Climate Change and the Austrian Tourism Sector: Impacts, Adaptation and Macroeconomic Spillover Effects

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Abstract

Even if all greenhouse gas emissions stopped at once, temperatures are predicted to continue rising due to the inertia of the climate system. As skiing tourism in the Austrian Alps is highly climate sensitive, higher temperature and changed precipitation patterns require increased artificial snow making. However, spa and urban tourism rely less on climatic conditions and may benefit from a shift in demand. In this paper, we assess the different climate change impacts and adaptation options for the Austrian tourism sector up to 2050 by taking account of macroeconomic feedback effects. We find in each of the climate scenarios negative effects on demand in all tourism region types. For the summer season, the extent of potential climate change impacts are found to be smaller and the impact direction to be less clear. Due to macroeconomic feedback effects, also non-tourism sectors are affected, but while until 2020 negative spillover effects emerge due to reduced demand from tourism sectors, the effect becomes positive until 2040. Appropriate adaptation measures may counteract a substantial fraction of climate change impacts, but this increases production costs, especially for artificial snow making. In particular, adaptation leads to price increases in the “focus on winter tourism” region for all climatic scenarios in 2020. In contrast, adaptation in the other tourism region types may lead to price decreases due to higher cost savings from reduced heating and reduced relative prices from other inputs.

Keywords: climate change, damage function, adaptation, tourism, computable general equilibrium.

1 Introduction

The impacts of climate change are already palpable in Europe, which has warmed by almost 1°C over the last century. Due to the inertia in the climate system, temperatures are predicted to continue rising even if all greenhouse gas emissions stopped at once (see e.g. Stern, 2007). One highly climate sensitive sector is tourism, where changed climatic conditions may lead to relocations of tourism demand, both across destinations and across segments of tourism (Scott et al., 2012). To deal with the unavoidable impacts of climate change, adaptation plays a crucial role to cope with a changing climate and to reduce the vulnerability to adverse climate effects. Hence, also the European Commission in its Green Paper on Adaptation (2007) has bound itself to develop and gradually refine its adaptation policy for climate sensitive sectors. For research, this implies that the mechanisms of adaptation, as well as the interplay with sectoral vulnerability, have to be better understood. Due to the cross-cutting nature of adaptation, the assessment of the vulnerability of climate-sensitive economic sectors such as tourism to future climate and their scope for adaptation requires an integration of climate, sectoral and economic models.

The aim of this paper is therefore to develop a modeling framework to assess the requirement for and economic consequences of adaptation in Austrian tourism. Tourism plays an important role for the Austrian economy, contributing 7.5 % of GDP when taking account of direct and indirect effects (Statistics Austria and WIFO, 2012). As a large share of Austrian value added in tourism is generated in winter season, one question is to what degree natural snow availability can be complemented by artificial snow making and what this implies for tourism demand. Second, when parts of revenues from winter tourism are lost due to climate change, this may induce a shift to other forms of tourism like spa and urban tourism or summer tourism (hiking & swimming in alpine lakes). Finally, a positive impact of warmer winters could be a reduced demand for heating (Prettenthaler et al., 2008) which reduces costs to hotels.

Many studies have assessed the impact of changed precipitation and temperature for natural snow availability, length of ski seasons, and ski tourism demand (König and Abegg, 1997; Breiling, 1999; Luzzi and Flückiger 2003; Töglhofer et al., 2011), and some have even taken account of artificial snow making as response option (Hennesy et al., 2008; Scott et al., 2003, 2006). While the focus of these analyses was on specific tourism regions, another strand of literature has dealt with the impacts from climate change for tourism on a global scale, such as how international tourism flows are affected by sea-level rise and other effects of climate change (Bigano et al., 2008; Lise and Tol, 2002). In the present analysis, we fill the gap in between by focusing on the impacts for different types of tourism at the country level and by considering both the direct and indirect effects (i.e. macroeconomic spillover effects) of climate change as well as seasonal differences. In addition, we also address the scope and limits of tourism type specific adaptation options.

To quantify consequences of climate change for tourism in Austria, the integrated modeling framework consists of coupling high-resolution climate change scenarios derived from different regional climate models with detailed sectoral econometric models for tourism demand, the latter taking the influence of variations in meteorological parameters into account. To take also account of the feedback effects of impacts and adaptation in this sector on the rest of the economy, results from the tourism demand model were fed into a computable general equilibrium (CGE) model of the Austrian economy.

In this paper, we set out to answer the following main research questions: What are the impacts of climate change on the Austrian tourism sector, how can the tourism sector adapt to climate change impacts and what are the sectoral as well as macroeconomic implications? Furthermore we are interested in how and why climate change impacts differ across winter and summer season and across four different types of tourism regions (*Urban or thermal spa tourism* (URB), *Mixed portfolio of lower intensity tourism* (TEX), *Regions with a focus on summer tourism* (SUF), and *Regions with a focus on winter tourism* (WIF)) and how the impacts evolve over time, from 2010 to 2050. With regard to adaptation in the tourism sector we will analyze summer and winter specific adaptation measures, their impacts on the overall cost structure of the four tourism clusters, and the macroeconomic feedback effects.

This paper is structured as follows. Section 2 provides an assessment of major tourism types in Austria and summarizes climate scenarios for summer and winter for two time periods (2011-30 and 2031-50). The modeling framework is summarized in Section 4. Results for tourism demand are presented in Section 5, while macroeconomic consequences are assessed in Section 6. A final section discusses summarizes results and concludes.

2 The Austrian tourism sector and climate change

Tourism plays an important role in the Austrian economy. According to the tourism satellite account, in 2010 tourism (excluding business trips) created € 15.09 billion in direct value added, corresponding to 5.3 % of the gross domestic product (GDP). Considering indirect effects as well, tourism even accounted for € 21.5 billion or 7.5 % of GDP (Statistics Austria and WIFO, 2012). Moreover, more than 33.4 million visitors and about 124.9 million overnight stays were reported in 2010 (Statistics Austria, 2012).

Tourism demand in Austria is characterized by a high spatial and temporal concentration. About 54 % of national annual overnight stays fall upon the states Tyrol and Salzburg and approximately one half of all overnight stays concentrate on the months January, February, July and August (Statistics Austria, 2012). The variety of natural and cultural landscapes as well as climatic conditions allow for diverse touristic utilization, ranging from urban tourism over lake and thermal spa tourism to ski tourism.

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, the same weather conditions might be unfavorable 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. Therefore, the assessment of climate change impacts for tourism in

Austria is carried out separately for different tourism region types. In this section, we therefore describe first how the Austrian tourism sector can be grouped into different characteristic types. Then, the selection of four representative climate scenarios for Austria up to 2050 is described.

2.1 Identifying tourism region types

In order to identify Austria's different tourism types, all 35 Austrian NUTS 3 regions[1] are classified into groups as homogenous as possible with respect to their 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[2]. For the purpose of classification the statistical technique of hierarchical cluster analysis (see e.g. Backhaus et al. 2003) is applied, 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.

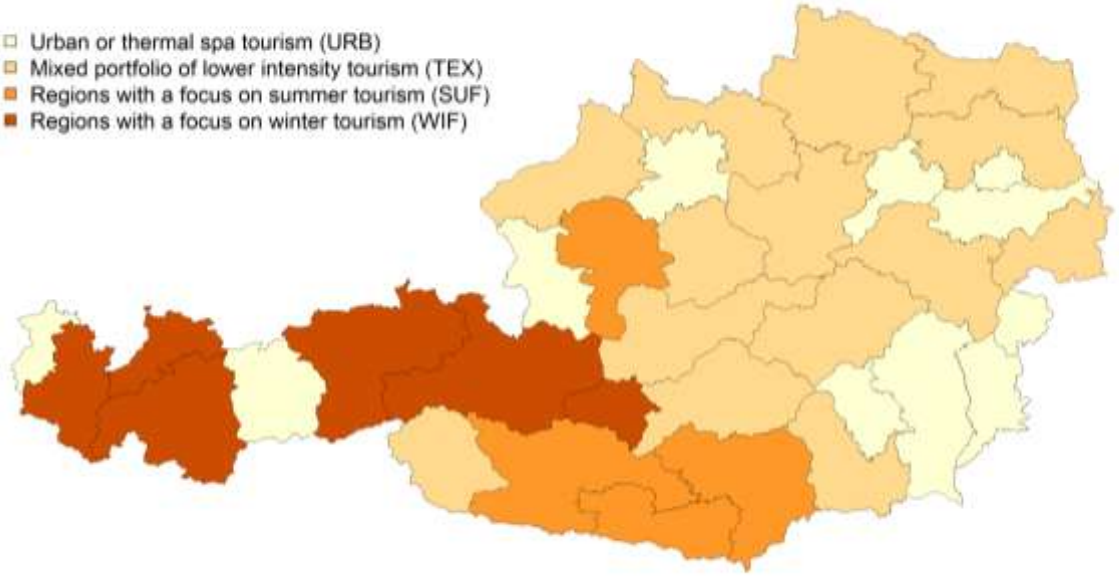

Figure 1: Four tourism region types identified by cluster analysis

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

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

Figure 1 illustrates the four tourism region types identified by cluster analysis. The “Urban or thermal spa tourism” (URB) 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” (TEX) cluster encompasses the by far largest number of NUTS 3 regions, but only accounts for about 14% of yearly overnight stays. The cluster labeled “Regions with a focus on summer tourism” (SUF) 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, “Regions with a focus on winter tourism” (WIF), is characterized by the highest tourism intensity. Consisting of only six NUTS 3 regions it accounts for about 50% of yearly overnight stays. Table 1 summarizes the specific characteristics of these four tourism clusters.

Table 1: Characteristics of the four tourism cluster regions

Urban and thermal spa tourism **URB**	Mixed portfolio of lower intensity **TEX**	Regions with focus on summer tourism **SUF**	Regions with focus on winter tourism **WIF**
• includes almost all NUTS 3 regions with federal capitals • encompasses important thermal spa regions • seasonal focus ranges from all year tourism to slight summer tendencies • low tourism density[a] • (rather) low importance of ski tourism[b] • highest share of 4/5 star beds	• biggest tourism cluster (14 NUTS3 regions), but overnight stays similar to smallest cluster (SUF) • seasonal focus ranges from clear summer to slight winter tendencies • very low tourism density[a] (exceptions: Liezen, Osttirol) • low concentration of employment in the tourism sector[c] (exceptions: Liezen, Osttirol) • lowest share of 4/5 star beds	• clear focus on summer season • includes some typical lake tourism regions • tourism density[a] below the all region’s average • concentration of employment in the tourism sector[c] above the national concentration • importance of ski tourism lower than in WIF cluster, but of significant role for winter season performance	• seasonal focus ranges from slight winter tendency to clear winter focus • highest tourism density[a] • highest concentration of employment in the tourism sector[c] • high importance of ski tourism, not only for winter season performance but also total performance

[a] measured as overnight stays per inhabitant and year

[b] measured as aggregated transport capacity (in ski areas) per tourism employee

[c] measured as share of tourism employees in total employees

2.2 Climate scenarios

In order to provide robust climate projections, four combinations of Global Climate Models (GCMs) and Regional Climate Models (RCMs) on the basis of the IPCC’s A1B emission scenario have been selected. These four representative scenarios are based on a statistical analysis of a sample of 19 GCM/RCM combinations, which have been generated within the EU-project “ENSEMBLES”. They are covering the representative range of possible climate changes with respect to combined seasonal temperature / precipitation changes on a grid with 25 km grid spacing. These four scenarios are used to prepare error corrected and downscaled meteorological data for the climate change impact modeling in the tourism sector model.

The four selected climate simulations are ETHZ_CLM (driven by the global climate model HadCM3), CNRM_RM4.5 (driven by APREGE), SMHI_RCA (driven by BCM), and ICTP_RegCM (driven by ECHAM5). Table 2 summarizes the characteristics of the four climate scenarios relative to the 19 models median. In summer, ETHZ_CLM and CNRM_RM4.5 represent over-average warming, with ETHZ_CLM being drier and CNRM_RM4.5 wetter than the multi-model median. SMHI_RCA and ICTP_RegCM represent below-average warming, with SMHI_RCA being drier and ICTP_RegCM being wetter. In winter, ETHZ_CLM remains warmer than the median, and shows slightly over-average precipitation increase. CNRM_RM4.5 shows slightly below-average warming and drier conditions than the median. As in summer, ICTP_RegCM and SMHI_RCA are colder than the average. While SMHI_RCA remains drier than the median in winter, ICTP_RegCM changes characteristics regarding precipitation.

Table 2: Characteristics of the climate scenarios for summer and winter relative to the median

	Summer		**Winter**	
	Temperature	Precipitation	Temperature	Precipitation
ETHZ_CLM	above-median	below-median	above-median	above-median
CNRM_RM4.5	above-median	above-median	below-median	below-median
SMHI_RCA	below-median	below -median	below-median	below-median
ICTP_RegCM	below-median	above-median	below-median	below-median

3 Methodology

Due to the cross-cutting nature of adaptation, the assessment of the vulnerability of climate-sensitive economic sectors to future climate and their scope for adaptation requires an integration (or coupling) of sector and macroeconomic models. In the following sections we first present the method underlying the tourism sector analysis, followed by a detailed description of the macroeconomic model. The final subsection deals with the model linkages.

3.1 Econometric tourism sector model

Since tourism is a strongly demand driven sector (Prideaux et al., 2009; McKercher, 1998), climate change impacts are assessed by studying the potential impacts of climate change on tourism demand. For this purpose, overnight stays are used as tourism demand indicator. The quantification of the potential impacts of climate change on tourism demand are carried out for each of the four identified tourism region types and separately for winter (November-April) and summer (May-October) season, using a two-step approach.

STEP 1:

In a first step, the historical weather sensitivity of tourism demand is quantified by means of dynamic, multiple regression models. Whereas investigations related to the winter half year are carried out on a seasonal basis, summer season analyses 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 natural logarithm of overnight stays in the considered tourism region type during the winter season or a particular summer month represents the dependent variable, whereas one of the weather indices listed in Table 3 enters the model as independent variable. In order to prevent multicollinearity, only one weather index – a snow index in case of winter season analyses 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, 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. Equation 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:

$$\ln(nights_{it}) = \beta_{i0} + \phi_{i1}\ln(nights_{it-1}) + \beta_{i1}WI_{jit}\,/\mathrm{sd}(WI_{ji}) + \varepsilon_{it} \tag{1}$$

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

where $\ln(nights_{it})$ describes the natural logarithm of overnight stays in tourism region type i at time t, $WI_{jit}/\mathrm{sd}(WI_{ji})$ 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}, $ø_{i1}$, $ø_{i2}$, $ø_{i3}$, 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.

Table 3: Tested weather indices

Abbr.	Explanation
Weather indices used within winter season analyses:	
S_{mean}	Mean depth of natural snow at the mean altitudes of the region's ski areas during the winter season [cm]
S_{day1}	Days with at least 1 cm natural snow depth at the mean altitudes of the region's ski areas [days/winter season]
S_{day30}	Days with at least 30 cm natural snow depth at the mean altitudes of the region's ski areas [days/winter season]
Weather indices used within summer season analyses:	
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]

The methodology described above is applied on data covering the periods 1973 to 2006 (winter season analyses) and 1977 to 2006 (summer season analyses). Original data on overnight stays (Statistics Austria) and on meteorological parameters (ZAMG[3]) are partly available on a finer regional and temporal resolution than required for the analyses 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 analyses) scale. Snow data, provided by ZAMG, stems from 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).

STEP 2:

In a second step, several tourism demand scenarios are simulated until 2050 using the estimated weather sensitivities (STEP 1) along with meteorological scenario data from four different climate models on the one hand – resulting in climate change scenarios – and

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[3] Zentralanstalt für Meteorologie und Geodynamik

meteorological “baseline” data on the other hand[4] – resulting in a future baseline scenario[5]. Long-term differences between the simulations of tourism demand evolution according to the climate change scenarios and the simulation of tourism demand evolution according to the future baseline scenario indicate the potential impacts of climate change on tourism demand.

For more details on data and methodology of the econometric tourism demand model see Köberl et al. (2011a, 2011b).

3.2 Macroeconomic analysis: Computable General Equilibrium model

We develop a computable general equilibrium (CGE) model to analyze the economic impacts of climate change on as well as the potential of adaptation measures for the Austrian tourism sector. The model is programmed and solved in GAMS/MPSGE (Rutherford, 1999) utilizing the solver PATH, which is calibrated to the previously described IO table for Austria, representing the year 2006. We focus in our analysis on Austria and its tourism sector and therefore generate a single-country, multi-sector CGE model. Following the small open economy assumption other regions are not modeled explicitly. Austria is linked to the rest of the world by flows of imports and exports in our model. The remainder of this chapter gives a detailed description of the CGE model structure.

3.2.1 Basic model structure

Following the structure of the Austrian IO table we construct a social accounting matrix (SAM) which forms the data basis for our CGE analysis of the Austrian tourism sector. The representative private household receives total labor and capital income (less depreciations), as well as transfers from the government. On the one hand, the representative household saves a constant fraction of its disposable income. On the other hand, the private households spend their income on the consumption of domestic as well as foreign goods and services. The government receives total tax revenues, which in turn is spent on the provision of public goods as well as on direct transfers to the representative household. We model capital and labor as mobile between the 23 sectors representing the Austrian economy. The following sections give a detailed description of the production structure of domestic industries, the international trade assumptions, and the final demand structure.

3.2.2 Production structure

Within the modeling framework MPSGE, nested constant elasticity of substitution (CES) production functions are employed, to specify the substitution possibilities in domestic

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[4] Meteorological “baseline data” exhibits the same mean and variability as observed within the period 1971 to 2000.

[5] For simulating future baseline and climate change scenarios, the same functional relationships and trends as observed within the calibration period are assumed. Hence, if overnight stays in a particular region and for a particular season show a significant (linear) trend, this trend is assumed to continue for the future period.

production between the primary inputs capital and labor, intermediate energy and non-energy inputs.

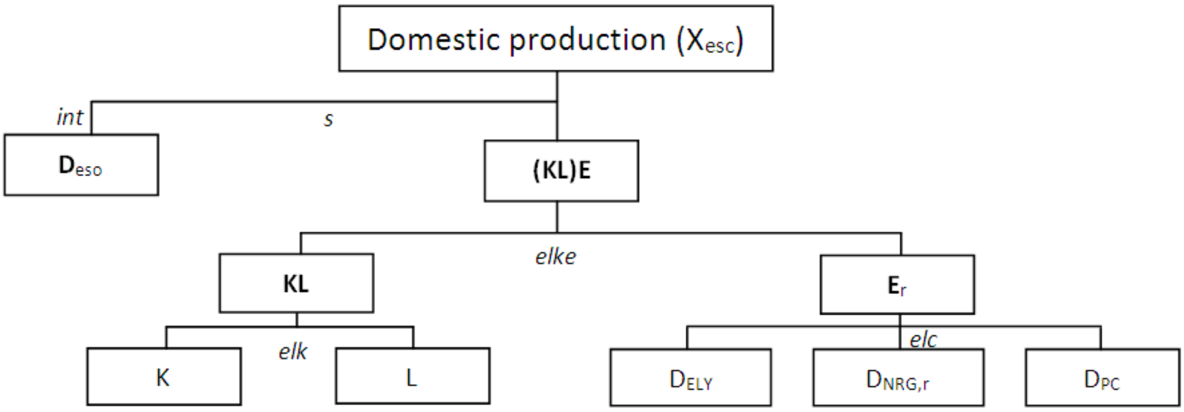

Figure 2: Nesting structure of domestic production

Figure 2 illustrates the production function of each of the 23 domestic sectors *esc*. At the top level an aggregate comprising of intermediate inputs from non-energy sectors – the domestic supply D_{eso} – trades off, subject to a constant elasticity *s*, with an aggregate of capital, labor and energy *(KL)E*. At the second nesting level, a CES composite of capital and labor *KL* is combined under a constant, but sectorally different elasticity *elke* with an energy-composite *E*. Capital is employed under the sectorally differentiated constant elasticity of substitution *elk* with labor. The energy composite is represented by a trade-off between electricity D_{ELY}, primary energy commodities (coal, oil, gas) D_{NRG}, and refined petroleum products D_{PC} at a constant elasticity of substitution *elc*.

The elasticities of substitution in the production processes (Table 12) are based on Okagawa and Ban (2008) as well as Beckman and Hertel (2009).

3.2.3 International trade

With respect to foreign trade, i.e. the allocation of final and intermediate consumption between domestic and foreign goods and services, we follow the small open economy assumption. It assumes that an economy that participates in international trade is small enough compared to its trading partners that it does not alter world prices because of its policies. This allows the explicitly modeled region to trade as much or as little as it wants at fixed world prices. Trading in the model is therefore represented by functions which allow the economy to transform exports into imports at a single world price ratio.

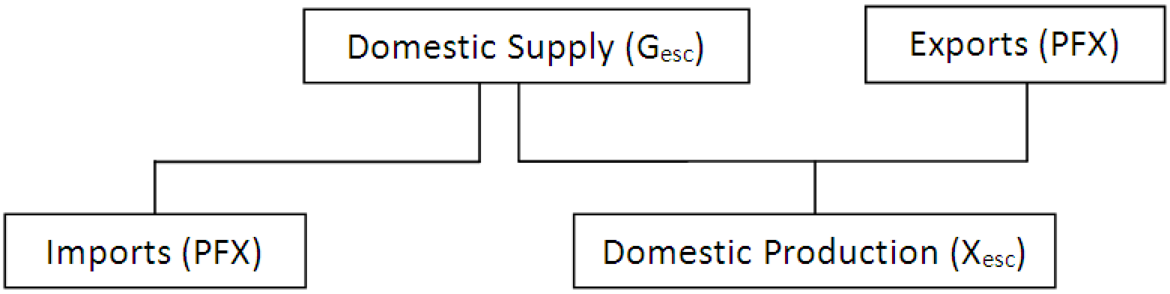

Figure 3: Trade nesting structure

Figure 3 summarizes the foreign trade modeling approach in the CGE model. The domestic production in all 23 sectors *esc* is used as domestic supply as well as for exports. Exports of all sectors are measured in a single world price *PFX*, representing foreign exchange. The foreign exchange reserves generated through exports is then used to purchase imports of all 23 sectors from the global market. Imports and the domestic production eventually sum up to the overall domestic supply which is then used to satisfy domestic private and public consumption. The just described modeling procedure with respect to the formation of aggregate domestic supply by combining domestic production and imports of corresponding foreign sectors is applied for all non-tourism sectors as well as for the fraction of tourism services which are not consumed by private households, i.e. the tourism services which are used as intermediate inputs in the production of other sectors. The following section on final demand will elaborate in more detail how the private household decides on whether consuming domestic tourism services or foreign tourism services.

3.2.4 Final demand

Final demand is determined by consumption of the private household and the government. Both the private household and the government (public good supply) maximize utility subject to their disposable income, labor and capital income or tax income, respectively. Public consumption is characterized by a constant elasticity of substitution between a material consumption bundle and an energy aggregate.

Similar to public consumption, consumption of private households is at the top nesting level characterized by a CES composite of a material consumption bundle and an energy aggregate. While the second nesting level of the energy composite is the same for private and public final demand, there are changes in the modeling of the material consumption bundle. While for public consumption the domestic supply (i.e. the aggregate of domestic production and imports) of all non-energy commodities trade-off against each other at a constant elasticity of substitution, in the case of private consumption we differentiate once more between non-tourism-non-energy commodities and tourism-non-energy services. As in the public consumption nesting structure, the non-tourism-non-energy commodities are represented by the domestic supply aggregate. The aggregation of domestic production and imports of tourism services for private consumption however is modeled directly in the final demand production function and not at the economy-wide level. This procedure is applied since we need to have an explicit modeling of private consumption allocation between domestic and imported tourism services – detached from intermediate and public demand – for the business as usual calibration (see the following sections). As Figure 4 reveals, we employ the four tourism clusters at a constant elasticity of substitution *tur* with each other before trading this tourism composite $D_{tourism}$ of with non-tourism commodities $D_{non\text{-}tourism}$ at a constant elasticity *int*.

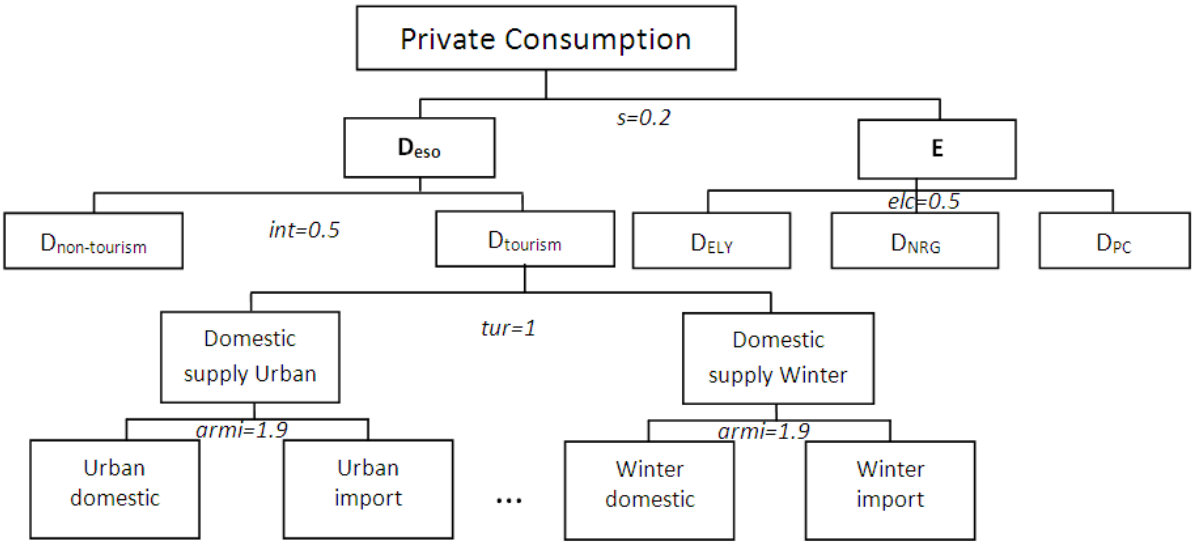

Figure 4: Nesting structure of private consumption

3.3 Data and calibration of the CGE model

Since the regional focus of the macroeconomic analysis of climate change impacts on the tourism sector is on Austria, we explicitly represent the Austrian economy as detailed as possible in our CGE model, especially with respect to its tourism industry. Other countries or world regions are not modeled explicitly in our CGE framework.

On the sectoral level, we differentiate between 16 economic sectors which were aggregated from the basic 57 × 57 national input-output table at NACE 2-digit level (Statistik Austria, 2010). In combination with additional information from the tourism satellite accounts (TSA; Statistik Austria, 2012) this database allows the identification of tourism relevant sectors and the disentangling of tourism specific services into four regionalized tourism sectors, giving in total 19 sectors. The aggregation as visualized in Table 4 covers sectors in more detail with important sectoral linkages to tourism (like electricity, transport, real estate and rental) as well as those which provide substitutes in demand (e.g. other services; recreation, culture and sport)

Table 4: Sectoral aggregation of the Austrian input-output table (IOT) 2006 for the CGE model

	Sectors	Code	Comprising sectors (NACE number.)
1	**Energy carriers**	**NRG**	10, 11
2	**Electricity**	**ELY**	40
3	**Refined oil products**	**P_C**	23
4	**Chemicals rubber and plastic**	**CRP**	24, 25
5	**Rest of Energy Intensive Industries**	**EIS**	21, 22, 26, 27
6	**Non energy-intensive industry**	**NEIS**	17, 18, 19, 20, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37
7	**Transport Commodities**	**TRN**	60-63
8	**Agriculture**	**AGR**	01
9	**Food products**	**FOOD**	15, 16
10	**Extraction**	**EXTR**	02, 05, 12-14
11	**Trade**	**TRD**	50, 51, 52, 55
12	**Insurance**	**ISR**	66
13	**Real Estate & Rental**	**OBS**	70, 71, 72, 73, 74
14	**Recreation, Culture, Sport**	**ROS**	92, 93, 95
15	**Other Services and Utilities**	**SERV**	41, 45, 64, 65, 67, 75-91
16	**Tourism Industry**	**TOUR**	
16a	Urban	URB	**disentangled from 55 (in trd), from 60, 61 (in otp, wtp), and from 92 (in ros)**
16b	Mixed tourism-extensive	TEX	
16c	Summer focus	SUF	
16d	Winter focus	WIF	

In a first step of disaggregation, the national IO table for Austria provided by Statistics Austria (2010) had to be regionalized in order to allow the derivation of regionally specific climate change impacts on Austrian tourism demand. Therefore NACE sectors identified by the TSA (tourism satellite accounts; Statistics Austria 2012) as containing tourism relevant services, namely sectors 55 (hotels and restaurants), 60 (more precisely 60.21-03: transport by cable railways, funiculars and ski-lifts), 61 (water transport), and 92 (culture, sport and entertainment) are disaggregated into the four tourism regions. In a second step, these four regionally clustered tourism relevant sectors can be split into tourism specific goods and services (A.1), tourism related goods and services (A.2), and non-tourism specific goods and services (B). As we want to focus on tourism specific goods and services only, we extracted therefore the respective shares of hotels and restaurants, tourism transport services & travel agencies, and culture, sport & entertainment from the tourism relevant sectors. In a final third step, the tourism specific shares of the regionalized sectors 55, 60.21-03, 61 and 92 were aggregated to form a single tourism sector for each of the four clusters.

Since our macroeconomic model is designed in a comparative static way, we have to rely on exogenous growth assumptions for our analysis of the Austrian economy until 2050. We rely on projections for the annual work force development by Statistics Austria, which is assumed to grow by 0.008% per annum. With respect to the development of the Austrian capital stock we follow Poncet (2006) and assume an annual growth rate of 1.3%.

With respect to assumptions about technological change, we assume autonomous energy efficiency improvements (AEEI) amounting to 1% per annum for all economic sectors, based on Boehringer (1999) and Burniaux et al. (1992). Furthermore, for non energy inputs in production we apply annual multifactor productivity (mfp) growth rates based on the EU-KLEMS database (1995-2004, see Table 13; EU-KLEMS 2009).

As the following section points out, the mfp growth rates corresponding to the four tourism clusters have to be adjusted in order to replicate in the CGE model the development of tourism overnight stays calculated by the detailed econometric tourism model.

3.4 Model interfaces

In the first step of linking the top-down CGE model to the detailed tourism sector model, we had to calibrate the CGE model in such a way that it is able to replicate the baseline development of overnight stays according to the sectoral analysis (for details on methodology, see section 3.1), for the target time periods 2011-2030 and 2031-2050 respectively.

In the second step, climate change impacts according to the four climate scenarios were modeled as demand shocks in the macroeconomic CGE model, i.e. the development of overnight stays relative to the baseline projection derived from the bottom-up tourism sector analysis (for results see section 4) was proportionately translated into a demand increase or decrease, respectively, for the four tourism region types.

In the third step, two adaptation options were integrated in both models: artificial snowmaking and changes in electricity demand in the tourism sectors due to changed heating and cooling demand. In the context of the CGE model both effects translate into a change of technology and hence into altered cost structures for the four tourism region types.

For a detailed description of the model linkages at both stages of the analysis – climate change impacts on and adaptation in the Austrian tourism sector – see sections 5.1.1 and 5.2.1.

4 Tourism sector analysis

4.1 Climate change impacts for tourism in Austria

To quantify the potential impacts of climate change on tourism demand we followed a two-step approach (see section 3.1 above). Table 5 summarizes an interim result of this two-step approach. It illustrates the weather sensitivity of overnight stays per tourism region type derived from region- and season-specific tourism demand models. This weather sensitivity indicates 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 tourism demand model and a symbol (√ or ×) indicating whether the estimated weather index coefficient shows the expected sign.

Statistically significant snow dependencies of winter overnight stays are only found in the tourism region types “focus on summer tourism” and “focus on winter tourism”, whereby results suggest winter overnight stays in the first-mentioned type 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.

Regarding the results for the single summer months, all tourism region types (except the “urban and thermal spa tourism”) 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, 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. But actually, there is some reasonable explanation for the two exceptions observed for the “urban and thermal spa tourism” region type. 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 and 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.

Table 5: Weather sensitivity of overnight stays according to the region- and season-specific tourism demand models

	URB			TEX			SUF			FOC		
WINTER												
Nov-Apr	0.70	(S_{mean})	√	0.61	(S_{mean})	√	**2.82*****	(S_{mean})	√	**1.60****	(S_{mean})	√
SUMMER												
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

S_{mean} … Mean depth of natural snow (in the region's ski areas) during the winter season [cm]

T_{mean} … Monthly average of the air temperature [°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]

Figure 5 illustrates the final results of the mentioned two-step approach, i.e. the potential impacts of climate change on tourism demand. Broad bars in Figure 5 indicate the average seasonal[6] deviation of overnight stays over the period 2011 to 2050 that is expected for the respective tourism region type under the considered climate change scenario compared to a situation where the climatic conditions remain the same as in the recent past. Error bars, which are represented by the narrower bars, illustrate model uncertainties.

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[6] For the summer season, results on the single summer months were aggregated on a seasonal level.

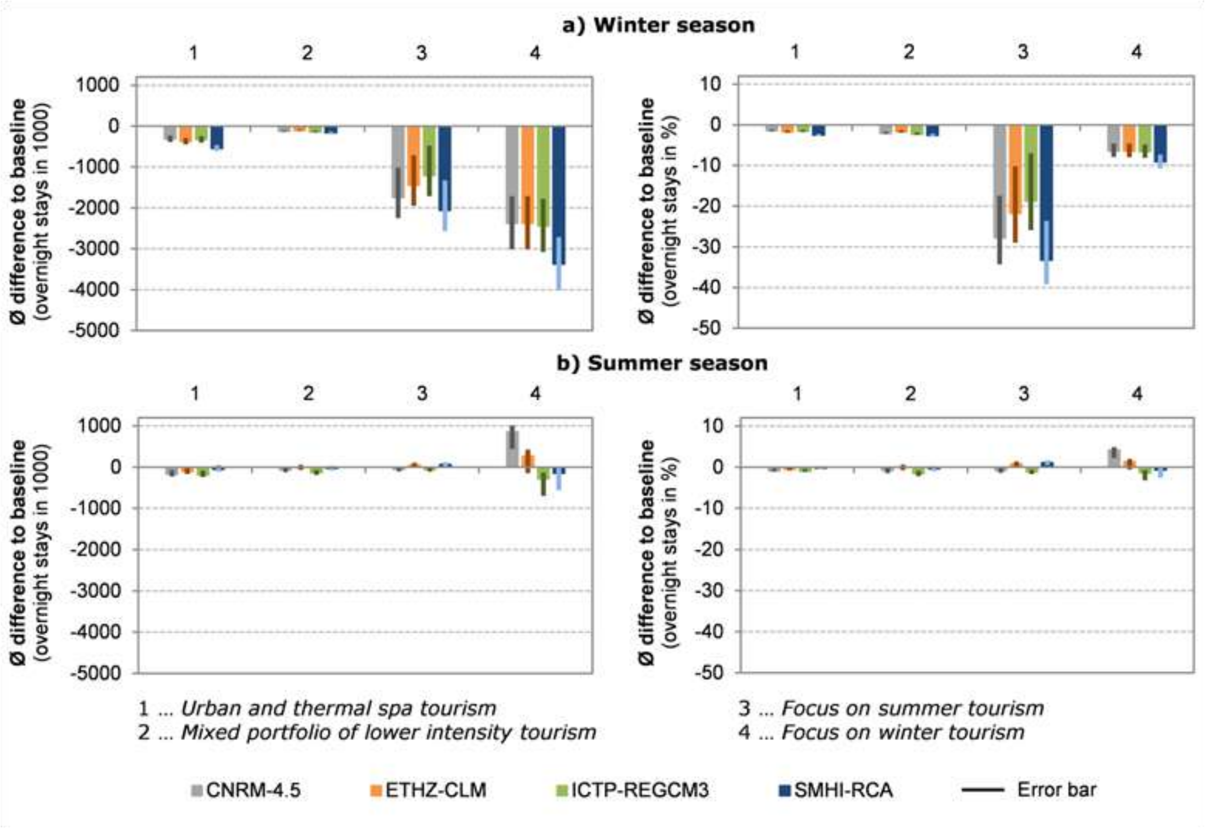

Figure 5: 40-year-averages (2011-2050) with respect to the deviations of overnight stays simulated under a climate change scenario from overnight stays simulated under a future baseline scenario

As shown in Figure 5a 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 (left hand-side), winter overnight stays in the *“Focus on summer tourism”* region type show the highest reductions due to potential climate change, whereas absolute decreases (right hand-side) are the highest in the *“Focus on winter tourism”* region type. Compared to the winter season, results for the summer season (see Figure 5b) suggest the extent of potential climate change impacts to be smaller and the impact direction to be less clear.

4.2 Adaptation to climate change for tourism in Austria

By definition, adaptation measures have the potential to partially counterbalance climate change impacts on the tourism sector. No proactive adaptation strategies are considered for tourism during the summer season, since impact assessment suggested relatively small effects with partly unclear directions. However, in order to take into account some indirect impacts of climate change on tourism demand during the summer season, the potential impacts of climate change on the energy demand of the accommodation sector are quantified additionally[7], assuming autonomous adaptation by the accommodation industry with respect to cooling needs. Assuming that changes in the energy demand and therefore in the energy costs will be (at least partly) passed on to the consumers, results serve as starting base for investigating the effects of climate induced accommodation price changes on tourism demand within CGE modeling.

Regarding tourism during the winter season, for which (partly considerable) negative potential impacts of climate change were found, the adaptation strategy “artificial snowmaking” is considered in addition to the autonomous adaptation by the accommodation industry with respect to heating needs. Since only limited data is available on the costs of artificial snowmaking, some simplifying assumptions have to be made for the present analysis, which rather serves to demonstrate a potential way of considering adaptation in the assessment of climate change impacts than to result in robust cost estimates of artificial snowmaking. Based on expert guess it is assumed that about 75 % of climate caused impacts during the winter season could be counterbalanced by artificial snow production – given current technology and the considered climate scenarios. Based on the simplifying assumption of constant costs of snow production – 3 € per cubic meter - and a constant extent of ski slopes, adaptation costs are roughly estimated by assessing the amount of artificial snow required for counterbalancing 75 % of the potential climate change impacts. Table 6 outlines the long-term seasonal averages of the additional costs of artificial snowmaking under each considered climate change scenario compared to the baseline scenario, both in absolute (left hand side) and in relative, i.e. per hectare (right hand side), terms. Not surprisingly, results suggest absolute adaptation costs to be highest for the “*Regions with a focus on winter tourism*”, which exhibits the by far biggest area of ski slopes. However, measured per hectare, results indicate costs to be highest for the “*Regions with a focus on summer tourism*”.

Table 6: Monetarily assessed snow depth required to prevent 75 % of potential impacts (seasonal average for the period 2011-2050)

	Costs in million €				**Costs in 1,000 € per ha**			
	URB	**TEX**	**SUF**	**WIF**	**URB**	**TEX**	**SUF**	**WIF**
CNRM	~1.3	~5.9	~5.3	~33.8	~0.8	~1.8	~2.6	~1.8
ETHZ	~1.6	~5.8	~7.0	~38.5	~1.0	~1.8	~3.4	~2.1
ICTP	~1.4	~6.7	~3.9	~36.9	~0.9	~2.0	~2.0	~2.0
SMHI	~2.2	~7.7	~6.3	~50.9	~1.4	~2.4	~3.1	~2.8

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[7] The climate caused change in cooling (and also heating) demand of the accommodation sector was assessed somewhat analogously to the potential climate change impacts on tourism demand. In a first step, the (non-linear) relationship between mean temperature and cooling/heating demand was analyzed by means of regression analysis and in a second step applied on meteorological “baseline” and scenario data – the same as used for tourism demand impact assessment – in order to derive climate induced changes.

5 Macroeconomic effects of tourism impact and adaptation scenarios

5.1 Baseline without climate change (BAU)

5.1.1 Linkage to the tourism sector model - baseline tourism calibration

The time horizon for the modeling exercise is 2050. The timeframe until 2050 is split into two periods, namely 2011-2030 and 2031-2050. Since we follow a comparative static modeling approach and in order to cancel out short term annual weather fluctuations, we calculate the mean of forecasted annual overnight stays (see section 4) in a business as usual scenario (no climate change impacts) for the two time periods 2011-2030 and 2031-2050, to represent the target years 2020 and 2040, respectively. Also for the presentation of our modeling results for these two periods we choose the years 2020 and 2040.

Table 7: Annual multifactor productivity growth rates for tourism sectors

	BAU 2020	BAU 2040
URB	0.84%	1.41%
MIX	-0.70%	-0.21%
SUM	-1.55%	-0.79%
WIN	-0.54%	-0.09%

To replicate the baseline overnight stays forecasted by the econometric tourism sector model, we proportionately translated these developments into changes in private final demand for domestic tourism services relative to the IO table base year 2006 within the CGE model (see Table 8). To achieve these target values for 2020 and 2040 multifactor productivities for each of the four tourism sectors were adjusted accordingly (Table 7).

Table 8: Baseline changes in final demand for domestic tourism services relative to 2006

	2020 (2011-2030)	2040 (2031-2050)
	relative to 2006	
Urban/thermal spa	1.17	1.54
Tourism extensive	0.96	0.92
Focus summer	0.88	0.79
Focus winter	0.99	0.98

Table 8 indicates that demand for all tourism sectors except for the urban/thermal spa tourism region (URB) is found to be lower than in the base year 2006 under business as usual assumptions (without climate change). While demand for urban and thermal spa tourism services increases by 17% compared to 2006 over the period from 2011-2030 and by 54% over the period 2031-2050, the focus region summer suffers, compared to 2006, from a loss of 12% during the first period and 21% during the second period. The focus region winter will be able to keep more or less the demand stable at 2006 levels, with only minor losses of 1% until 2020 and 2% until 2040, both compared to 2006. The already by definition tourism extensive region TEX will be confronted with slight decreases in demand for its tourism services by 4% compared to 2006 over the period from 2011-2030 and by 8% over the period 2031-2050.

5.1.2 Baseline results

Based on the BAU assumptions outlined in the previous sections, we derive changes in sectoral economic output of the 23 economic sectors for 2020, and respectively 2040, as indicated in Figure 6. Without accounting for climate change impacts, the output of most economic sectors is going to increase in the BAU scenario. Only sectors insurance (ISR), real estate, rental, and other businesses (OBS), as well as recreation, culture, sport (ROS), which are subject to decreasing multi factor productivity growth rates according to the EU-KLEMS, are facing reduced output until 2020 and 2040, respectively.

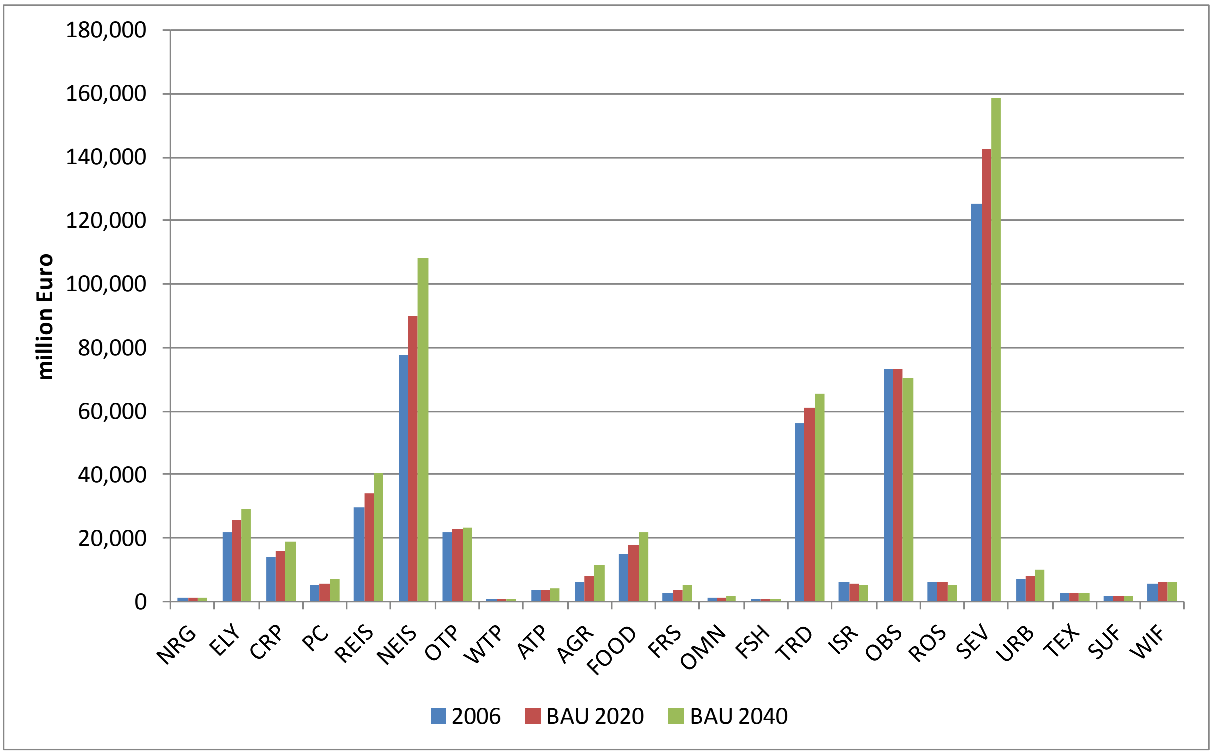

Figure 6: Output of economic sectors in 2006, 2020 and 2040 (in Mio. €)

By adjusting mfp growth rates for the four tourism clusters URB, TEX, SUF, and WIF we are able to replicate the econometrically projected changes in overnight stays by private consumers in the Austrian tourism sector for the periods 2011-2030 and 2031-2050. These econometric projections are based on calibrated region- and season-specific tourism demand models, which were used to simulate how overnight stays could potentially evolve until 2050 – assuming the same functional relationships and trends hold as observed within the calibration period – if the climatic conditions remained the same as in the recent past (see also section 3.1). Figure 7 contains the CGE model results with respect to output of the four tourism clusters and a non-tourism aggregate (comprising all other economic sectors).

When comparing these results for economic output with the BAU assumptions for the development of overnight stays until 2050 (Table 8), we can see that the numbers do not match exactly. While Table 8 reveals, for example for the cluster WIF, a slightly negative development of overnight stays until 2050, Figure 7 visualizes that under BAU assumptions output of the respective tourism cluster increases. This traces back to the fact that even though private consumption of overnight stays change according to the econometric projections, public demand responds differently (i.e. slightly increase for WIF compared to 2006). Therefore total output slightly increases as well. The same holds true for the other three tourism sectors as well.

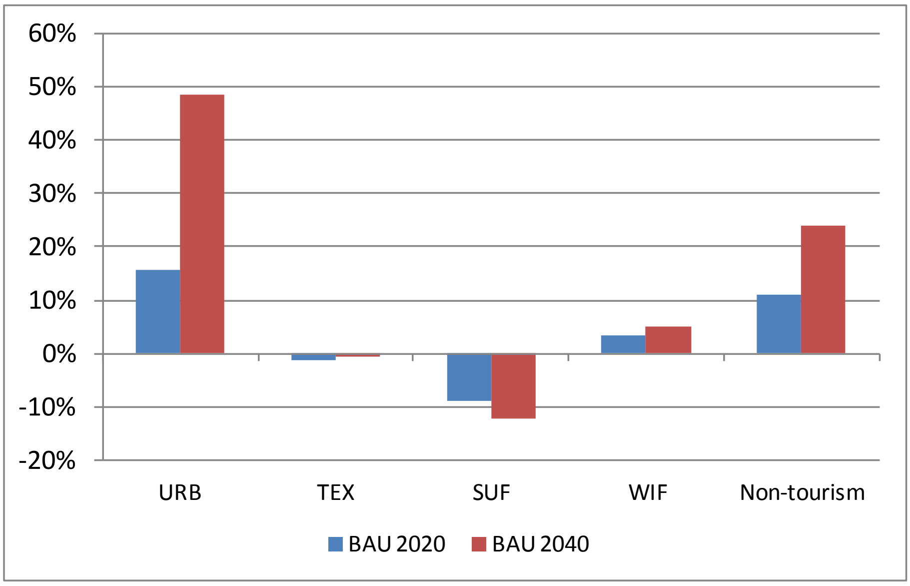

Figure 7: BAU output change for tourism and non tourism sectors relative to 2006

Figure 7 indicates that the urban and thermal spa (URB) cluster is projected to increase its output by 16% until 2020 and 48% until 2040. In contrast the tourism extensive cluster (TEX) will not be subject to substantial output changes in a climate baseline scenario, which exhibits the same climatic mean and variability as observed in the climate normal period 1971-2000. The tourism cluster focusing on summer tourism (SUF) will be confronted with reduced tourism demand compared to 2006 (-9% until 2020 and -12% until 2040). The output (i.e. the overnight stays) of the focus winter tourism cluster (WIF) on the other hand is expected to increase in the BAU scenario by 3% until 2020 and by 5% until 2040 compared to 2006. Total economic output of non tourism sectors is projected to increase until 2020 by 11% and respectively by 24% until 2040 (relative to 2006).

5.2 Climate change impacts

5.2.1 Linkage to the tourism sector model

Climate change impacts according to the four climate scenarios were modeled as demand shocks, i.e. the development of overnight stays relative to the baseline projection derived from the bottom-up tourism sector analysis in section 4 was proportionately translated into a demand increase or decrease, respectively, for the four tourism region types.

Table 9: Climate change impacts during tourism year relative to baseline final demand

	2020 (2011-2030)				2040 (2031-2050)			
	CNRM	ETHZ	ICTP	SMHIRCA	CNRM	ETHZ	ICTP	SMHIRCA
	realtive to baseline				realtive to baseline			
Urban/thermal spa	99%	99%	99%	99%	99%	98%	99%	98%
Tourism extensive	99%	99%	99%	99%	98%	99%	98%	98%
Focus summer	93%	98%	97%	91%	78%	79%	82%	76%
Focus winter	99%	98%	97%	95%	96%	95%	94%	92%

Table 9 shows that the strongest climate change impacts predicted by the econometric tourism sector model will arise in the focus region summer, with demand shocks relative to the baseline in the range of -2% over the period 2011-2030 according to climate scenario ETHZ to -24% over the period 2031-2050 according to climate scenario SMHIRCA. The focus region winter, which by definition is mainly relying on winter tourism, is confronted with less severe climate change impacts (at least measured in relative terms), since its ski resorts are situated at higher elevations than the ones from the focus region summer, and hence are less vulnerable to climate change.

Table 10: Climate change impacts during winter season relative to baseline final demand

	2020 (2011-2030)				2040 (2031-2050)			
	CNRM	ETHZ	ICTP	SMHIRCA	CNRM	ETHZ	ICTP	SMHIRCA
	realtive to baseline				realtive to baseline			
Urban/thermal spa	99%	99%	99%	99%	99%	99%	99%	98%
Tourism extensive	99%	99%	99%	99%	99%	99%	99%	99%
Focus summer	93%	98%	97%	91%	78%	78%	83%	75%
Focus winter	97%	97%	97%	95%	95%	95%	94%	93%

By comparing Table 9, Table 10, and Table 11 it can be seen that the main climate change impacts on the Austrian tourism industry will take place during the winter season. During summer season some regions under some climate scenarios (e.g. focus winter under CNRM) will even profit from climate change impacts. Table 9, and Table 10 furthermore indicate that impacts are going to be substantially more severe during the later period 2031-2050 than over 2011-2030.

Table 11: Climate change impacts during summer season relative to baseline final demand

	2020 (2011-2030)				2040 (2031-2050)			
	CNRM	ETHZ	ICTP	SMHIRCA	CNRM	ETHZ	ICTP	SMHIRCA
	realtive to baseline				realtive to baseline			
Urban/thermal spa	100%	100%	100%	100%	100%	100%	99%	100%
Tourism extensive	100%	100%	100%	100%	99%	100%	99%	99%
Focus summer	100%	100%	100%	100%	100%	100%	99%	101%
Focus winter	102%	101%	100%	100%	101%	100%	100%	99%

Since tourism relevant services in the Austrian IOT are accounted for according to the principal of national treatment, which means that all domestic tourism services consumed either by residents or foreign tourists are treated as if they were consumed only by residents, the domestic disposable income after climate change impacts has to be adjusted downwards to correct for that accounting error. Under the assumption that the initial foreign tourism share in total tourism expenditures for 2020 and respectively 2040 proportionally translate into the reduction or increase of foreign tourism expenditures and therefore into the change of domestic disposable income, we apply in the CGE model a reduction in the capital endowment of the representative household. The reasoning behind this approach is that in the medium to long run, less foreign tourism expenditures also translate into reduced investments which eventually implies a reduced capital stock.

5.2.2 Results of impact scenarios

Climate change impacts on the Austrian tourism sector are measured in terms of output reduction relative to BAU 2020 and BAU 2040, respectively (in million Euro; Figure 8).

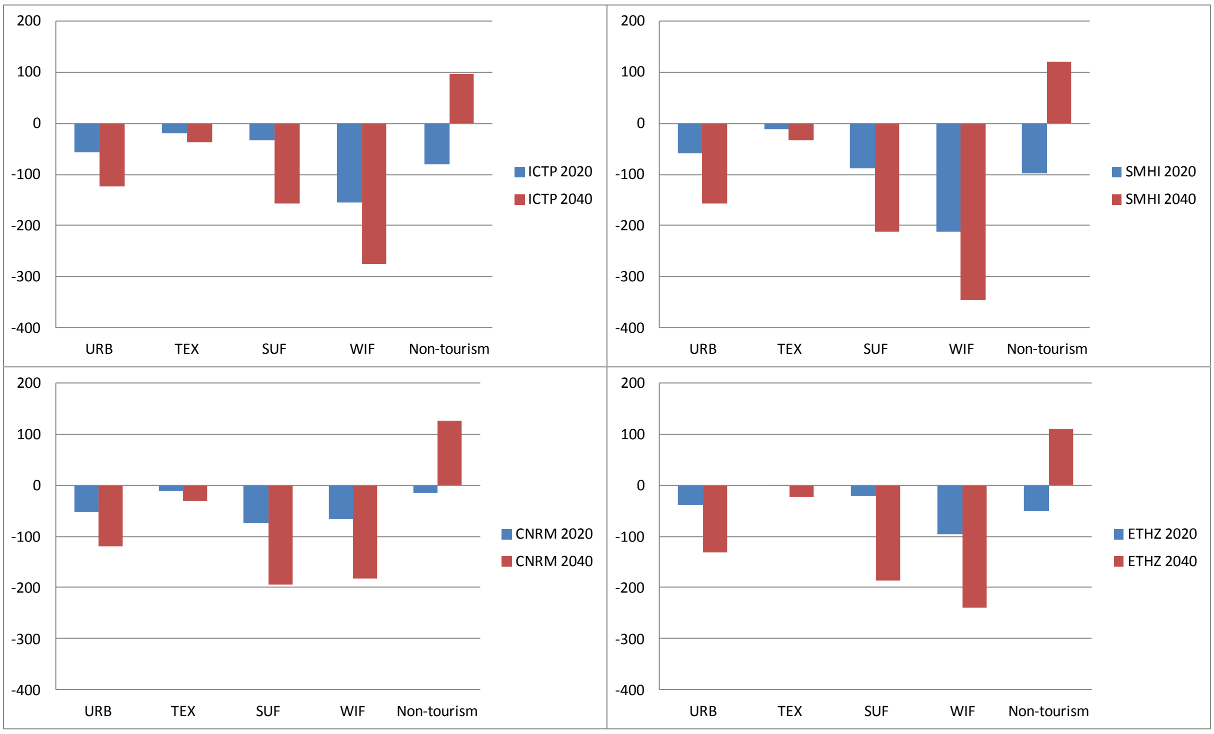

Figure 8: Climate change impacts according to the four climate scenarios 2020 and 2040 (relative to BAU in million Euro)

Total impacts on tourism output in Austria until 2020 are found to be strongest under climate scenario SMHI, followed by ICTP, CNRM, and ETHZ. Splitting up the overall impacts on tourism, we find that impacts are strongest for the focus winter cluster (WIF), which is characterized by high winter intensity. Impacts are lowest on the mixed, tourism extensive cluster (TEX), which by definition is tourism extensive and therefore less severely hit by climate change impacts. Also non-tourism sectors are negatively affected by climate change impacts, which is due to negative feedback effects and, most importantly, due to less expenditures of foreign tourists in Austria. Reduced foreign tourism expenditures translate into a reduction of domestic disposable income, which not only reduces demand for, and therefore output of, tourism sectors, but also of non-tourism sectors. Even though in all climate scenarios climate change impacts in monetary terms are highest for the WIF cluster, in relative terms (compared to BAU 2020), SUF is stronger effected than WIF in climate scenarios SMHI (-5.4%) and CNRM (-4.6%) and only slightly less negatively affected in ICTP (-2.0%) and ETHZ (-1.3%). Yet, despite this strong impact on summer tourism regions (e.g. Carinthian lakes) in relative terms, absolute impacts are stronger for winter tourism regions. For the Austrian tourism sector in total, output reductions in the range of -0.9% (ETHZ) to -2.0% (SMHI) are projected until 2020.

For all climate scenarios the trend from period 2020 to period 2040 points in the same direction, namely that impacts are increasing substantially, even though the magnitude of impacts in 2020 as well in 2040 varies across the four scenarios and four clusters. In particular, we find that while impacts relative to BAU associated with climate scenarios ICTP and SMHI almost double from 2020 to 2040, impacts more than double under climate scenarios CNRM and ETHZ over the same time period. With respect to the development of cluster specific impacts, we find that in 2040 the very negative position of cluster SUF is even intensified. The summer focus cluster is projected to achieve output losses relative to BAU in the range from -9.9% (ICTP) to -13.3% (SMHI). These negative effects on the cluster SUF are even exaggerated by the fact that already the BAU scenario projects negative output effects in the magnitude of -9.0% (2020) and -12.2% (2040) relative to the base year 2006. Also the impacts on the other three tourism clusters relative to BAU are increasing compared to 2020, however at a much lower rate. Output changes associated with clusters URB and TEX however remain below -2% compared to BAU 2040, which is mainly a result of the comparatively low importance of the climate sensitive ski snow-based tourism in these clusters.

As Figure 9 points out the lion’s share of climate change impacts on the Austrian tourism sector is arising during the winter season. This holds even for the focus region summer (SUF), due to the relatively low lying ski resorts in that cluster, climate change impacts during winter season will be the driving force behind the negative impacts on SUF. While the climate change induced effects on tourism output is for some clusters (particularly for WIF) in some climate scenarios (especially CNRM and ETHZ) even positive, on a net basis these positive summer effects are more than counterbalanced by negative winter season effects across all clusters and climate scenarios, leading to the overall negative climate change impacts. In the period 2031-2050 climate change induced impacts on tourism output in the four clusters compared to BAU are now mainly negative as well during the summer season. Nevertheless, the share of summer season impacts remains relatively low.

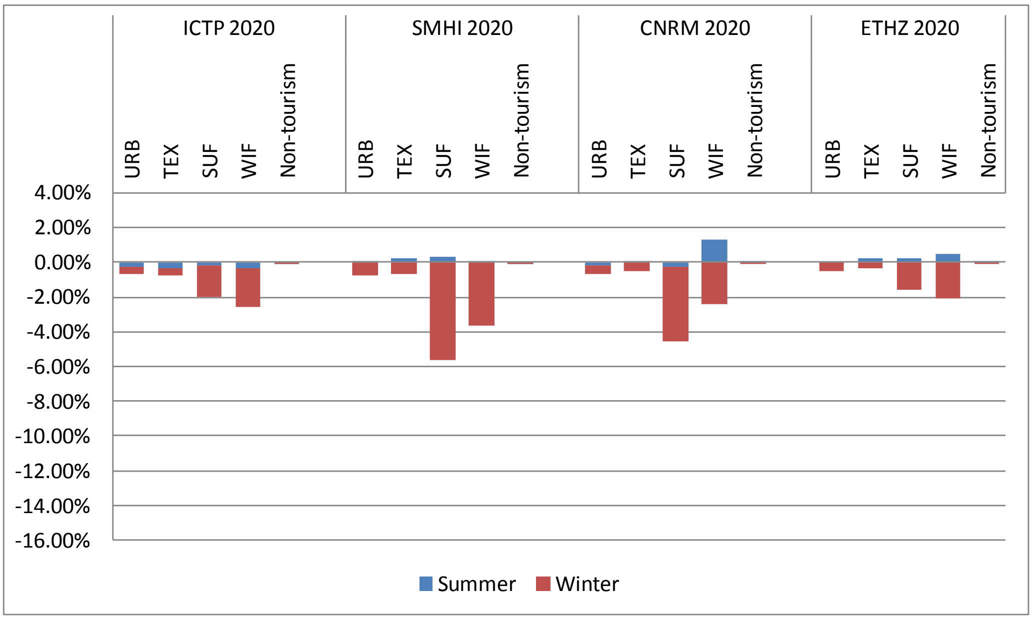

Figure 9: Seasonal decomposition of climate change impacts - Change in output relative to BAU 2020 (in %)

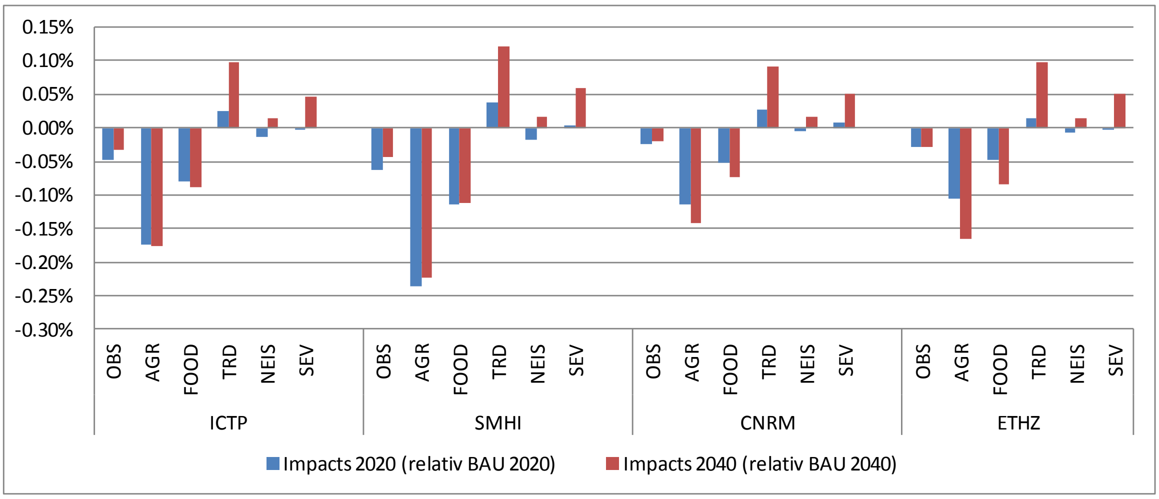

Figure 10: Top three non-tourism winners and losers over whole tourism year, compared to BAU 2020 and 2040 (in %)

Figure 10 depicts the top three winners and losers of all non-tourism sectors for the periods 2011-2030 and 2031-2050. It can be seen that important intermediate input sectors for the tourism industry such as agriculture (AGR), real estate & rental (OBS), and food products (FOOD) are those non-tourism sectors most strongly affected by climate change impacts on the tourism sector. This holds true for the first period as well as for the second period.

Over the first period negative effects on the non-tourism sectors prevail, and outweigh the positive impacts (mainly in sector trade TRD). In contrast to the first period 2011-2030, non-tourism sectors in total are eventually gaining in the second period 2013-2050 from climate change impacts on the Austrian tourism sectors. Even though overall disposable income of the Austrian households is reduced due to lower foreign tourists' expenditures, most of this income effect addresses the tourism sectors themselves, and non-tourism sectors are profiting from a change in consumption patterns of domestic consumers. For 2040 we find that other services & utilities (SEV), trade (TRD), and non-energy intensive industries (NEIS) are the top three beneficiaries of climate change impacts on the tourism industries. In total and for all scenarios for non-tourism sectors these positive effects on some industries outweigh the negative impacts. However in percentage terms, these total output gains of non-tourism sectors remain quite low.

5.3 Adaptation to climate change in the tourism sector

5.3.1 Linkage to the tourism sector model - adaptation

Regarding adaptation we assume on the one hand that the four tourism clusters respond to climate change impacts by undertaking investments in artificial snow making and on the other hand that impacts would also confront them with changing energy bills due to changing heating and cooling expenditures. Both effects lead to altered cost structures (for details, see **Fehler! Verweisquelle konnte nicht gefunden werden.**the Appendix). Additional expenses for electricity (ELY), other businesses (OBS), labor (LAB), capital (CAP), and taxes during the winter season can be attributed to artificial snow making. Changes in the expenses for refined petroleum products (PC) during the winter season are driven by altered heating expenditures. During summer season additional expenses for electricity (ELY) are arising due to additional cooling demand. Most of the changes in the cost structure are due to winter season adaptation measures. While artificial snow making leads to cost increases, climate induced reductions in heating partially counterbalance these increases in all four tourism regions over all four scenarios. In the mean over the period 2011-2030, additional costs for cooling during summer season are relatively low across all scenarios and tourism regions.

The highest absolute cost increases are found in the focus winter region (WIF), which is highly winter tourism intensive, due to additional artificial snowmaking expenses. In this region snowmaking costs outweigh reductions in heating costs due to warmer temperatures. Depending on the respective climate scenario production costs for WIF increase in the range of 0.55% (ETHZ) to 0.86% (SMHIRCA) relative to 2006. The second highest increases in production costs until 2020 are found in the focus summer region (SUF) as ski tourism is an important driver for overnight stays during the winter season for this region and low lying ski resorts induce relatively high costs for artificial snow making, which leads to cost increases in the range of 0.25% (ICTP) to 0.42% (SMHIRCA). Due to the same reasons tourism cluster TEX is confronted with cost increases relative to 2006 in the range of 0.20% (ETHZ) to 0.36% (SMHIRCA). The urban and thermal spa cluster faces almost no cost increases. The additional costs for cooling during summer season and the additional costs for artificial snow making, which are relatively low compared to other clusters, counterbalance each other.

Moving from 2020 to 2040, heating costs drop even further due to climate change induced temperature increases, but additional costs for artificial snowmaking rise over-proportionally at the same time (see Table 16-19). Additional cooling expenditures in the Austrian tourism sector during summer season double from period 2011-2030 to period 2031-2050, but remain relatively low in absolute terms. In sum these effects lead to cost increases until 2040 for WIF in the range of 0.58% (CNRM) to 1.01% (SMHIRCA), for SUF in the range of 0.22% (ICTP) to 0.47% (ETHZ), for TEX in the range of 0.19% (CNRM) to 0.30% (SMHIRCA), while for URB savings due to less heating in winter counterbalance additional snow making and cooling expenditures.

With regard to the effectiveness of the just described adaptation measures, we assume that they have the potential to reduce climate change impacts on the tourism sector by 75%, but not to fully counterbalance them. This means that the climate change induced demand shocks applied in the impact scenarios can be reduce by 75%, however at altered production costs.

5.3.2 Results of adaptation scenarios

When the tourism clusters apply adaptation as outlined in section 5.3.1, we assume that 75% of initial climate change impacts (reduced tourism demand by domestic and foreign consumers) can be counterbalanced. Figure 11 illustrates that the adaptation measures are effective at reducing the negative impacts on the tourism sector, but not exactly 75% effective due to cross-sectoral general equilibrium feedback effects, which are mainly triggered by higher tourism prices triggered by the costs of adaptation. While the urban and thermal spa tourism cluster, which is characterized by relatively low climate change impacts and therefore also relatively low adaptation costs until 2020, outperforms the 75% threshold, all other tourism sectors do not achieve a 75% effectiveness of adaptation measures. On the one hand this implies an intra-sectoral restructuring of tourism expenditures away from TEX, SUF, and WIF to URB and on the other hand a redistribution of private spending to other non tourism commodities.

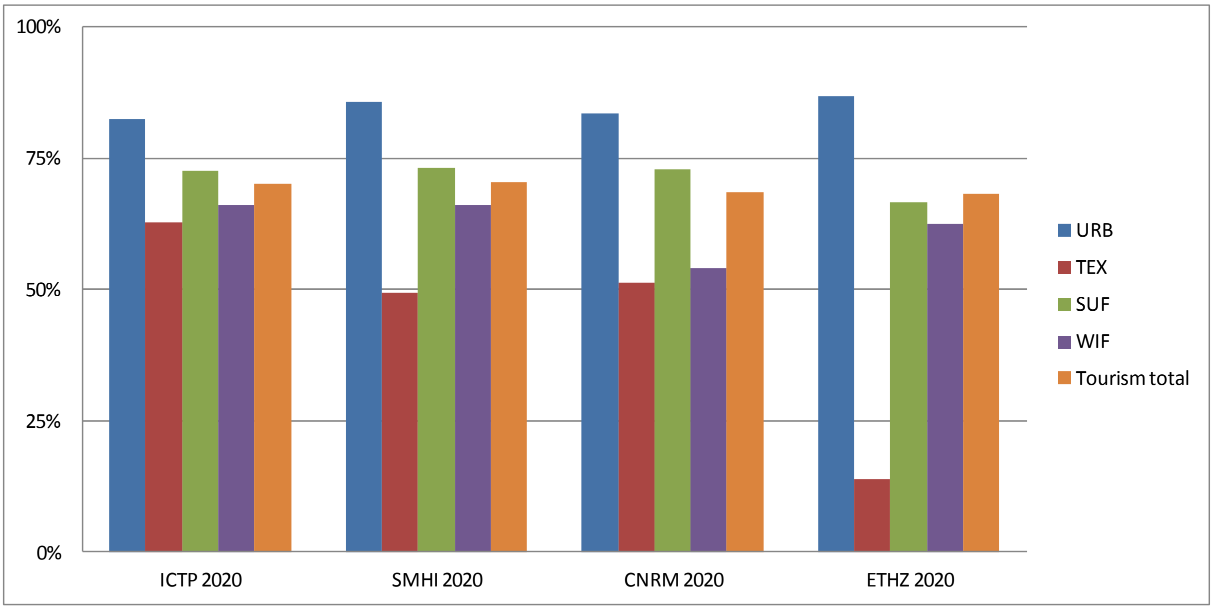

Figure 11: Regained output due to climate change adaptation (in % of output lost due to climate change impacts in 2020)

Until 2040, the reporting median year for our second time period under investigation 2031-2050, the substantially more severe climate change impacts on the four tourism clusters can be counteracted by adaptation measures as well. As Figure 12 points out, until 2040 the adaptation measures are even more effective in reaching their target of 75% effectiveness, measured in regained output losses due to adaptation measures compared to climate change induced tourism demand reduction. This is due to the fact that the intra-sectoral as well as the inter-sectoral consumption redistributions can be more or less cancelled out.

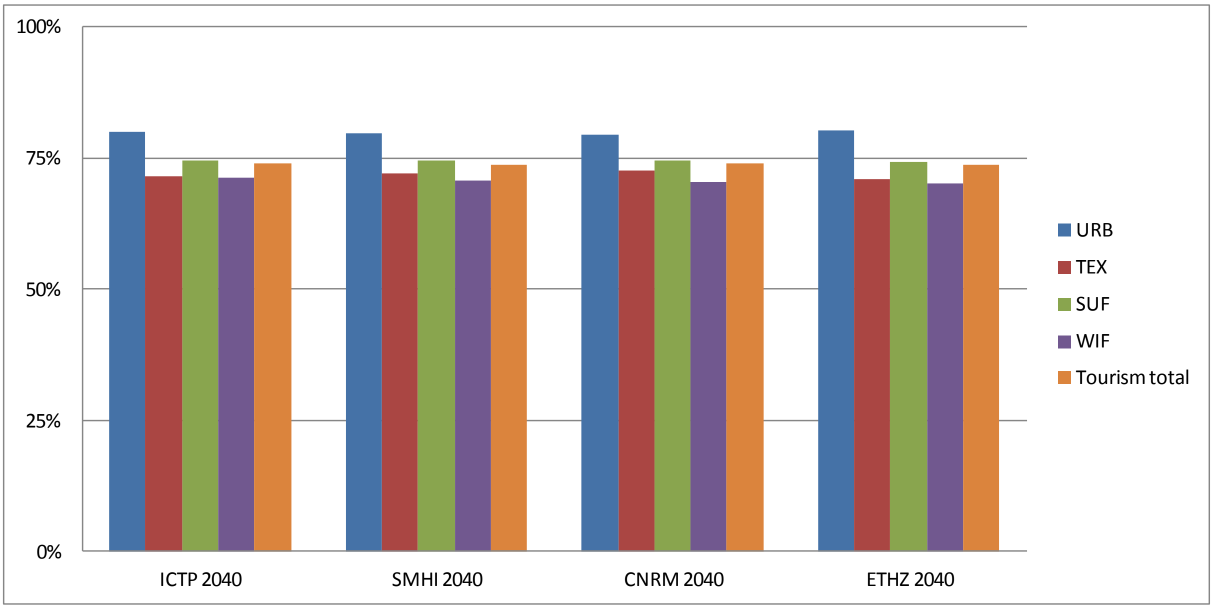

Figure 12: Regained output due to climate change adaptation (in % of output lost due to climate change impacts in 2040)

These differences in the intra-sectoral and cross-sectoral equilibrium effects in turn are due to the different equilibrium price effects when comparing period one to period two (Figure 13). In period one the tourism cluster price levels with and without adaptation do not differ much for clusters TEX and SUF. The equilibrium price for tourism services in cluster URB even decreases compared to the impact scenario, since this cluster is subject to relatively minor cost increases due to climate change adaptation measures. In contrast, the focus winter cluster WIF has to bear high adaptation costs and investments for artificial snow making, which translates into a higher equilibrium price for tourism services from this cluster. These tourism equilibrium price effects eventually lead to an intra-sectoral redistribution of tourism expenditures away from WIF to URB, therefore strengthening the effects already apparent in the BAU projection for 2020, which projects higher growth in overnight stays for cluster URB than for any other cluster (Figure 7).

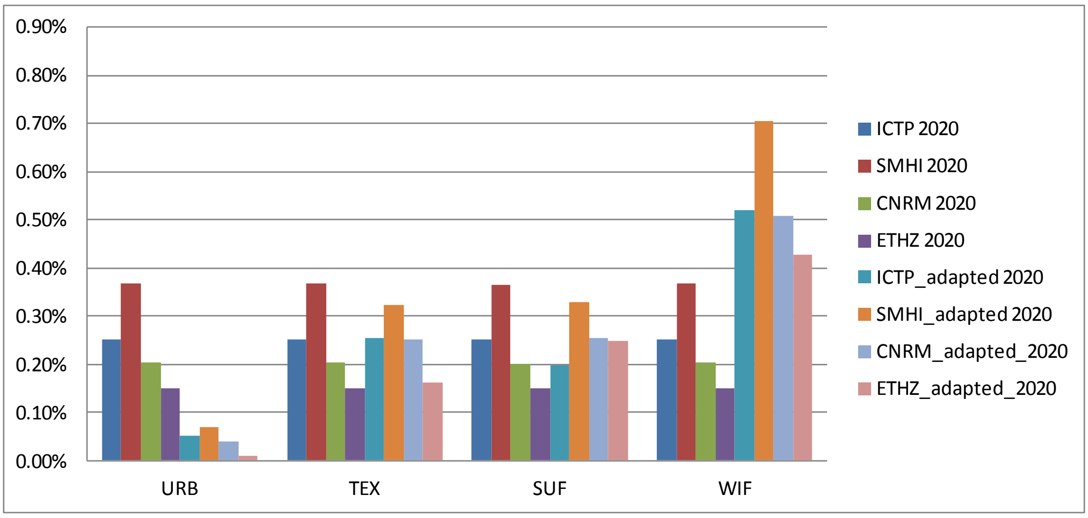

Figure 13: Change in relative tourism prices over the period 2011-2030 (compared to BAU prices in %)

With respect to the second equilibrium effect, the cross-sectoral redistribution of consumption patterns, it is also the relative equilibrium prices which drive the results. While three of four tourism clusters are subject to higher or almost equal relative prices in the adaptation scenarios compared to the impact scenarios, other sectors have substantially lower equilibrium prices in the adaptation scenarios than in the impact scenarios (Figure 14). Since these sectors do not have to adjust their cost structures because of climate change impacts, they can fully profit from lower rental prices for capital. These are in turn achieved by regained foreign tourism expenditures, which stimulate investments and increase the capital stock (i.e. capital services) as well as disposable income. Due to these effects and due technical change over time, real prices for all non-tourism products and services are lower in adaptation scenarios than in impact scenarios.

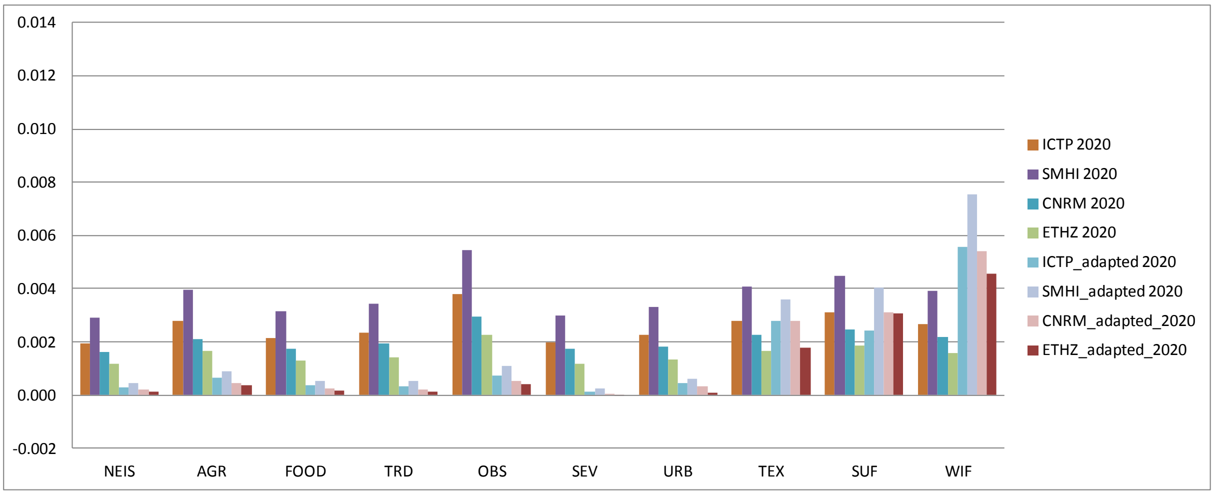

Figure 14: Change in relative tourism prices and selected non-tourism sectors' prices over the period 2011-2030 (compared to BAU prices in %)

In period two however, also all tourism clusters profit from this foreign expenditure effect, and can counterbalance increasing adaptation costs with lower costs for intermediate and factor inputs in the adaptation scenarios. This is visualized by higher price differentials between impacts and adaptation scenarios in Figure 15. The fact that equilibrium prices for tourism services provided by the four tourism clusters are lower in the adaptation scenarios than in the impact scenarios (even for WIF), makes it less attractive for consumers to substitute away from tourism services, which allows for an almost 75% effectiveness of adaptation measures in the total tourism sector. Nevertheless slight intra-sectoral consumption redistributions benefiting cluster URB are still present (Figure 12).

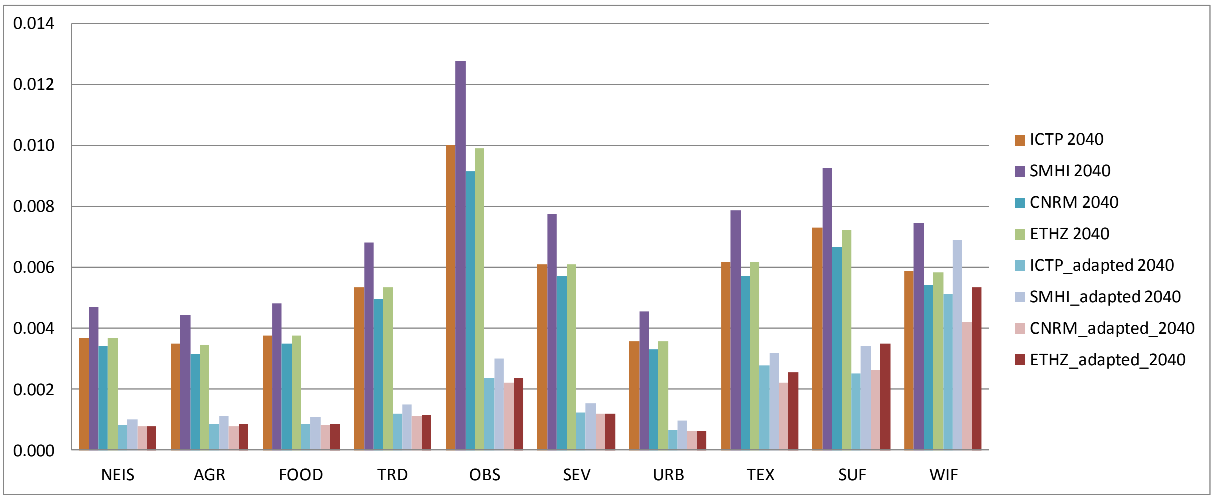

Figure 15: Change in relative tourism prices and selected non-tourism sectors' prices over the period 2031-2050 (compared to BAU prices in %)

6 Conclusions

The present analysis has shown that climate change impacts on Austrian tourism can be severe, especially in the longer term until 2050. For tourism during the winter season, each of the four considered climate change scenarios indicates negative climatic effects on demand in all four tourism region types. For the summer season, the extent of potential climate change impacts are found to be smaller and the impact direction to be less clear.

By distinguishing four different tourism clusters, we found that negative effects on the tourism sector can vary substantially with respect to the focus and the geographical situation of the tourism region in question. While impacts on the tourism regions with a focus on urban and thermal spa tourism are found to be less severe, tourism regions with a high winter tourism intensity – clustered in focus winter tourism cluster – will suffer considerably more. Strongest relative impacts are likely to occur in the tourism cluster focusing on summer tourism, for which however snow-based tourism is also an important source of income during the winter season. Since the relevant ski resorts are situated at relatively low altitudes they will be most strongly affected by reduced precipitation, leading to output losses of the focus summer cluster amounting to 13 % compared to a business as usual output projection (which projects output losses for this cluster even without climate change impacts).

Due to macroeconomic feedback effects, not only the directly affected tourism sector suffers from climate change impacts, but also non-tourism sectors are affected. While until 2020 negative overall non-tourism sector effects prevail (due to reduced demand from tourism sectors), the overall effect becomes positive until 2040. Overall, the indirect effects on other sectors are found to be smaller than the direct effects.

Appropriate adaptation measures may counteract a substantial fraction of climate change impacts on tourism. But this increases production costs, in particular for artificial snow making. As the dominance of the winter season differs across tourism types, adaptation leads to price increases in the focus winter tourism region for all climatic scenarios in 2020. In contrast, adaptation in the other clusters may lead to price decreases as cost savings from reduced heating as well as reduced prices from other inputs outweigh additional costs for cooling in summer and artificial snow making.

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8 APPENDIX

Table 12: Elasticities of substitution in production and final demand

Sector	s*	int*	elke*	elk*	elc**
NRG	0.729	0.309	0.553	0.139	0.160
ELY	0	0.391	0.256	0.460	0.160
CRP	0.848	0.082	0	0.334	0.160
PC	0.848	0.082	0	0.334	0.160
REIS	0.629	0	0.300	0.323	0.160
NEIS	0.563	0.490	0.493	0.149	0.160
OTP	0.352	0.331	0.281	0.310	0.160
WTP	0.352	0.331	0.281	0.310	0.160
ATP	0.352	0.331	0.281	0.310	0.160
AGR	0.392	0	0.516	0.023	0.160
FOOD	0.329	0	0.395	0.382	0.160
FRS	0.695	0.115	0.456	0.087	0.160
OMN	0.392	0.309	0.553	0.139	0.160
FSH	0.392	0	0.395	0.382	0.160
TRD	0.902	0.132	0.784	0.316	0.160
ISR	0.492	0	0.320	0.264	0.160
OBS	0.492	0	0.320	0.264	0.160
ROS	0.902	0.132	0.784	0.316	0.160
SEV	0.582	0	0.481	0.295	0.160
URB	0.902	0.132	0.784	0.316	0.160
TEX	0.902	0.132	0.784	0.316	0.160
SUF	0.902	0.132	0.784	0.316	0.160
WIF	0.902	0.132	0.784	0.316	0.160
Final Demand	0.200	0.500	-	-	0.500

Source: **Okagawa and Ban (2008), **Beckman and Hertel (2009)*

Table 13: Annual multifactor productivity growth rates for non tourism sectors; Source: EU-KLEMS 2009

NRG	0.10%
ELY	2.24%
CRP	1.31%
PC	0.56%
REIS	0.92%
NEIS	1.05%
OTP	0.08%
WTP	0.08%
ATP	0.08%
AGR	1.08%
FOOD	0.97%
FRS	1.08%
OMN	2.86%
FSH	1.08%
TRD	0.38%
ISR	-0.94%
OBS	-1.39%
ROS	-0.92%
SEV	-0.09%
INVEST	-0.94%

Table 14: Adaptation cost structures in ICTP_2020 scenario rel. to 2006 [1,000 €]

Winter_ ICTP_2020	URB	TEX	SUF	WIF
ELY	392	1,849	1,153	9,570
PC	-690	-310	-200	-1,690
OBS	54	255	159	1,320
LAB	176	829	517	4,290
CAPITAL	729	3,443	2,147	17,820
taxes	224	1,108	697	5,738
Total	884	7,173	4,472	37,048
Total (%)	0.01%	0.29%	0.25%	0.64%

Summer_ ICTP_2020	URB	TEX	SUF	WIF
ELY	130	60	60	70
PC	0	0	0	0
OBS	0	0	0	0
LAB	0	0	0	0
CAPITAL	0	0	0	0
taxes	2	1	1	1
Total	132	61	61	71
Total (%)	0.00%	0.00%	0.00%	0.00%

Table 15: Adaptation cost structures in SMHIRCA_2020 scenario rel. to 2006 [1,000 €]

Winter_ SMHI_2020	URB	TEX	SUF	WIF
ELY	500	2,327	1,958	13,246
PC	-1,270	-610	-310	-3,860
OBS	69	321	270	1,827
LAB	224	1,043	878	5,938
CAPITAL	932	4,334	3,645	24,665
Taxes	282	1,391	1,184	7,915
Total	737	8,806	7,624	49,730
Total (%)	0.01%	0.36%	0.42%	0.86%

Summer_ SMHI_2020	URB	TEX	SUF	WIF
ELY	70	40	50	40
PC	0	0	0	0
OBS	0	0	0	0
LAB	0	0	0	0
CAPITAL	0	0	0	0
Taxes	1	1	1	1
Total	71	41	51	41
Total (%)	0.00%	0.00%	0.00%	0.00%

Table 16: Adaptation cost structures in CNRM_2020 scenario rel. to 2006 [1,000 €]

Winter_ CNRM_2020	URB	TEX	SUF	WIF
ELY	305	1,936	1,631	9,635
PC	-500	-310	-190	-1,950
OBS	42	267	225	1,329
LAB	137	868	731	4,319
CAPITAL	567	3,605	3,038	17,942
taxes	175	1,160	988	5,773
Total	725	7,525	6,423	37,048
Total (%)	0.01%	0.31%	0.36%	0.64%

Summer_ CNRM_2020	URB	TEX	SUF	WIF
ELY	230	110	120	140
PC	0	0	0	0
OBS	0	0	0	0
LAB	0	0	0	0
CAPITAL	0	0	0	0
Taxes	3	2	2	3
Total	233	112	122	143
Total (%)	0.00%	0.00%	0.01%	0.00%

Table 17: Adaptation cost structures in ETHZ_2020 scenario rel. to 2006 [1,000 €]

Winter_ ETHZ_2020	URB	TEX	SUF	WIF	**Summer_ ETHZ_2020**	URB	TEX	SUF	WIF
ELY	326	1,414	1,740	8,961	ELY	160	80	80	100
PC	-1,920	-880	-500	-4,530	PC	0	0	0	0
OBS	45	195	240	1,236	OBS	0	0	0	0
LAB	146	634	780	4,017	LAB	0	0	0	0
CAPITAL	608	2,633	3,240	16,686	CAPITAL	0	0	0	0
taxes	171	838	1,049	5,320	Taxes	2	1	1	2
Total	-624	4,833	6,549	31,690	Total	162	81	81	102
Total (%)	-0.01%	0.20%	0.36%	0.55%	Total (%)	0.00%	0.00%	0.00%	0.00%

Table 18: Adaptation cost structures in ICTP_2040 scenario rel. to 2006 [1,000 €]

Winter_ ICTP_2040	URB	TEX	SUF	WIF	**Summer_ ICTP_2040**	URB	TEX	SUF	WIF
ELY	413	2,023	1,131	11,832	ELY	230	110	120	140
PC	-2,390	-1,070	-600	-5,410	PC	0	0	0	0
OBS	57	279	156	1,632	OBS	0	0	0	0
LAB	185	907	507	5,304	LAB	0	0	0	0
CAPITAL	770	3,767	2,106	22,032	CAPITAL	0	0	0	0
taxes	218	1,202	678	7,034	taxes	3	2	2	3
Total	-747	7,107	3,978	42,424	Total	233	112	122	143
Total (%)	-0.01%	0.29%	0.22%	0.73%	Total (%)	0.00%	0.00%	0.01%	0.00%

Table 19: Adaptation cost structures in SMHIRCA_2040 scenario rel. to 2006 [1,000 €]

Winter_ SMHI_2040	URB	TEX	SUF	WIF	**Summer_ SMHI_2040**	URB	TEX	SUF	WIF
ELY	740	2,132	1,675	16,291	ELY	110	50	60	60
PC	-2,790	-1,330	-730	-7,430	PC	0	0	0	0
OBS	102	294	231	2,247	OBS	0	0	0	0
LAB	332	956	751	7,303	LAB	0	0	0	0
CAPITAL	1,377	3,969	3,119	30,335	CAPITAL	0	0	0	0
taxes	407	1,264	1,006	9,685	taxes	1	1	1	1
Total	167	7,284	6,051	58,430	Total	111	51	61	61

Total (%)	0.00%	0.30%	0.33%	1.01%	Total (%)	0.00%	0.00%	0.00%	0.00%

Table 20: Adaptation cost structures in CNRM_2040 scenario for tourism region types rel. to 2006 [1,000 €]

Winter_ CNRM_2040	URB	TEX	SUF	WIF	**Summer_ CNRM_2040**	URB	TEX	SUF	WIF
ELY	413	1,479	1,436	9,918	ELY	350	180	200	240
PC	-2,500	-1,200	-740	-6,540	PC	0	0	0	0
OBS	57	204	198	1,368	OBS	0	0	0	0
LAB	185	663	644	4,446	LAB	0	0	0	0
CAPITAL	770	2,754	2,673	18,468	CAPITAL	0	0	0	0
taxes	216	873	861	5,860	taxes	4	2	3	4
Total	-859	4,773	5,071	33,520	Total	354	182	203	244
Total (%)	-0.01%	0.19%	0.28%	0.58%	Total (%)	0.01%	0.01%	0.01%	0.00%

Table 21: Adaptation cost structures in ETHZ_2040 scenario for tourism region types rel. to 2006 [1,000 €]

Winter_ ETHZ_2040	URB	TEX	SUF	WIF	**Summer_ ETHZ_2040**	URB	TEX	SUF	WIF
ELY	566	1,914	2,306	13,333	ELY	330	170	210	220
PC	-3,220	-1,490	-870	-8,240	PC	0	0	0	0
OBS	78	264	318	1,839	OBS	0	0	0	0
LAB	254	858	1,034	5,977	LAB	0	0	0	0
CAPITAL	1,053	3,564	4,293	24,827	CAPITAL	0	0	0	0
taxes	298	1,131	1,387	7,887	taxes	4	2	3	4
Total	-972	6,241	8,467	45,622	Total	334	172	213	224
Total (%)	-0.01%	0.25%	0.47%	0.79%	Total (%)	0.00%	0.01%	0.01%	0.00%