# Modeling Climate Change Adaptation in a Computable General Equilibrium Model: an Application to Tourism

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# Outline

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# Project goals

- The research project is a mandate from the Swiss federal office for the environment which aims at:
  - identifying the Swiss sectors most at risk from climate change
  - introducing and detailing these sectors in the CGE model GEMINI-E3
  - using GEMINI-E3 to assess the general equilibrium costs of climate change for Switzerland
  - studying the role of adaptation processes and measures to alleviate climate change costs
- The research project focuses on the following sectors:
  - Agriculture ; Energy ; Health ; Infrastructures ; Insurance ; Tourism ; Water

# The GEMINI-E3 model

- World computable general equilibrium model
- Fifth version
- Dedicated to the analysis of climate change & energy policies
- 28 regions (including Switzerland)
- 5 energy sectors
- 13 non-energy sectors
- All GHG Emissions (EMF 21)
- Database GTAP 6 (2001)
- gemini-e3.epfl.ch

# Outline

# The Swiss tourism sector - some stylized facts

## Why consider tourism ?

- "Only" 3.1% of the Swiss GDP in 2001 but highly important for certain regions
- Third largest export sector in 2001
- Highly sensitive to climate change
- One of the most vulnerable sectors of the Swiss economy
- Ski industry: between 7 to 9% of worldwide skier visits

# Tourism and climate change in Switzerland

- Valuation of impacts:
  - *NFP31 Studie (1998)*
  - *Ecoplan/Sigmaplan Studie (2007)*
  - *FIF-Studie (2007)*
- Main insights from the above-mentioned studies:
  - Impact costs ranging from 2 billion to 100 million CHF (2050) !
  - Alpine tourism: losses (winter) $>$ extra-revenues (summer)
  - The most vulnerable segment $\Rightarrow$ low-lying ski areas relying on day-trippers
  - Adaptation is important to alleviate the costs of climate change
  - A general equilibrium problem requiring a general equilibrium framework

# Outline

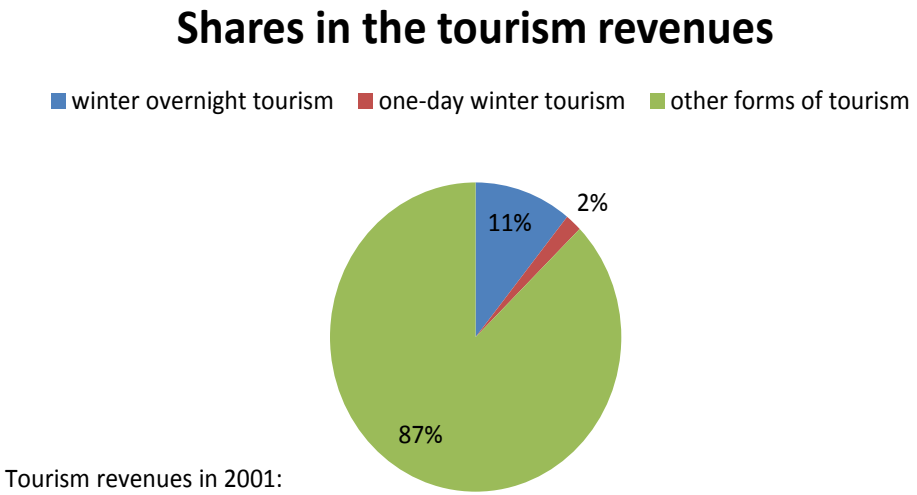
# Four steps

1. Create three tourism segments:
   - Winter Overnight Tourism
   - One-day Winter Tourism
   - Other Forms of Tourism
2. Determine and implement in GEMINI-E3:
   - A production structure for the snow-dependent segments
   - How tourism enters the household consumption function
3. Valuate the natural snow resource for the snow-dependent segments
4. Simulate a decrease in the snow resource

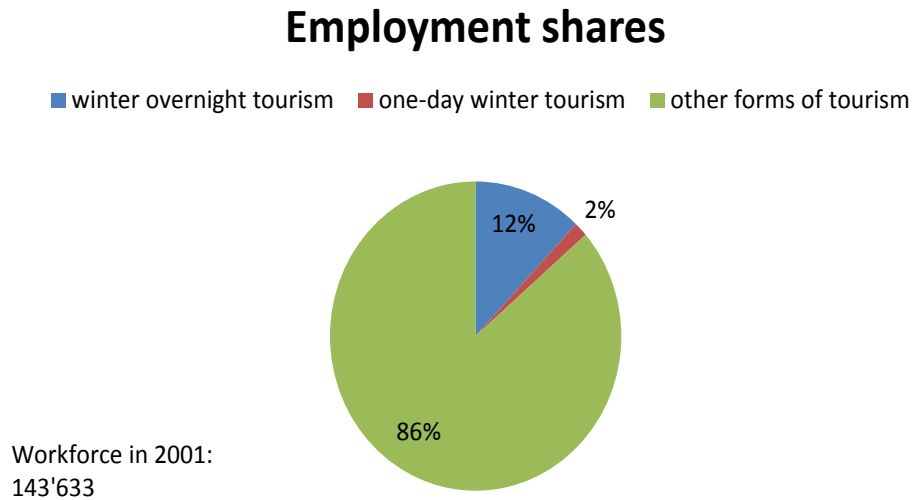
# The Swiss tourism sector

- The tourism sector in 2001 (CST):
  - 17 892 mio USD
  - 143 633 jobs

- Snow-dependent winter tourism segments:
  - 13% of revenues
  - 14% of FTE




Tourism revenues in 2001:
17'892 million USD

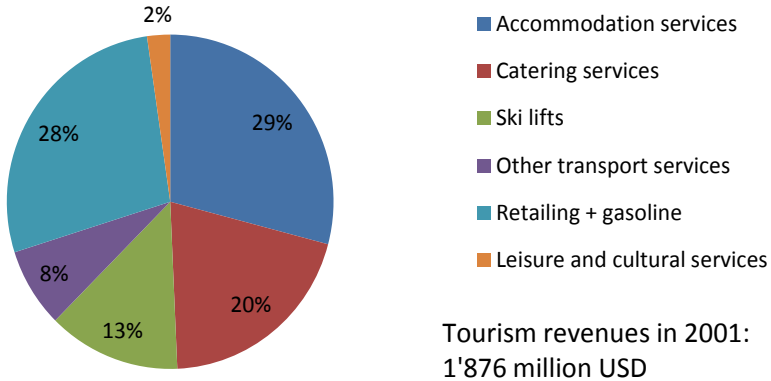



Workforce in 2001:
143'633

# Snow-dependent winter tourism segments

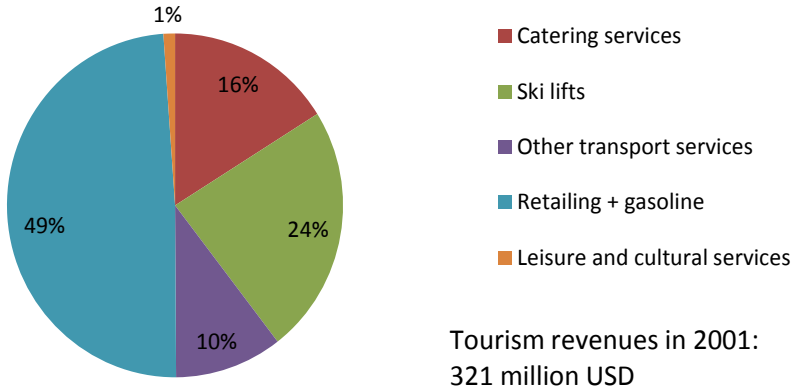
- Size difference:
  - 1 876 versus 321 million USD
- Relative shares of tourism products change:
  - Accommodation
  - Ski lifts
  - Gasoline

**Winter overnight tourism: share of different tourism products**




Tourism revenues in 2001: 1'876 million USD

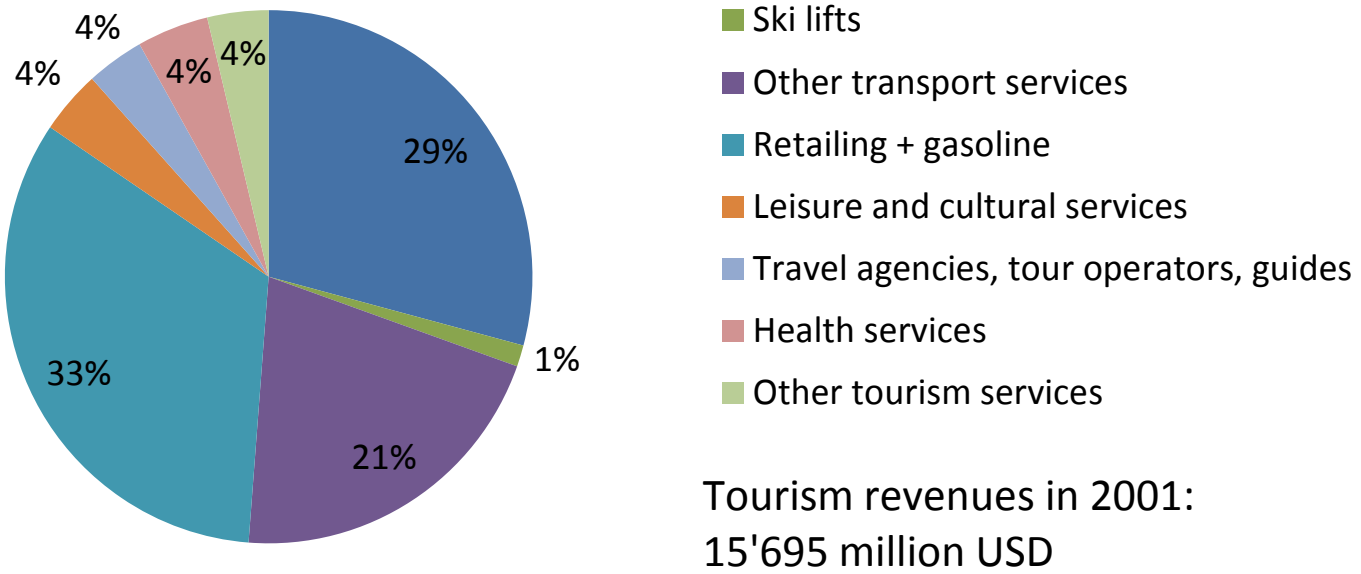
**One-day Winter Tourism: share of different tourism products**




Tourism revenues in 2001: 321 million USD

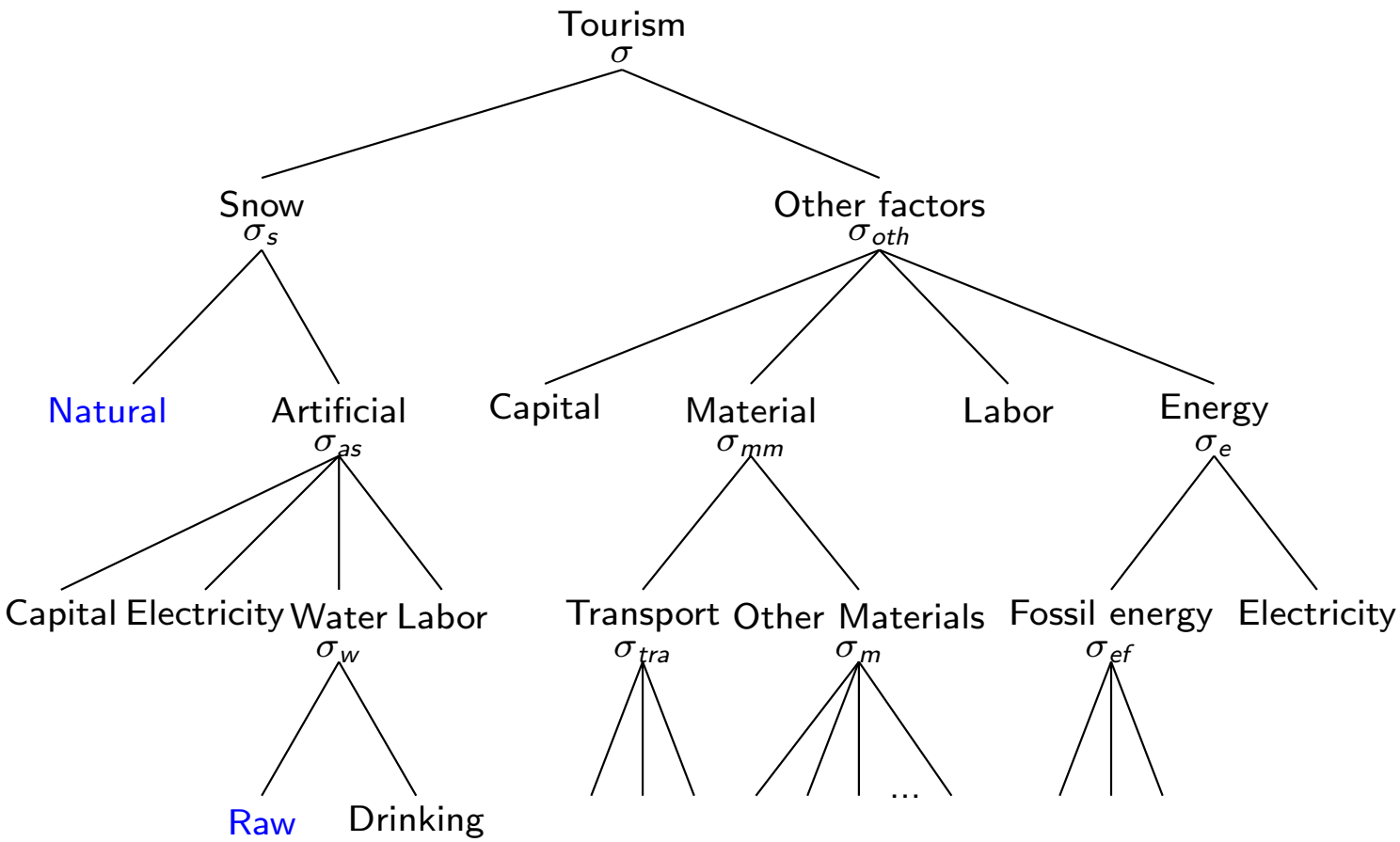
# The "other forms of tourism" segment

**Other forms of tourism:**
**share of different tourism products**




Tourism revenues in 2001:
15'695 million USD

# Nested CES production function

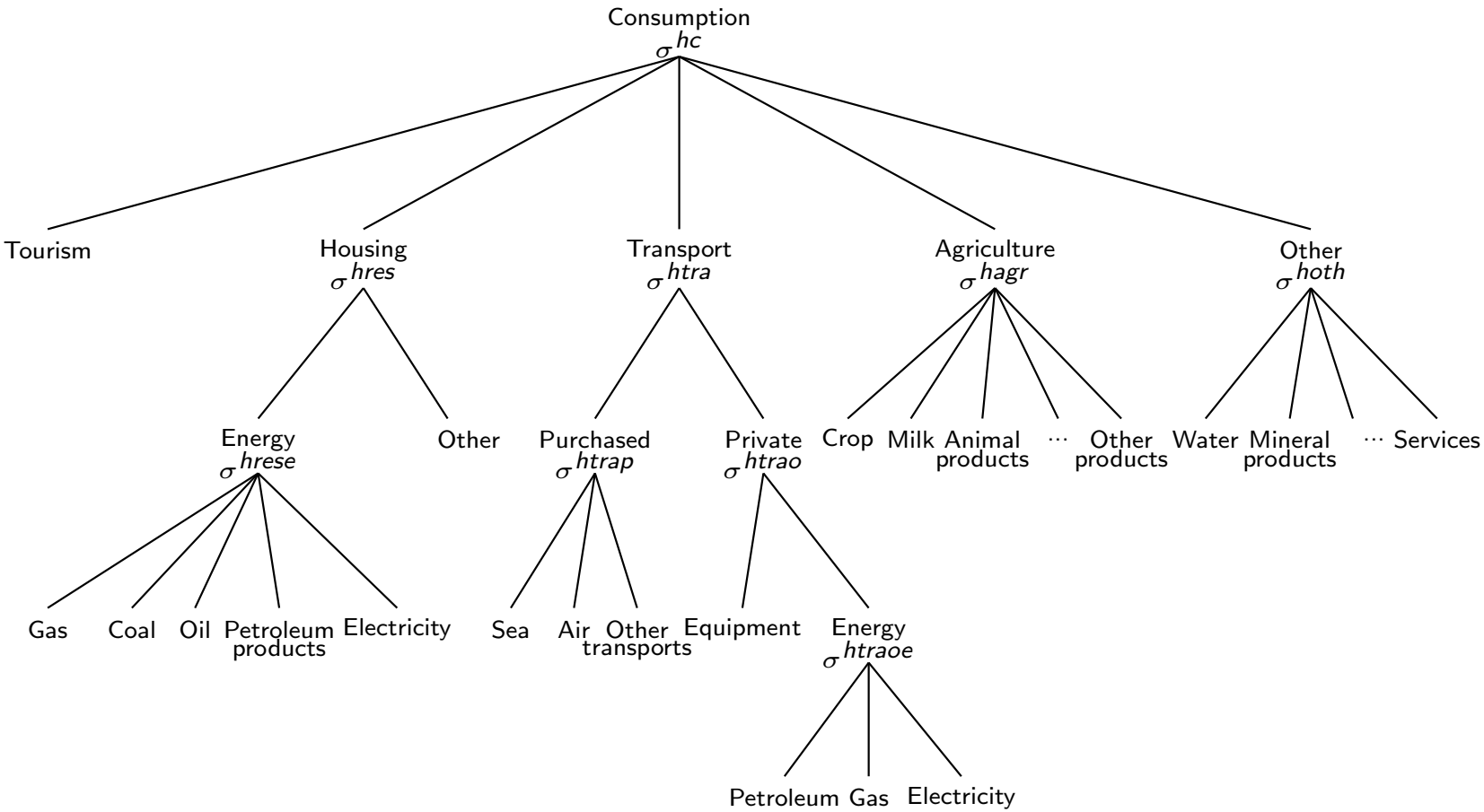


# Nested CES production function

TABLE 1: Elasticities of substitution

| Elasticities of substitution | | |
|---|---|---|
| Snow and other factors | $\sigma$ | 0.1 |
| Natural and artificial snow (overnight) | $\sigma_s$ | 0.9 |
| Natural and artificial snow (one-day) | $\sigma_s$ | 0.45 |
| Among inputs used to produce artificial snow | $\sigma_{as}$ | 0.3 |
| Industrial and drinking water | $\sigma_w$ | 0.5 |

# Tourism demand in GEMINI-E3



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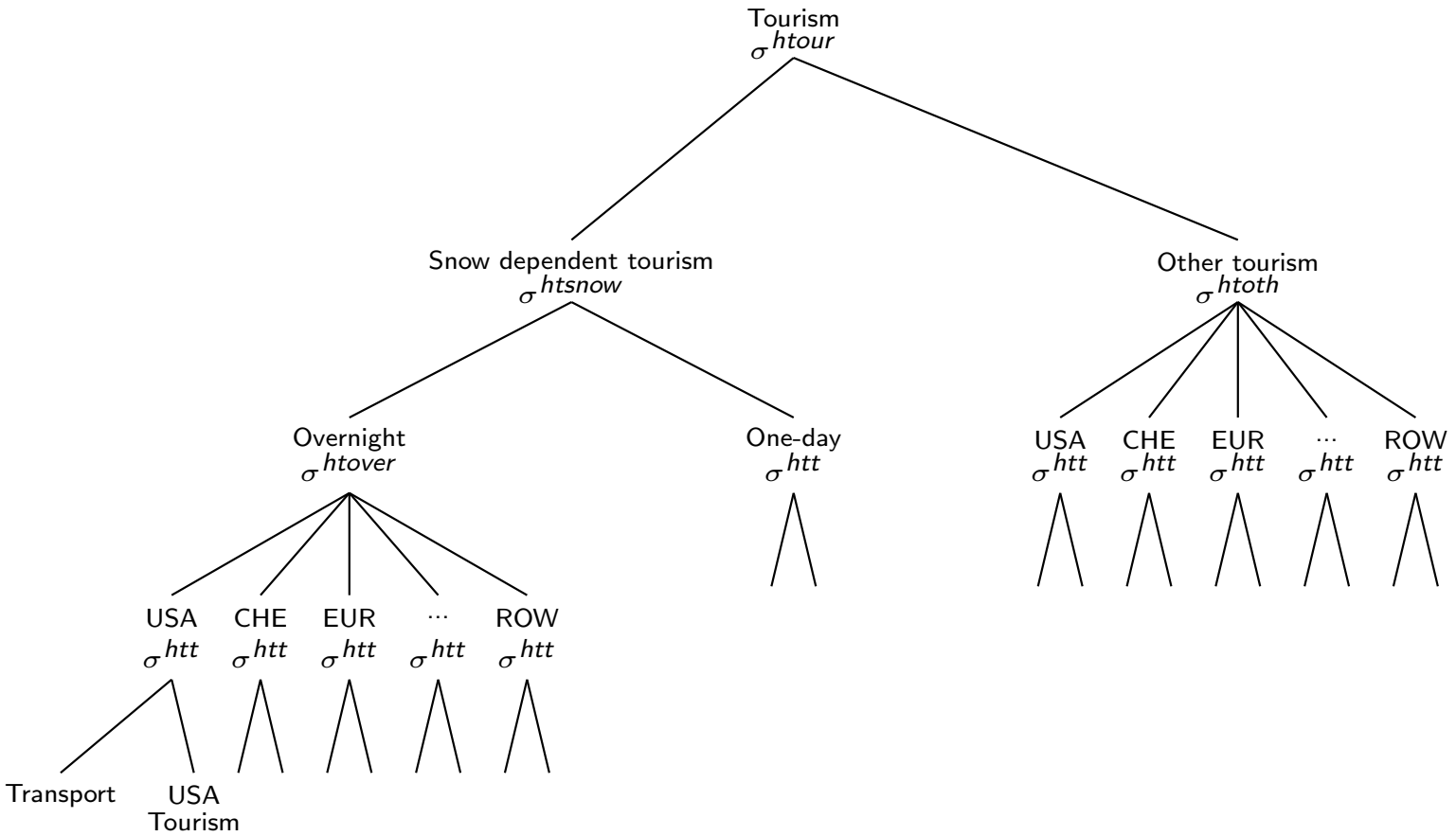


# Tourism demand in GEMINI-E3

TABLE 2: Elasticities of substitution

| Elasticities of substitution | | |
|---|---|---|
| Snow dependent and other tourism | $\sigma^{htour}$ | 0.7 |
| Overnight and one-day tourism | $\sigma^{htsnow}$ | 0.5 |
| Domestic and foreign tourism (overnight) | $\sigma^{htover}$ | 0.1 |
| Domestic and foreign tourism (other tourism) | $\sigma^{htoth}$ | 0.1 |
| Transport and other goods consumed | $\sigma^{htt}$ | 0.2 |

# Valuation of the snow resource: method

- Econometric analysis both at the Swiss ski lifts companies and ski domains levels:
  - Control for omitted variable bias (e.g. weather conditions in lowlands, snow conditions in the other ski areas, monthly features of tourism demand)
  - Estimation of linear panel data regression models using different samples and estimators
- Winter season profit from "snow days" extrapolated:
  - first for the ski lifts sector and the hotel industry
  - then for the snow-dependent tourism segments

# Valuation of the snow resource: results

- Results from the econometric analysis:
  - Partial effects of snow on ski lift tickets sales, skier visits and overnight stays
  - Coefficients interpreted as (short-term) semi-elasticities
  - Differentiated impacts for ski areas located at different altitudes

TABLE 3: Table of semi-elasticities

| Max. altitude | tickets sales (winter season) | Skier visits (winter season) | Overn. Stays (monthly) |
|---|---|---|---|
| $< 2000m$ | 0.23% | 0.67% | 0.57% |
| $> 2000m$ | | 0.10% | -0.04% |

- Snow endowment valuation (preliminary results):

$$V_{one-day,snow} : 8\,647\,704\ USD$$
$$V_{overnight,snow} : 84\,924\,888\ USD$$

# Variation in the snow endowment

- We downscale our climate change impacts by using the ENSEMBLES regional scenarios (simulations for scenario A1B)
- We use 4 GCM/RCM combinations (grid with a mesh of 25x25km):
  - KNMI - ECHAM5-r3 avec RACMO (1951-2100) ;
  - SMHI - BCM-RCA (1961-2100) ;
  - C4I - HadCM3Q16-RCA3 (1951-2099) ;
  - DMI - ARPEGE-HIRHAM (1951-2100) ;
- Climate variable: Fractional snow cover (monthly values)

# Variation in the snow endowment: method

- For the 176 meshes covering the Swiss territory, averages of monthly values are first computed for the period 1961-1990 and then by decades up to 2050
- A specific set of (time-invariant) grid weights is defined for each snow-dependent winter tourism segment
- Monthly variations are aggregated into a single winter season variation by giving a (time-invariant) weight to each month

# Variation in the snow endowment: grid weights

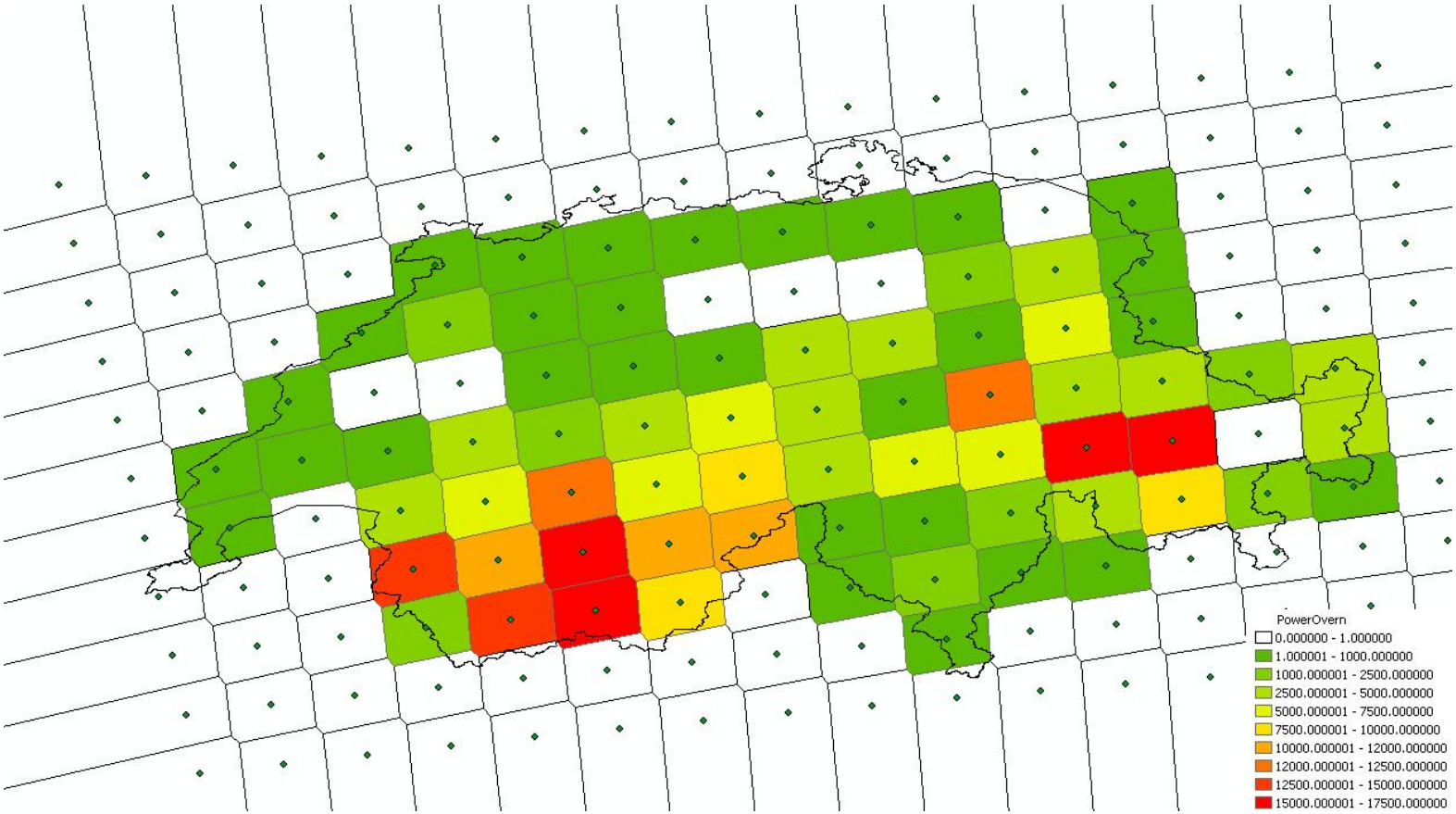



FIGURE 1: Weights obtained for the winter overnight tourism segment (using data on ski lifts' transport capacities and skier visits)

# Variation in the snow endowment: grid weights

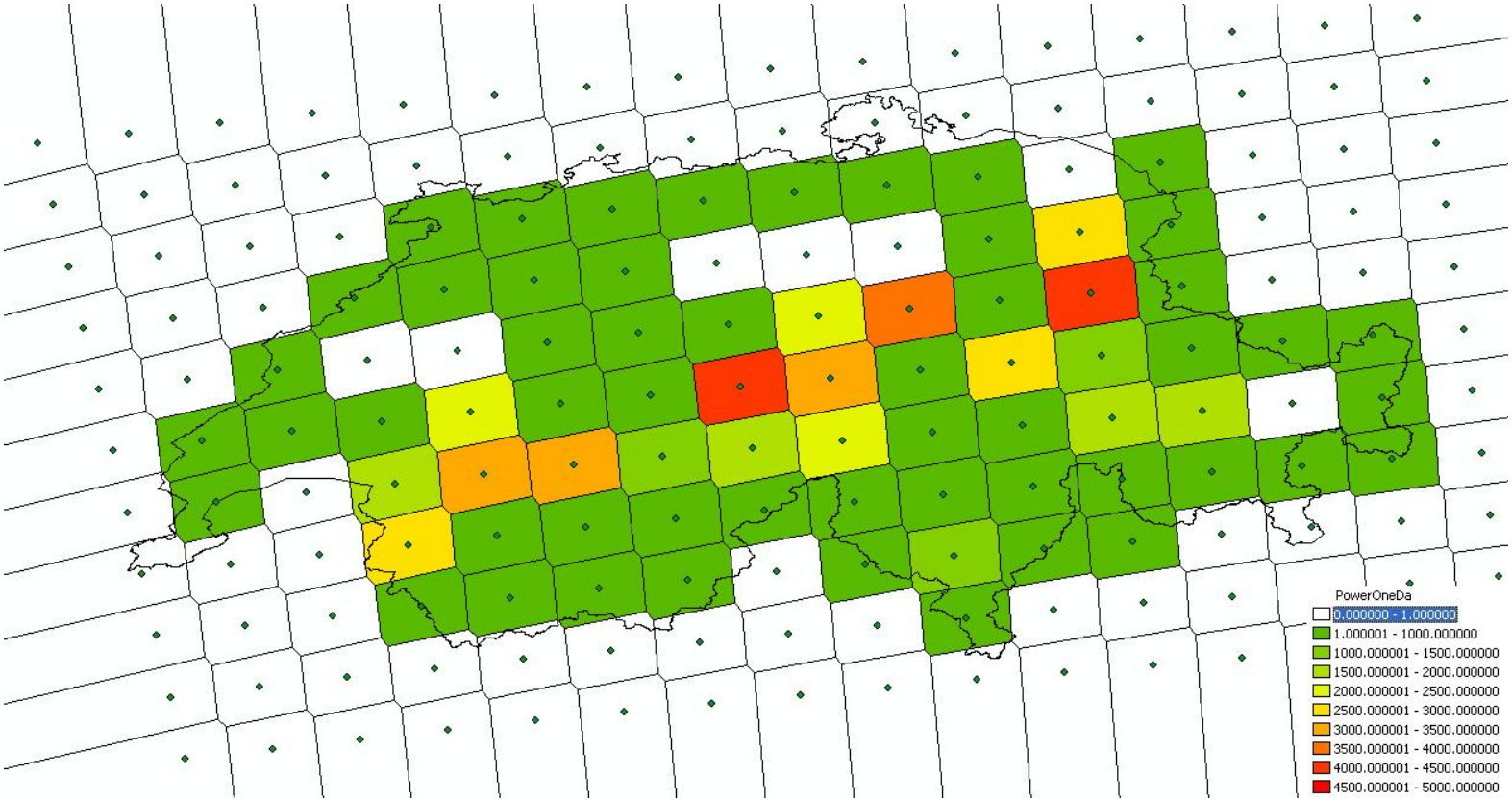



FIGURE 2: Weights obtained for the one-day winter tourism segment (using data on ski lifts' transport capacities and skier visits)

# Variation in the snow endowment: time weights

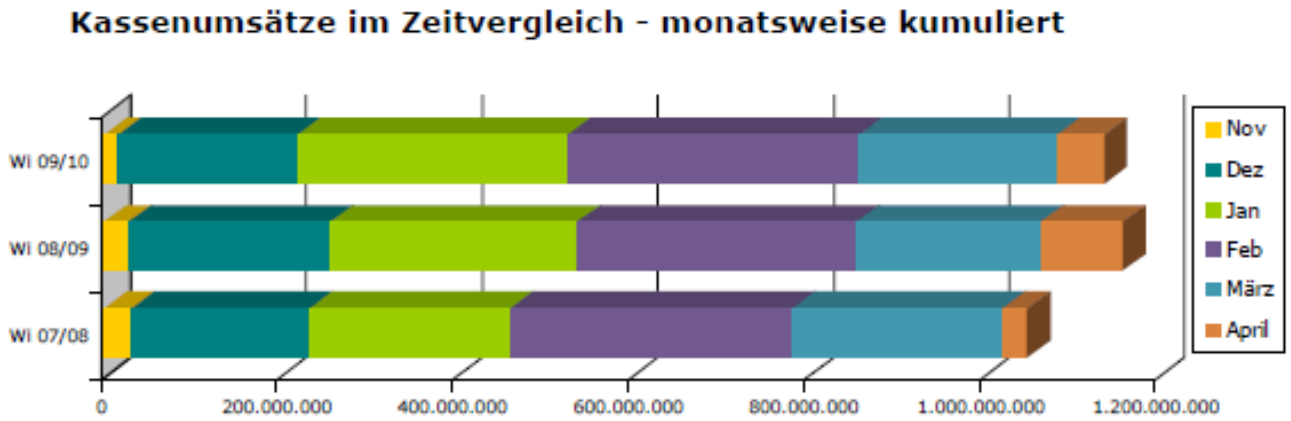


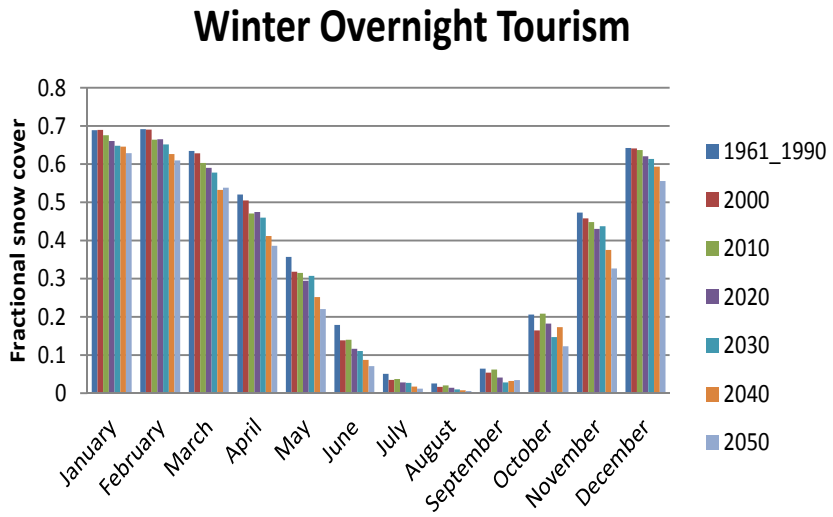

FIGURE 3: Distribution of transport revenues during the winter season for the Austrian ski lifts (Source: Fachverband der Seilbahnen Österreichs)

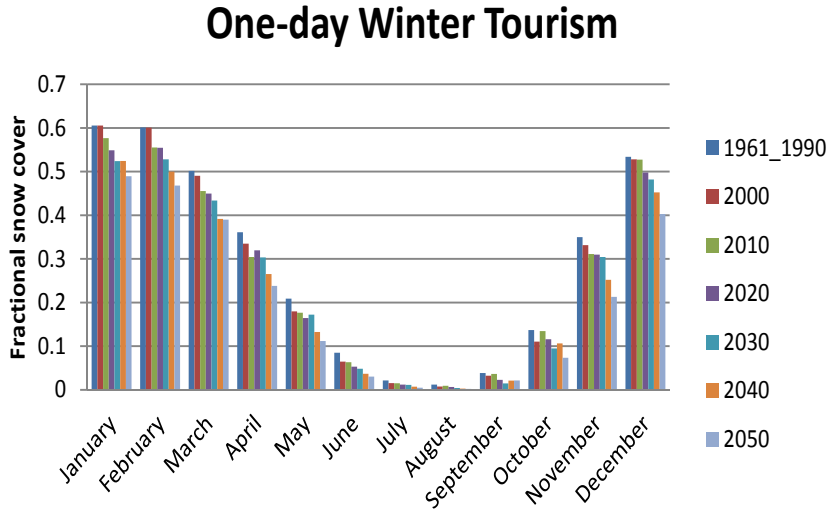
| November | December | January | February | March | April |
|---|---|---|---|---|---|
| 0.03 | 0.17 | 0.25 | 0.35 | 0.15 | 0.05 |

TABLE 4: Weights given to each of winter season months

# Variation in the natural snow endowment: results

| Segment | $Variation_{2050}$ |
|---|---|
| Overnight | -13.1% |
| One-day | -22.9% |



# Scenarios performed in the tourism sector

We perform 8 scenarios:

1. *With adaptation*: We implement the variation of the natural snow endowment derived from Ensembles with adaptation
2. *Without adaptation*: We run the same scenario without adaptation on the supply side ($\sigma$=0 and $\sigma_s$=0)
3. *High adaptation*: We suppose high level of adaptation on the supply side ($\sigma$ and $\sigma_s$ are multiplied by 2)
4. *Low elasticities of consumption*: We assume low level of substitution within tourism ($\sigma_{htour}$ and $\sigma_{htsnow}$ are divided by 2)
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# Results of the scenarios in 2050

| | With Adapt. | Without Adapt. | With High Adapt. | Low elas. Conso. | High elas. Conso. | High Snow ↘ | High Snow ↘ + sub. 25% | High Snow ↘ +sub. 50% |
|---|---|---|---|---|---|---|---|---|
| **Ski Overnight** | | | | | | | | |
| Production* | -2.6% | -13.1% | -1.4% | -2.0% | -3.5% | -6.3% | -4.3% | -1.7% |
| Natural Snow | -13.1% | -13.1% | -13.1% | -13.1% | -13.1% | -26.2% | -26.2% | -26.2% |
| Artificial Snow | 19.8% | -13.1% | 25.7% | 21.8% | 16.7% | 45.3% | 66.5% | 100.0% |
| Production price | 2.8% | 16.3% | 1.5% | 2.9% | 2.5% | 6.7% | 4.1% | 1.0% |
| Employment† | -1.9% | -13.1% | -0.7% | -1.3% | -2.9% | -4.8% | -2.9% | -0.4% |
| **Ski One day** | | | | | | | | |
| Production* | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -19.4% | -18.5% | -17.3% |
| Natural Snow | -22.9% | -22.9% | -22.9% | -22.9% | -22.9% | -45.9% | -45.9% | -45.9% |
| Artificial Snow | 23.9% | -22.9% | 35.1% | 31.3% | 14.5% | 60.9% | 82.1% | 116.8% |
| Production price | 10.7% | 59.9% | 4.9% | 12.8% | 8.2% | 49.8% | 47.3% | 44.3% |
| Employment† | -3.8% | -22.9% | -1.3% | -1.4% | -7.0% | -14.4% | -13.4% | -12.2% |
| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
| Ski One day | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -8.2% | -18.4% | -17.3% |
| Other Tourism | 0.1% | 0.5% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.2% |
| Surplus Mio $USD_{2010}$ | -35 | -122 | -24 | -28 | -41 | -108 | -93 | -75 |
| in % Household Final Consumption | -0.01% | -0.03% | -0.01% | -0.01% | -0.01% | -0.02% | -0.02% | -0.02% |

* Constant price sales revenue

† Employment expressed as full-time job equivalents

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| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
| Ski One day | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -8.2% | -18.4% | -17.3% |
| Other Tourism | 0.1% | 0.5% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.2% |
| Surplus Mio $USD_{2010}$ | -35 | -122 | -24 | -28 | -41 | -108 | -93 | -75 |
| in % Household Final Consumption | -0.01% | -0.03% | -0.01% | -0.01% | -0.01% | -0.02% | -0.02% | -0.02% |

* Constant price sales revenue

† Employment expressed as full-time job equivalents

# Results of the scenarios in 2050

| | With Adapt. | Without Adapt. | With High Adapt. | Low elas. Conso. | High elas. Conso. | High Snow ↘ | High Snow ↘ + sub. 25% | High Snow ↘ +sub. 50% |
|---|---|---|---|---|---|---|---|---|
| **Ski Overnight** | | | | | | | | |
| Production* | -2.6% | -13.1% | -1.4% | -2.0% | -3.5% | -6.3% | -4.3% | -1.7% |
| Natural Snow | -13.1% | -13.1% | -13.1% | -13.1% | -13.1% | -26.2% | -26.2% | -26.2% |
| Artificial Snow | 19.8% | -13.1% | 25.7% | 21.8% | 16.7% | 45.3% | 66.5% | 100.0% |
| Production price | 2.8% | 16.3% | 1.5% | 2.9% | 2.5% | 6.7% | 4.1% | 1.0% |
| Employment† | -1.9% | -13.1% | -0.7% | -1.3% | -2.9% | -4.8% | -2.9% | -0.4% |
| **Ski One day** | | | | | | | | |
| Production* | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -19.4% | -18.5% | -17.3% |
| Natural Snow | -22.9% | -22.9% | -22.9% | -22.9% | -22.9% | -45.9% | -45.9% | -45.9% |
| Artificial Snow | 23.9% | -22.9% | 35.1% | 31.3% | 14.5% | 60.9% | 82.1% | 116.8% |
| Production price | 10.7% | 59.9% | 4.9% | 12.8% | 8.2% | 49.8% | 47.3% | 44.3% |
| Employment† | -3.8% | -22.9% | -1.3% | -1.4% | -7.0% | -14.4% | -13.4% | -12.2% |
| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
| Ski One day | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -8.2% | -18.4% | -17.3% |
| Other Tourism | 0.1% | 0.5% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.2% |
| Surplus Mio $USD_{2010}$ | -35 | -122 | -24 | -28 | -41 | -108 | -93 | -75 |
| in % Household Final Consumption | -0.01% | -0.03% | -0.01% | -0.01% | -0.01% | -0.02% | -0.02% | -0.02% |

* Constant price sales revenue

† Employment expressed as full-time job equivalents

# Results of the scenarios in 2050

| | With Adapt. | Without Adapt. | With High Adapt. | Low elas. Conso. | High elas. Conso. | High Snow ↘ | High Snow ↘ + sub. 25% | High Snow ↘ +sub. 50% |
|---|---|---|---|---|---|---|---|---|
| **Ski Overnight** | | | | | | | | |
| Production* | -2.6% | -13.1% | -1.4% | -2.0% | -3.5% | -6.3% | -4.3% | -1.7% |
| Natural Snow | -13.1% | -13.1% | -13.1% | -13.1% | -13.1% | -26.2% | -26.2% | -26.2% |
| Artificial Snow | 19.8% | -13.1% | 25.7% | 21.8% | 16.7% | 45.3% | 66.5% | 100.0% |
| Production price | 2.8% | 16.3% | 1.5% | 2.9% | 2.5% | 6.7% | 4.1% | 1.0% |
| Employment† | -1.9% | -13.1% | -0.7% | -1.3% | -2.9% | -4.8% | -2.9% | -0.4% |
| **Ski One day** | | | | | | | | |
| Production* | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -19.4% | -18.5% | -17.3% |
| Natural Snow | -22.9% | -22.9% | -22.9% | -22.9% | -22.9% | -45.9% | -45.9% | -45.9% |
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| Production price | 10.7% | 59.9% | 4.9% | 12.8% | 8.2% | 49.8% | 47.3% | 44.3% |
| Employment† | -3.8% | -22.9% | -1.3% | -1.4% | -7.0% | -14.4% | -13.4% | -12.2% |
| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
| Ski One day | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -8.2% | -18.4% | -17.3% |
| Other Tourism | 0.1% | 0.5% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.2% |
| Surplus Mio $USD_{2010}$ | -35 | -122 | -24 | -28 | -41 | -108 | -93 | -75 |
| in % Household Final Consumption | -0.01% | -0.03% | -0.01% | -0.01% | -0.01% | -0.02% | -0.02% | -0.02% |

* Constant price sales revenue

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# Results of the scenarios in 2050

| | With Adapt. | Without Adapt. | With High Adapt. | Low elas. Conso. | High elas. Conso. | High Snow ↘ | High Snow ↘ + sub. 25% | High Snow ↘ +sub. 50% |
|---|---|---|---|---|---|---|---|---|
| **Ski Overnight** | | | | | | | | |
| Production* | -2.6% | -13.1% | -1.4% | -2.0% | -3.5% | -6.3% | -4.3% | -1.7% |
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| Artificial Snow | 19.8% | -13.1% | 25.7% | 21.8% | 16.7% | 45.3% | 66.5% | 100.0% |
| Production price | 2.8% | 16.3% | 1.5% | 2.9% | 2.5% | 6.7% | 4.1% | 1.0% |
| Employment† | -1.9% | -13.1% | -0.7% | -1.3% | -2.9% | -4.8% | -2.9% | -0.4% |
| **Ski One day** | | | | | | | | |
| Production* | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -19.4% | -18.5% | -17.3% |
| Natural Snow | -22.9% | -22.9% | -22.9% | -22.9% | -22.9% | -45.9% | -45.9% | -45.9% |
| Artificial Snow | 23.9% | -22.9% | 35.1% | 31.3% | 14.5% | 60.9% | 82.1% | 116.8% |
| Production price | 10.7% | 59.9% | 4.9% | 12.8% | 8.2% | 49.8% | 47.3% | 44.3% |
| Employment† | -3.8% | -22.9% | -1.3% | -1.4% | -7.0% | -14.4% | -13.4% | -12.2% |
| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
| Ski One day | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -8.2% | -18.4% | -17.3% |
| Other Tourism | 0.1% | 0.5% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.2% |
| Surplus Mio $USD_{2010}$ | -35 | -122 | -24 | -28 | -41 | -108 | -93 | -75 |
| in % Household Final Consumption | -0.01% | -0.03% | -0.01% | -0.01% | -0.01% | -0.02% | -0.02% | -0.02% |

* Constant price sales revenue

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# Results of the scenarios in 2050

| | With Adapt. | Without Adapt. | With High Adapt. | Low elas. Conso. | High elas. Conso. | High Snow ↘ | High Snow ↘ + sub. 25% | High Snow ↘ +sub. 50% |
|---|---|---|---|---|---|---|---|---|
| **Ski Overnight** | | | | | | | | |
| Production* | -2.6% | -13.1% | -1.4% | -2.0% | -3.5% | -6.3% | -4.3% | -1.7% |
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| Production price | 2.8% | 16.3% | 1.5% | 2.9% | 2.5% | 6.7% | 4.1% | 1.0% |
| Employment† | -1.9% | -13.1% | -0.7% | -1.3% | -2.9% | -4.8% | -2.9% | -0.4% |
| **Ski One day** | | | | | | | | |
| Production* | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -19.4% | -18.5% | -17.3% |
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| Employment† | -3.8% | -22.9% | -1.3% | -1.4% | -7.0% | -14.4% | -13.4% | -12.2% |
| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
| Ski One day | -5.4% | -22.9% | -2.6% | -3.3% | -8.2% | -8.2% | -18.4% | -17.3% |
| Other Tourism | 0.1% | 0.5% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.2% |
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# Results of the scenarios in 2050

| | With Adapt. | Without Adapt. | With High Adapt. | Low elas. Conso. | High elas. Conso. | High Snow ↘ | High Snow ↘ + sub. 25% | High Snow ↘ +sub. 50% |
|---|---|---|---|---|---|---|---|---|
| **Ski Overnight** | | | | | | | | |
| Production* | -2.6% | -13.1% | -1.4% | -2.0% | -3.5% | -6.3% | -4.3% | -1.7% |
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| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
| **Consumption** | | | | | | | | |
| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
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| **Other Tourism** | | | | | | | | |
| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
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| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
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| Employment† | 0.1% | 0.4% | 0.0% | 0.0% | 0.2% | 0.3% | 0.2% | 0.1% |
| Total Employment in Tourism† | -0.2% | -1.1% | -0.1% | -0.2% | -0.1% | -0.4% | -0.3% | -0.1% |
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| Ski Overnight | -1.8% | -9.2% | -0.9% | -1.0% | -3.0% | -4.6% | -3.2% | -1.6% |
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# Results of the scenarios in 2050

- Scenario "With Adapt.":
  - Relative small welfare impact for 2050: 35 mio USD (0.01% of HFC)
  - Nearly no effect on employment in the tourism sector: -0.2%
  - Both domestic *and* foreign consumptions of "Ski Overnight" are reduced
- The role of adaptation:
  - Adaptation on the demand side is important and reduces costs from -377 to -122 mio USD
  - Adaptation on the supply side reduces costs from -122 to -35 mio USD (or even to -24 mio USD $\Rightarrow$ high adaptation scenario)
  - The net effect of public authorities subsidizing artificial snow ($\Rightarrow$ **exogenous adaptation**) is positive
- Snow endowment variations:
  - A doubling effect of climate change on snow cover more than double the detrimental welfare effect

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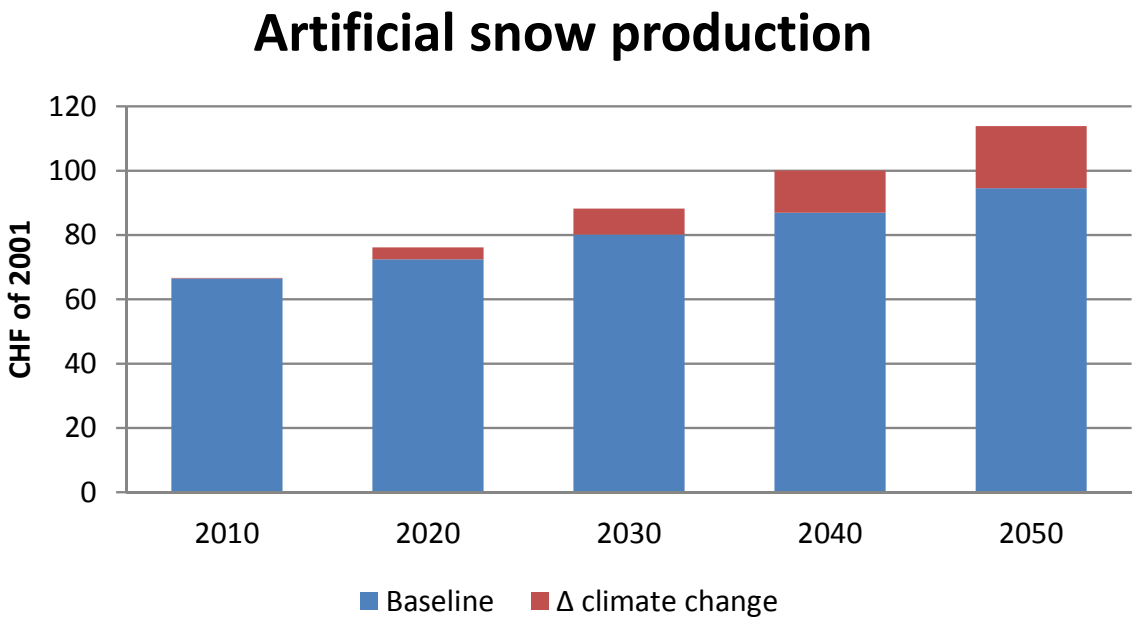
  - Both domestic *and* foreign consumptions of "Ski Overnight" are reduced
- The role of adaptation:
  - Adaptation on the demand side is important and reduces costs from -377 to -122 mio USD
  - Adaptation on the supply side reduces costs from -122 to -35 mio USD (or even to -24 mio USD $\Rightarrow$ high adaptation scenario)
  - The net effect of public authorities subsidizing artificial snow ($\Rightarrow$ **exogenous adaptation**) is positive
- Snow endowment variations:
  - A doubling effect of climate change on snow cover more than double the detrimental welfare effect

# Results of the scenarios in 2050

- Snowmaking production in the scenario "With Adapt.":




- In 2050, a 20.4% change in artificial snow production compared to the baseline (same increase for the production factors)
- From 2010 to 2050, a 70.8% increase in artificial snow production versus a 42.2% increase in the baseline (same increases for the production factors)

# Conclusion and next steps

- Summary
  - A tourism sector endowed with a snow resource has been included for Switzerland in GEMINI-E3
  - ENSEMBLES data have been extracted and processed in order to get the evolution of the snow cover up to 2050
  - First simulations of a decrease in the snow resource show moderate impacts on the Swiss economy
  - Adaptation changes drastically the size of the welfare impacts
- Next steps
  - Impacting the tourism sector of the other regions included in GEMINI-E3 (OECD, 2007)
  - Constraining the future production of artificial snow:
    - Legal restrictions already exist (period for running the equipment, ski slopes that could be equipped, limits on water withdrawal)
    - Less favorable weather conditions for snowmaking (rising temperatures)
    - Impact of the reduction in water availability
  - Carrying more in-depth sensitivity analysis

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# Thank you for your attention !