The economic aspects of artificial snow production in the perspective of climate change

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Outline

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Most common approach in the literature

1. Quantifying future snowmaking needs
   - Compensate the snow deficit to preserve ski season length
   - Daily snowmaking capacity (time-invariant)
   - Threshold air temperature to start snowmaking
   - In general, however, no limit due to water scarcity
2. Discussing/computing the increase in costs
   - Needs often double by 2050
   - Energy costs increase more than proportionately with the volume of artificial snow production
   - Combined with revenue losses (i.e. shorter ski season)
3. Feasible but hardly profitable

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Pros

- Mimic choices made by ski area operators concerning snow production
- Technical constraints are included (with the exception of water scarcity)
- Intra-seasonal patterns of snow-reliability

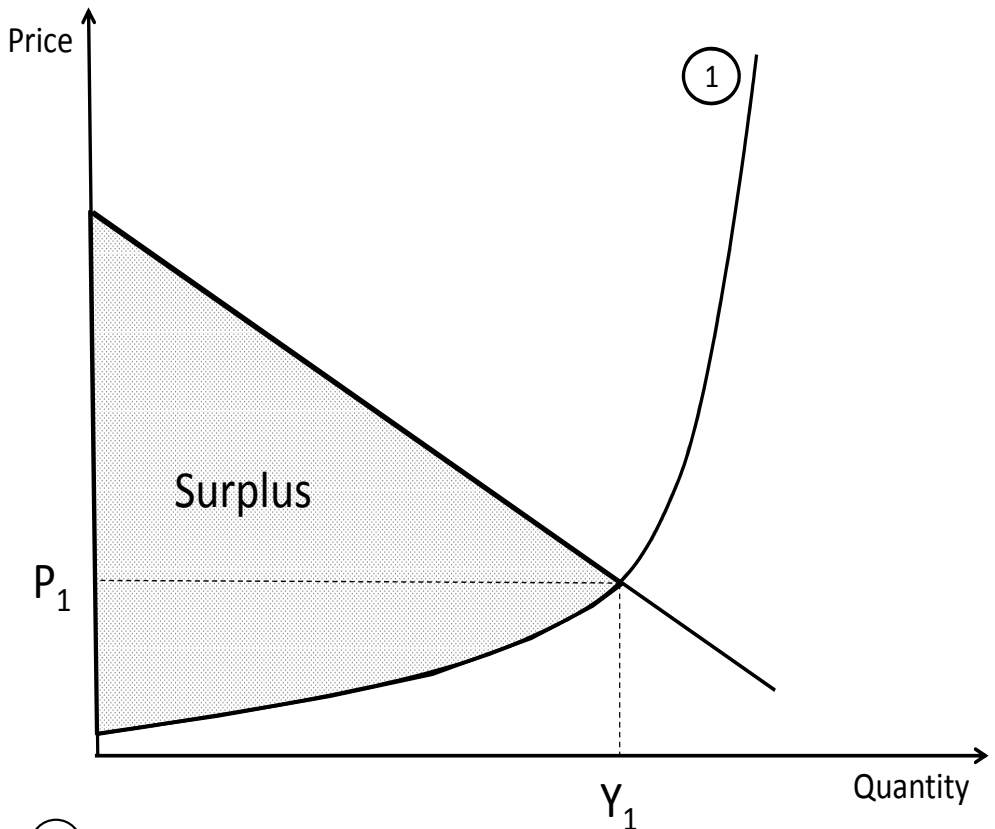
Cons

- Focus nearly exclusively on energy costs
- Too simple estimations of revenue changes
- Above all, only the supply side is dealt with ; no interactions with the demand side that determine equilibrium quantity and price

Outline

Ski market response to climate change

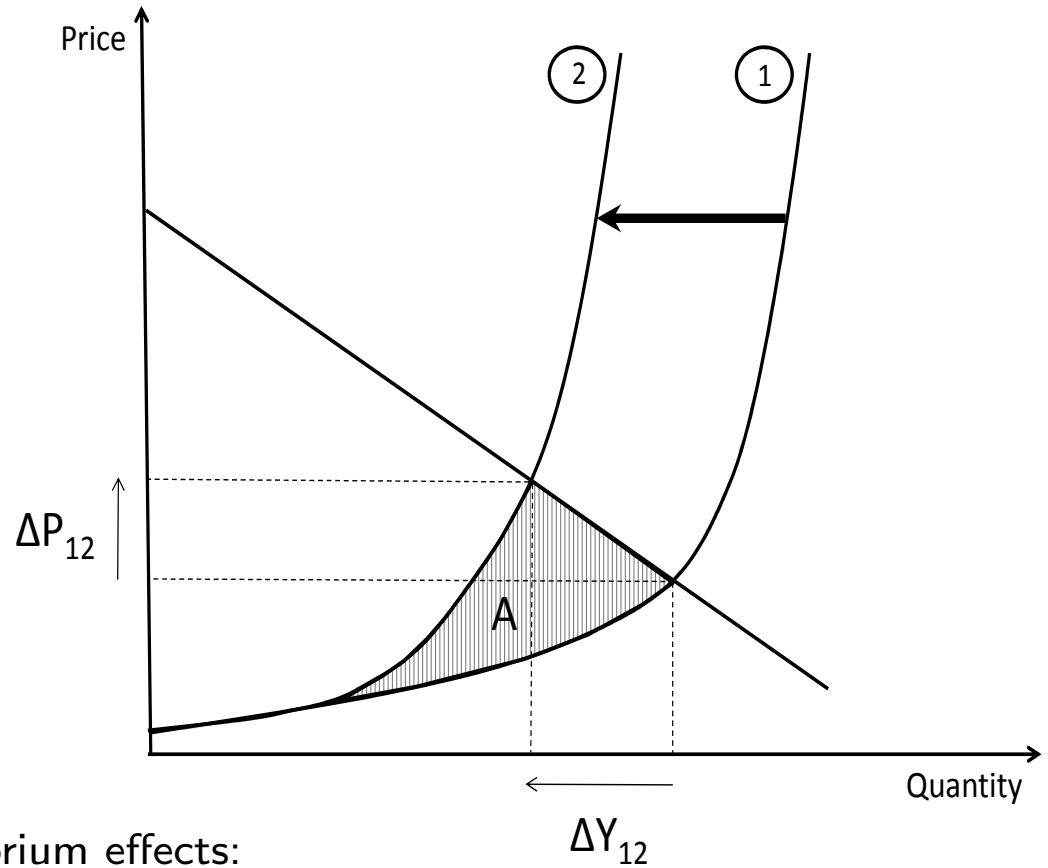
Initial situation: a winter tourism sector produces one good for which there is a demand



The supply curve (1) assumes no snowmaking, no fixed and external costs of production

Ski market response to climate change

Climate change shifts the supply curve from ① to ②:

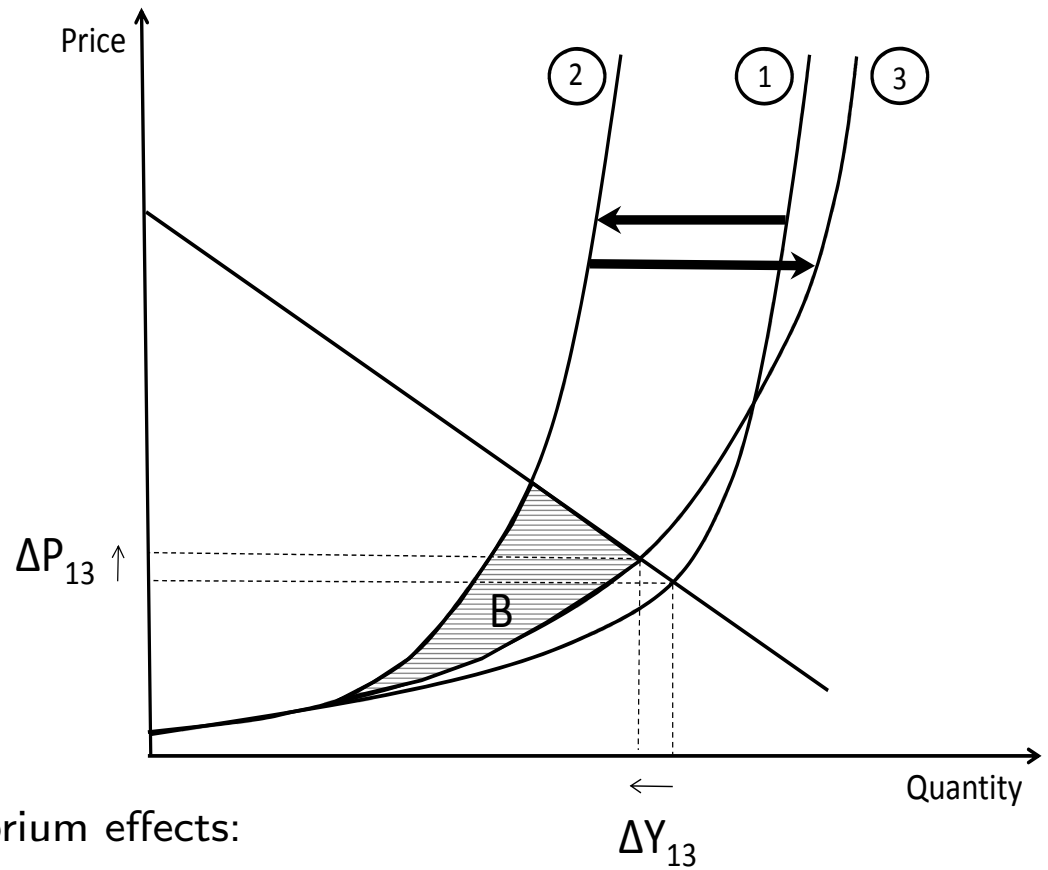


Partial equilibrium effects:

- ΔP_{12} ↗, ΔY_{12} ↘
- Welfare (surplus) losses = A

Ski market response to climate change

Snowmaking shifts the supply curve from ② to ③:

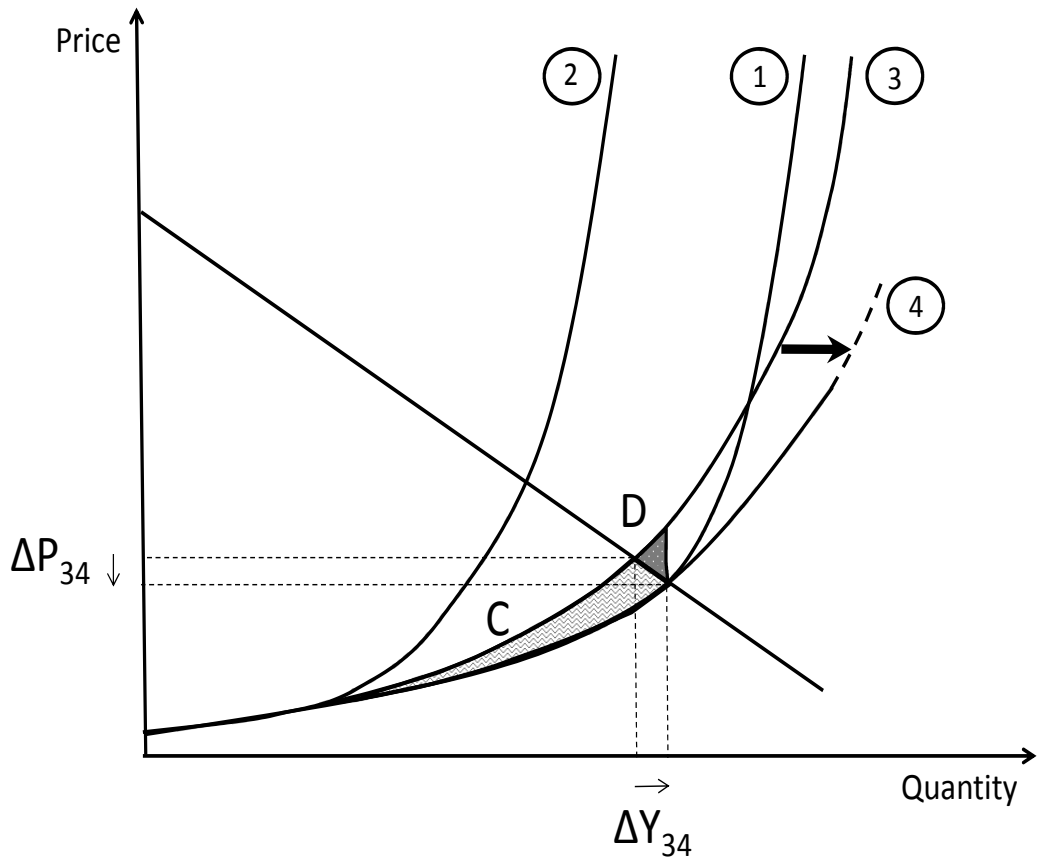


Partial equilibrium effects:

- $|\Delta Y_{13}| < |\Delta Y_{12}|$; $\Delta P_{13} < \Delta P_{12}$
- Welfare increases, resp. loss is reduced, by an amount of B (before fixed cost)
- $\Delta welfare = \Delta surplus$ - investment costs in snowmaking

Ski market response to climate change

The supply curve ④ integrates subsidies on snowmaking:



- Subsidies cover the variable costs of snowmaking (=C+D)
- $\Delta P_{34} \searrow$, $\Delta Y_{34} \nearrow$; $(Y_4, P_4) = (Y_1, P_1)$; snow production $\nearrow$
- Welfare is decreased by D when moving to the new equilibrium

Ski market response to climate change

- Main insights from the partial equilibrium analysis:
  - Climate change will lead to higher equilibrium price and lower quantity which implies a loss of surplus
  - Snowmaking will relax the effects of climate change on price and quantity thereby reducing surplus losses. The net effect on total welfare also depends upon investment costs
  - Maintaining the pre-CC consumption with subsidies to artificial snow production generates a loss of surplus
- Climate change may also impact the demand curve:
  - Changes in the number of domestic tourists (backyard hypothesis, non renewal of skiers)
  - Changes in international tourist flows due to differentiated impacts of climate change across countries

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Simulation scenarios

We perform 5 scenarios using the GEMINI-E3 model:

1. *Scenario CHE-*: a reduced snow resource is simulated for Switzerland only. No adaptation from the Swiss producers (no increase in the production of artificial snow)
2. *Scenario CHE*: same as scenario *CHE-* but with adaptation from the Swiss producers
3. *Scenario WORLD*: reduced snow resources are simulated worldwide
4. *Scenario WORLD ART*: in 2050, the cost of artificial snow in the scenario *WORLD ART* is exogenously raised by 25% compared to the baseline
5. *Scenario WORLD SUB*: in 2050, Swiss authorities implement subsidies on the cost of artificial snow sufficient to maintain the baseline levels of winter sports production. In the model, subsidies are financed through lump sum transfers

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Impacts of climate change for the Swiss tourism sector

TABLE 1: Outcomes from GEMINI-E3 for 2050* (Source: Gonseth and Vielle in review)

	CHE-	*CHE*	*WORLD*	*WORLD ART*	*WORLD SUB*
Higher lying ski resorts (snow endowment: -11.1%)					
Production	-5.8%	-3.6%	-1.0%	-2.4%	0.0%
Artificial snow	0.0%	11.6%	20.7%	9.5%	26.7%
Production price	2.9%	1.8%	2.5%	4.2%	2.0%
Lower and medium located ski resorts (snow endowment: -22.3%)					
Production	-7.9%	-4.9%	-5.0%	-6.1%	0.0%
Artificial snow	0.0%	23.1%	22.9%	13.9%	135.3%
Production price	16.0%	9.5%	9.5%	11.3%	-0.6%
Welfare changes**	-23	-17	83	116	82

* *percentage change with respect to the reference scenario*
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Conclusion

- We derived climate change-induced rises in artificial snow production by 2050. Adaptation is at the sectoral level (i.e. no spillover effects). Our simulations ensure *economic* feasibility
- Are they *technically* feasible ? This is a multidimensional issue that is handled in GEMINI-E3 through different paramaters: water resource price, technological progress, elasticities of substitution between natural and artificial snow
- We found that snowmaking helps reducing the costs of climate change both at the sectoral and aggregate levels
- However, there is a caveat: our analyses do not deal with the full social costs of snowmaking thereby tending to overestimate its beneficial effects for the Swiss economy and society

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