easter holiday dummy was significantly and positively associated with overnight stays, implying that early Easter school holidays stimulated winter tourism. Early Easter holidays in a given season raised the number of overnight stays by 1.9 per cent on average. The long-run elasticity of the price index ranged between −0.49 and −0.67 using the MG estimator, indicating that winter tourism was rather sensitive to changes in price.

Since the direction of causality between the number of overnight stays can go in both directions, I re-estimated the panel error correction model using the lag of log prices (as well as the lagged change in prices) instead of price in the same period.[12] Unreported results showed that the price coefficient remained negative and highly significant. Furthermore, there was only a small decrease in the price coefficient in absolute terms. It now ranged between −0.59 and −0.77 using the PMG estimator and between −0.56 and −0.78 using the MG estimator. These estimates are available upon request. The results of the dynamic panel data model using the alternative dependent variable (i.e. capacity utilization) led to similar results for the impact of snow depth (see Table A4 in the appendix). The long-run elasticity of capacity utilization with respect to snow depth was 0.042 using the MG estimator.

In order to account for possible parameter heterogeneity, one can divide the sample into two groups of resorts according to the elevation of their highest slope, with a threshold value of 2000 m. The results in Table 4 show some striking differences in the impact of GDP per capita of the origin countries and snow depth between low and high-elevation resorts. Specifically, while the long-run coefficient of snow depth was not significantly different from zero in the group of ski resorts with slopes above 2000 m, the coefficient was highly significant in the case of low-elevation ski resorts. This finding held for both the MG and PMG estimates. Furthermore, for high-elevation resorts one could observe a long-run income elasticity greater than 1, which one would expect since skiing at high-elevation resorts can be considered as a luxury good. Using the MG estimates, the long-

[11] These estimation results are available upon request.

[12] I would like to thank an anonymous contributor for pointing this out.

run elasticity of 1.63 for high-elevation resorts implied that an income increase by 1 per cent would lead to an increase in winter tourism demand by 1.63 per cent, holding all other factors constant. Furthermore, the early Easter dummy was significantly and positively associated with overnight stays in the sample of low-elevation resorts, while the effect was insignificant for high-elevation ski resorts.

In the next step we investigated whether the long-run effects were the same for small and large ski resorts. In order to divide ski resorts into large and small resorts we had to select an appropriate cutoff value. There were several ways to choose the cutoff value. One way was to use the median value of the length of slopes or the number of overnight stays. The advantage was that the median in such a small sample is less sensitive to outliers than the mean. The median of the length of slopes of the ski resort equal to 80 km was therefore used to differentiate between larger and smaller ski resorts. However, the group of ski resorts characterised by a lower than average (median) value of slopes included three ski resorts that were not fully lift-linked. I decided to exclude these three ski resorts because they differed considerably in their characteristics compared to the truly lift-linked ski areas. This resulted in 17 ski resorts in the large group and 11 in the small group.

Table 5 shows the results for the sample of ski resorts characterised by large and extensive slopes that were fully lift-linked. Again, one could observe a relatively large and highly significant coefficient of snow depth. For small resorts we did not find a significant coefficient of snow depth based on the mean group estimator. Again, one could see that weighted real GDP per capita had a positive impact on number of overnight stays, with a larger effect for large ski resorts than for small ski resorts. The results based on the preferred specification (the PMG estimates) revealed that an increase of 1 per cent in weighted real GDP per capita of the major visitor countries led to a rise of 1.46 in the number of overnight stays in the group of large ski resorts and of 0.41 in the group of small ski resorts.

A further robustness check concerned the stability of the snow depth coefficient over time. Some authors suggested that tourism demand was becoming increasingly independent of snow depth in the course of huge investments in snowmaking facilities; according to the Austrian cable car association, more than half the slopes were already outfitted with snowmaking facilities. Using survey data on Austrian lift operators, Wolfsegger et al. (2008) suggested that increased investment in snowmaking was the key strategy in adapting to climate change. In order to determine whether the relationship between overnight stays and snow depth was stable over time, we re-estimated the winter tourism demand model for the group of low-elevation resorts for various subsamples. Starting from the 1986/87 to 1999/2000 winter seasons, the sample was extended by one year to the 2005/06 period. The main hypothesis was that the coefficient of snow depth decreased over time. The recursive coefficient estimates in Graph 2 showed that the long-run coefficient of snow depth based on the MG estimator was rather stable over time. Generally, the stability of the regression coefficients could also be tested using the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests proposed by Brown, Durbin, and Evans (1975). Unreported results showed that the CUSUM statistics lay within the critical bounds of 5 per cent significance, implying that the null hypothesis—that all coefficients in the error correction model were stable—could not be rejected.

As a final robustness check, one could investigate whether the relationship between tourism demand and snow depth was nonlinear. The previous literature suggested that the relationship between tourism flows and temperature was likely to be nonlinear (see Gössling & Hall, 2006; Maddison, 2001). This could also hold for the relationship between snow depth and tourism flows, since significant amounts of snow depth are often accompanied by long bad-weather periods and increased avalanche risk for skiers. However, statistical tests using spline functions or the quadratic specification indicated no evidence of a nonlinear relationship.

5. Conclusions

This paper analysed the impact of snow depth on the number of overnight stays, controlling for weighted real GDP per capita of the visitor countries, price of accommodation service and the effect of early Easter holidays in March based on panel data covering 28 Austrian ski resorts for the period 1986/87–2005/06. Separate estimates were provided for low and high-elevation ski resorts, as well as for large and small ski resorts. In addition, we used different measures of snow depth. Results using dynamic panel data models (i.e. mean group and pooled mean group estimators) showed that the number of overnight stays increased as snow depth increased. There were differences in the effects between low and high-elevation ski resorts. Specifically, the relationship was only significant for low-elevation resorts with slopes below 2000 m, while at high-elevation resorts the evolution of overnight stays was independent of snow depth. Furthermore, recursive coefficient estimates evaluating the stability of snow depth elasticity showed that the snow depth coefficient had remained stable in recent years.

Overall, the magnitude of the impact of snow depth on overnight stays was low. One explanation is that a decrease in natural snow depth had little impact on winter tourism because of the large extent of snowmaking in Austria, where more than half the slopes were equipped with snowmaking facilities. For low-elevation resorts the results indicated that snow was still an important determinant of overnight stays despite increasing snowmaking capacity in recent years. Therefore, we do not expect the link between natural snow depth and winter tourism demand to weaken in future as a result of further investment in snow depth, since the level of snowmaking capacity is already very high at most low-elevation ski resorts.

Another important finding was the magnitude of the long-run effect of real income. A 1 per cent increase in weighted real GDP per capita of the major countries of visitor origin led to an average increase of 1.09 per cent in the number of overnight stays. However, income elasticity was much higher for high-elevation resorts than for low-elevation resorts, at 1.63 and 0.55, respectively. This implied that the economic recession in the most important origin countries (i.e. Germany and the Netherlands) as well as in the domestic market in 2009 and 2010 would hit high-elevation ski resorts harder than low-elevation ski resorts. Similarly, the economic recession would also harm large ski resorts more than small ski resorts.

In summary, this paper contributed to the existing literature on the impact of climate variability on winter tourism by providing long-run evidence of the effects of weather conditions on the number of overnight stays using a new and unique dataset. This is an important area of research since snow depth and snow cover are expected to change substantially in the next decades. In particular, ski resorts at low elevations are the most vulnerable to climate change. The findings indicated that the presence of natural snow still plays a key role in determining visitor numbers, particularly at low-elevation resorts. However, real income was much more important than snow depth in determining a sufficient number of visitors. The derived policy implications should be of interest to tourism operators, local communities, interested stakeholders, media representatives and visitors/tourists.

With regard to future research, applying panel data models to ski resorts in other countries could produce promising results. This would also allow comparisons of the results across countries. It would also be interesting to investigate the impact of snow depth on lift ticket sales rather than on the number of overnight stays. Lift ticket sales should be more responsive than the number of overnight stays to variations in snowfall. Our own evidence, based on annual reports, showed that in the extraordinarily warm 2006/07 winter season the reduction was more pronounced in terms of lift ticket sales and skier visits than overnight stays.[13]

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Appendix

Table A1
Descriptive statistics at the resort level.

Ski resort	Average annual growth rate of overnight stays in per cent	Average annual growth rate weighted real GDP of visitors countries in per cent
Arlberg (St. Anton, Lech & Zürs)	1.5	2.2
Bad Aussee	2.3	2.3
Bad Mitterndorf & Tauplitz	−0.3	2.3
Damuels, Mellau, Schoppernau	0.7	2.1
Ehrwald, Lermoos, Berwang	0.7	2.3
Galtür	1.8	2.1
Gastein Valley (Bad Hofgastein, Bad Gastein, Dorfgastein & Großarl)	1.0	2.3
Ischgl	3.8	2.1
Kals/Matrei	3.3	2.2
Kappl	2.7	2.2
Kaprun	1.7	2.3
Kitzbühel (Aurach close to Kitzbühel, Kirchberg in Tirol, Kirchdorf in Tirol, Kitzbühel, Jochberg & Reith close to Kitzbühel)	−0.6	2.4
Klösterle	1.3	2.2
Lundgau area (Mariapfarr, Mauterndorf & Sankt Michael/Lungau)	0.9	2.3
Ramsau	−0.4	2.2
Rauris	−0.4	2.2
Serfaus, Fiss & Ladis	3.7	2.2
Saalbach, Hinterglemm & Leogang	0.9	2.3
Salzburg Sportwelt (Altenmarkt/Pongau, Eben/Pongau, Filzmoos, Flachau, Kleinarl, Radstadt, Wagrain & Sankt Johann/Pongau)	1.7	2.3
See	3.1	2.2
Seefeld	−0.7	2.1
Sillian	6.6	2.4
Sölden & Obergurgl	2.7	2.1
St. Jakob (St. Jakob/Defereggen valley)	−0.1	2.1
Schladming area (Rohrmoos-Untertal, Schladming, Pichl-Preunegg & Haus)	1.3	2.3
Warth	2.1	2.1
Zell am See	0.9	2.3
Ziller valley (Aschau, Finkenberg, Fügen, Fügenberg, Gallzein, Gerlos, Gerlosberg, Hainzenberg, Hippach, Kaltenbach, Mayrhofen, Ramsau/Ziller valley, Zell am Ziller, Zellberg & Wald/Pinzgau)	4.0	2.2
Low-elevation ski resorts	0.4	2.3
High-elevation ski resorts	2.2	2.2
Large ski resorts	1.7	2.3
Small ski resorts	1.6	2.3
All ski resorts	1.6	2.2

Notes :Statistics Austria, SourceOECD and New Cronos, own calculations.

[13] Evidence based on annual reports revealed that Kitzbühel experienced a decrease in lift ticket sales of 20 per cent in the 2006/2007 season as compared to the previous season. The ski resorts Saalbach, Hinterglemm & Leogang reported a decrease in the number of skier visits of 18 per cent as compared to the previous winter season.

Table A2
Composition of the number of overnight stays by country of origin (percentages).

	Total sample	High-elevation resorts	Low-elevation resorts	Large resorts
Austria	18	11	24	20
Belgium	3	2	3	2
Switzerland	4	5	2	3
Germany	58	64	52	54
Denmark	1	1	1	2
France	1	1	1	1
Finland	0	0	0	0
Hungary	0	0	1	0
Italy	1	1	1	1
Netherlands	11	11	11	11
Sweden	1	1	1	1
United Kingdom	2	2	2	4
United States	0	0	0	0
Total	100	100	100	100

Notes :Data refer to the year 1996. Percentages are calculated for the major 13 visitor countries in terms of the number of overnight stays. Data are calculated as the unweighted mean across 28 resorts. Source: Statistics Austria, own calculations.

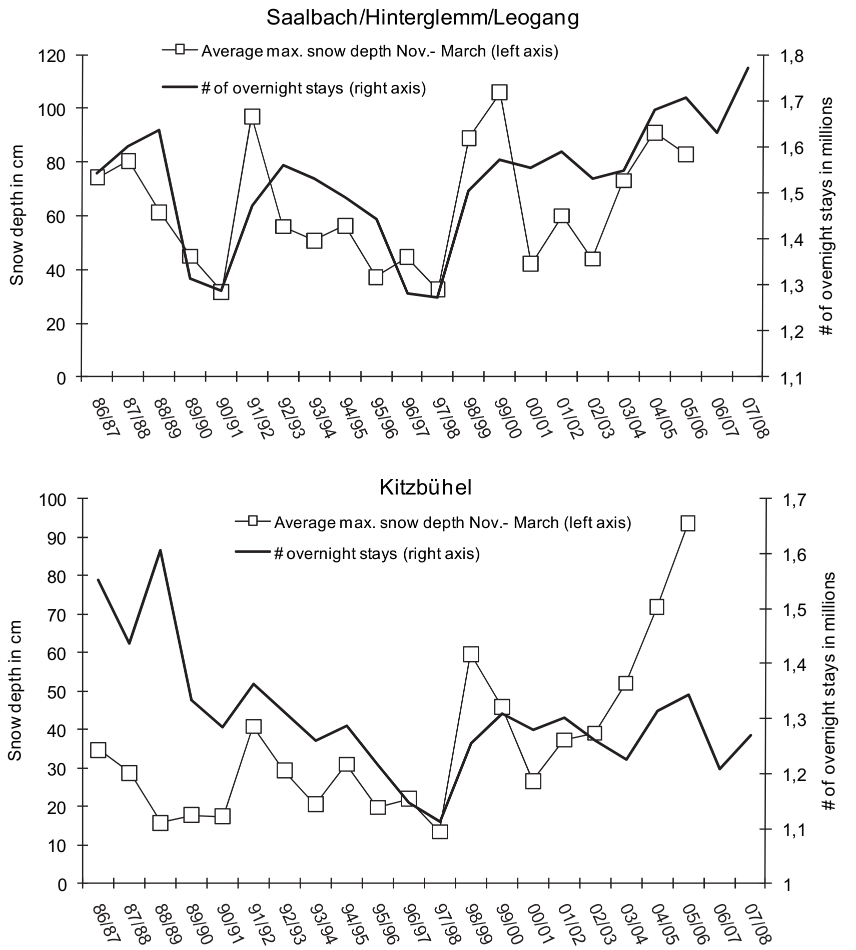
Table A3
Matched ski resorts and weather stations and information on average snow depth.

Weather stations	Elevation in metres	Max. monthly snow depth	Average max. snow depth Nov.–Mar.	Average max. snow depth Nov.–Jan.	Matched ski resorts
		Mean of 1986/87–2005/06			
Bad Mitterndorf	808	88	49	38	Bad Mitterndorf & Tauplitz; Bad Aussee
Badgastein	1100	60	40	34	Gastein valley
Ehrwald	1030	73	41	33	Ehrwald, Lermoos & Berwang
Galtür	1587	114	73	54	Ischgl; See; Galtür, Kappl
Kals	1336	55	36	32	Kals & Matrei
Kitzbühel	763	62	36	29	Kitzbühel
Krimml	1009	48	30	25	Ziller valley
Langen	1270	149	89	72	Klösterle
Obergurgl	1938	121	81	61	Sölden & Obergurgl
Radstadt	858	61	38	29	Salzburg Sportwelt (Flachau, Wagrain, Zauchensee, Kleinarl, etc.)
Ramsau	1203	98	58	44	Ramsau
Rauris	931	52	33	28	Rauris
Rohrmoos	1080	90	58	45	Rohrmoos, Schladming & Haus
Rudolfshütte	2304	282	200	163	Kaprun
Saalbach	1022	104	63	47	Saalbach, Hinterglemm & Leogang
Schoppernau	835	106	65	49	Damuels, Mellau & Schoppernau
Seefeld	1182	97	60	46	Seefeld
Sillian	1075	53	30	28	Sillian
St. Anton	1298	98	58	44	St. Anton, Lech and Zürs; Serfaus, Fiss & Ladis
St. Jakob/Defereggen valley	1400	65	45	42	St. Jakob/Defereggen valley
St. Michael/Lungau	1049	41	25	23	Katschberg-Aineck, Grosseck-Speiereck, Mariapfarr & Fanningberg
Warth	1475	160	100	76	Warth
Zell am See	766	59	35	27	Zell am See (Schmittenhöhe)

Table A4
Panel error correction estimates of the determinants of capacity utilization (total sample).

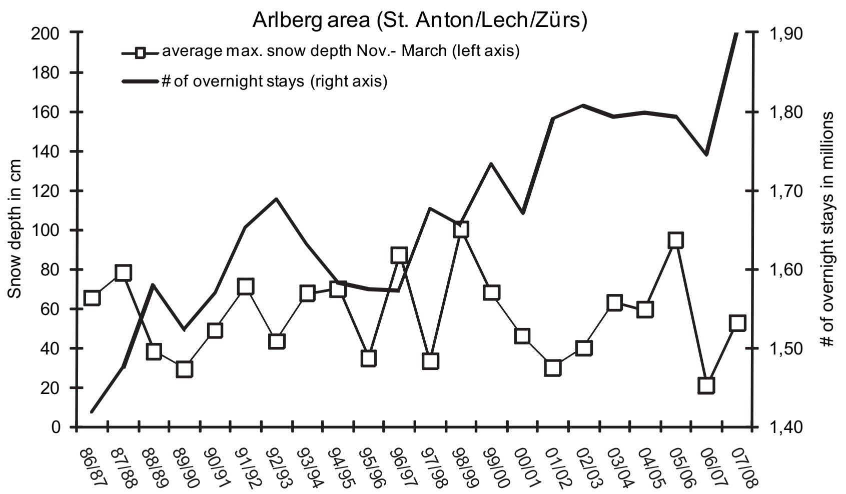
	Mean group estimates		PMG group estimates	
	Coeff.	*z*-value	Coeff.	*z*-value
Error correction term	−0.757***	−19.03	−0.546***	−14.78
Ln average max. snow depth Nov.–Mar., in cm	0.042*	1.93	0.091***	8.14
Ln weighted GDP per capita at 2000 ppp	0.637***	3.99	0.658***	6.00
Ln price index accommodation	−0.465***	−5.21	−0.597***	−8.11
Dummy variable, early Easter holiday	0.011	1.52	0.026***	3.39
Short-run coefficients	Yes		Yes	
Constant	−1.427***	−3.53	−0.916	−12.70
# of obs. (# of ski resorts)	532 (28)		532 (28)	

Notes :***, ** and * denote significance at the 1, 5 and 10 per cent levels, respectively. The dependent variable is the logarithmic change in capacity utilization. The short-run coefficients have not reported in order to save space.



Note: The slopes of the two resorts are located at elevationsof between 1000 and 2100 metres (Saalbach) and between 800 and 2000 metres (Kitzbühel) above sea level.

Graph A1. Evolution of overnight stays and snow depth for two low-elevation resorts.



Note: Slopes are located at elevation of between 1300 and 2650 metres above sea level.

Graph A2. Evolution of overnight stays and snow depth for one high-elevation resort.

References

Abegg, B., & Froesch, R. (1994). Climate change and winter tourism: impact on transport companies in the Swiss Canton of Graubünden. In M. Beniston (Ed.), *Mountain environment in changing climates* (pp. 328–340). London/New York: Routledge Publishing.

Baltagi, B. H. (2005). In *Econometric analysis of panel data* (3rd ed.). Chicester: John Wiley and Sons.

Banerjee, A., Dolado, J. J., & Mestre, R. (1998). Error correction mechanism tests for cointegration in a single-equation framework. *Journal of Time Series Analysis, 19*, 267–283.

Breiling, M., & Charamza, P. (1999). The impact of global warming on winter tourism and skiing: a regionalised model for Austrian snow conditions. *Regional Environmental Change, 1*(1), 4–14.

Brown, R. L., Durbin, J., & Evans, J. M. (1975). Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society, Series B* 149–192.

Butsic, V., Hanak, E., & Valletta, R. G. (2008). Climate change and asset prices: Hedonic estimates for North American ski resorts. FRBSF Working Paper 12.

Crouch, G. (1992). Effect of income and price on international tourism. *Annals of Tourism Research, 19*(4), 643–664.

Crouch, G. (1995). A meta-analysis of tourism demand. *Annals of Tourism Research, 22*(1), 103–118.

Elsasser, H., & Bürki, R. (2002). Climate change as a threat to tourism in the Alps. *Climate Research, 20*, 253–257.

Englin, J., & Moeltner, K. (2004). The value of snowfall to skiers and boarders. *Environmental and Resource Economics, 29*, 123–136.

Fukushima, T., Kureha, M., Ozaki, N., Fujimori, Y., & Harasawa, H. (2003). Influences of air temperature change on leisure industries: case study on ski activities. *Mitigation and Adaptation Strategies for Global Change, 7*, 173–189.

Garín-Muñoz, T. (2006). Inbound international tourism to the Canary Islands: a dynamic panel data model. *Tourism Management, 27*, 281–291.

Garín-Muñoz, T., & Montero-Martín, L. F. (2007). Tourism in the Balearic Islands: a dynamic model for international demand using panel data. *Tourism Management, 28*, 851–865.

Gómez Martín, M. B. (2005). Weather, climate and tourism: a geographical perspective. *Annals of Tourism Research, 32*(3), 571–591.

Gössling, S., & Hall, M. (2006). Uncertainties in predicting tourist travel flows under scenarios of climate change. Editorial essay. *Climatic Change, 79*(3–4), 163–173.

Hamilton, L. C., Brown, C., & Keim, B. D. (2007). Ski areas, weather and climate: time series models for New England case studies. *International Journal of Climatology, 23*, 733–750.

Harrison, S. J., Winterbottom, S. J., & Sheppard, C. (1999). The potential effects of climate change on the Scottish tourist industry. *Tourism Management, 20*, 203–211.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*, 53–74.

IPCC. (2007). United Nations' intergovernmental panel on climate change, IPCC AR4 synthesis report. http://www.ipcc.ch/graphics/gr-ar4-syr.htm.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics, 90*(1), 1–44.

Koenig, U., & Abegg, B. (1997). Impacts of climate change on winter tourism in the Swiss Alps. *Journal of Sustainable Tourism, 5*(1), 46–57.

Kremers, J., Ericsson, N., & Dolado, J. (1992). The power of cointegration tests. *Oxford Bulletin of Economics and Statistics, 54*(2), 325–348.

Kuo, H. I., Chen, C. C., Tseng, W. C., Ju, L. F., & Huang, B. W. (2008). Assessing impacts of SARS and avian flu on international tourism demand to Asia. *Tourism Management, 29*, 917–928.

Levin, A., Lin, C., & Chu, C. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics, 108*, 1–24.

Lim, C. (1997). Review of international tourism demand models. *Annals of Tourism Research, 24*, 835–849.

Lise, W., & Tol, R. S. J. (2002). Impact of climate on tourist demand. *Climatic Change, 55*(4), 429–449.

Maddison, D. (2001). In search of warmer climates? The impact of climate change on flows of British tourists. *Climatic Change, 49*, 193–208.

Moeltner, K., & Englin, J. (2004). Choice behavior under dynamic quality changes: state dependence versus 'play it by ear' in selecting ski resorts. *Journal of Business and Economic Statistics, 22*, 214–224.

Moen, J., & Fredman, P. (2007). Effects of climate change on alpine skiing in Sweden. *Journal of Sustainable Tourism, 15*(4), 418–437.

Narayan, P. K. (2004). Fiji's tourism demand: the ARDL approach to cointegration. *Tourism Economics, 10*(2), 193–206.

OECD. (2007). In S. Agrawala (Ed.), *Climate change in the European Alps: Adapting winter tourism and natural hazards management*. Paris, France: OECD.

Pesaran, H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. *Journal of the American Statistical Association, 94*, 621–634.

Scott, D., Dawson, J., & Jones, B. (2008). Climate change vulnerability of the northeast US winter tourism sector. *Mitigation and Adaptation Strategies to Global Change, 13*(5–6), 577–596.

Scott, D., McBoyle, G., Mills, B., & Minogue, A. (2006). Climate change and the sustainability of ski-based tourism in eastern North America. *Journal of Sustainable Tourism, 14*(4), 376–398.

Shih, C., Nicholls, S., & Holecek, D. F. (2009). Impact of weather on downhill ski lift ticket sales. *Journal of Travel Research, 47*(3), 359–372. doi:10.1177/0047287508321207.

Song, H., & Li, G. (2008). Tourism demand modeling and forecasting—a review of recent research. *Tourism Management, 29*(2), 203–220.

Wolfsegger, C., Gössling, S., & Scott, D. (2008). Climate change risk appraisal in the Austrian ski industry. *Tourism Review International, 12*(1), 13–23. doi:10.3727/154427208785899948.

Wooldridge, J. M. (2002). In *Econometric analysis of cross section and panel data* (1st ed.). Cambridge: MIT Press.

ZAMG (Zentralanstalt fuer Meteorologie and Geodynamik). Yearbook, various issues.