Exploring the impact of co-varying water availability and energy price on productivity and profitability of Alpine hydropower

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(1) MOTIVATION AND OBJECTIVES

Alpine HP systems are experiencing a phase of transition due to:

- climate change, which is affecting water availability,
- energy market liberalization, increasing share of new renewable energy sources, phasing out of nuclear plants in many European countries.

In this work, we develop a simulation framework to:

- assess the impacts of changes in water availability and energy price on Alpine hydropower systems,
- evaluate the adaptive capacity or hydropower reservoir operation to water availability and price changes.

(2) THE MATTMARKSEE HYDROPOWER SYSTEM

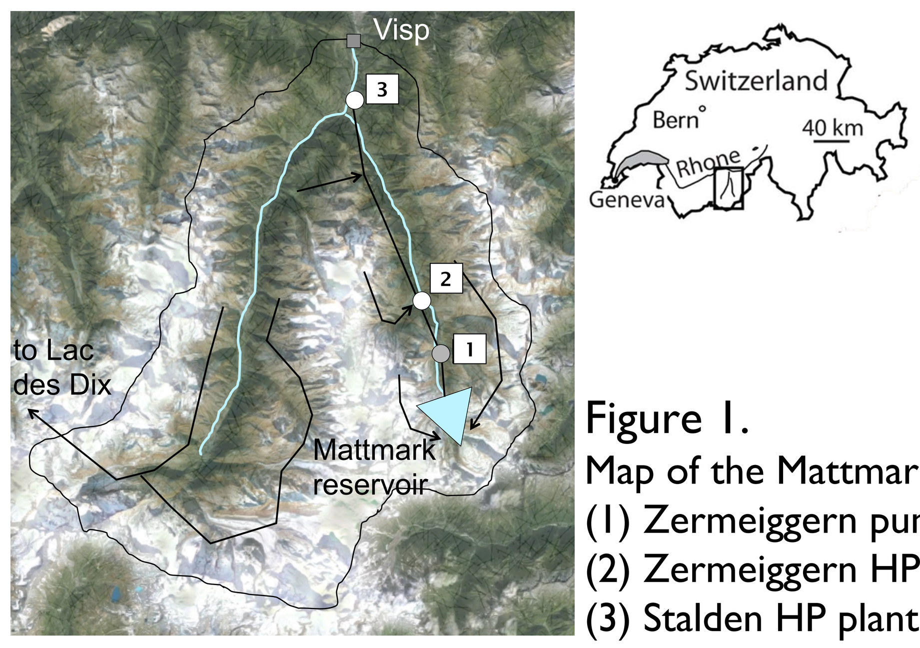

Figure 1.
Map of the Mattmarksee HP system.
(1) Zermeiggern pumping station
(2) Zermeiggern HP plant
(3) Stalden HP plant

Catchment area = 778 km^2

Mattmarksee: 100,101,000 m^3

Zermeiggern power plant: 38.8 MW

Stalden power plant: 187 MW

- Glaciers 29% of the basin.
- 2008: partial liberalization of the Swiss energy market.
- 2035: phase out of Swiss nuclear plants.

The case study is suitable for the assessment of climate change and price variability impacts

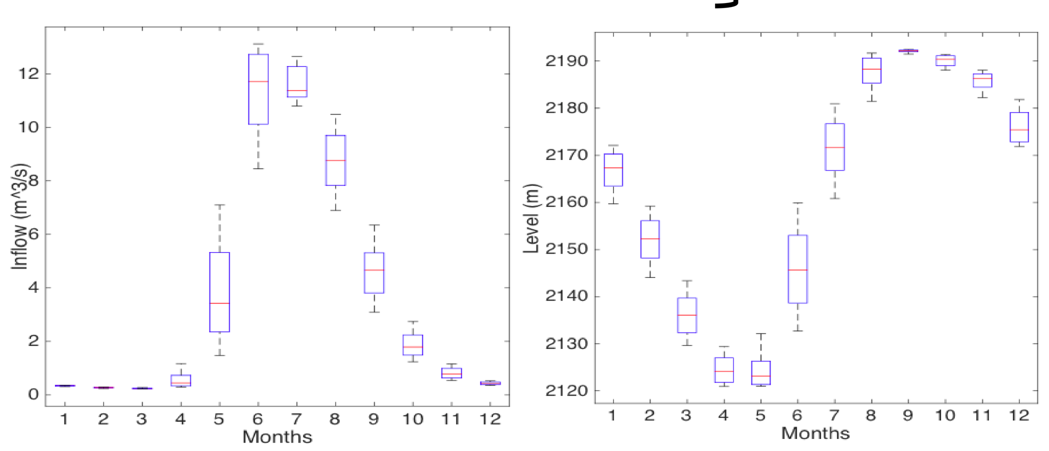

Figure 2.
Left panel: Historical inflow to Mattmarksee. The inflow shows the typical alpine regime, characterized by the peak during the melting season (spring-summer) and low inflow during autumn-winter.
Right panel: Historical Mattmarksee level. The level of Mattmarksee is characterized by a draw-down period during the production season (in winter mainly) and a refill period during melting season (in spring and summer). The boxplots are computed on the period 1994-2014.

(3) METHODOLOGY

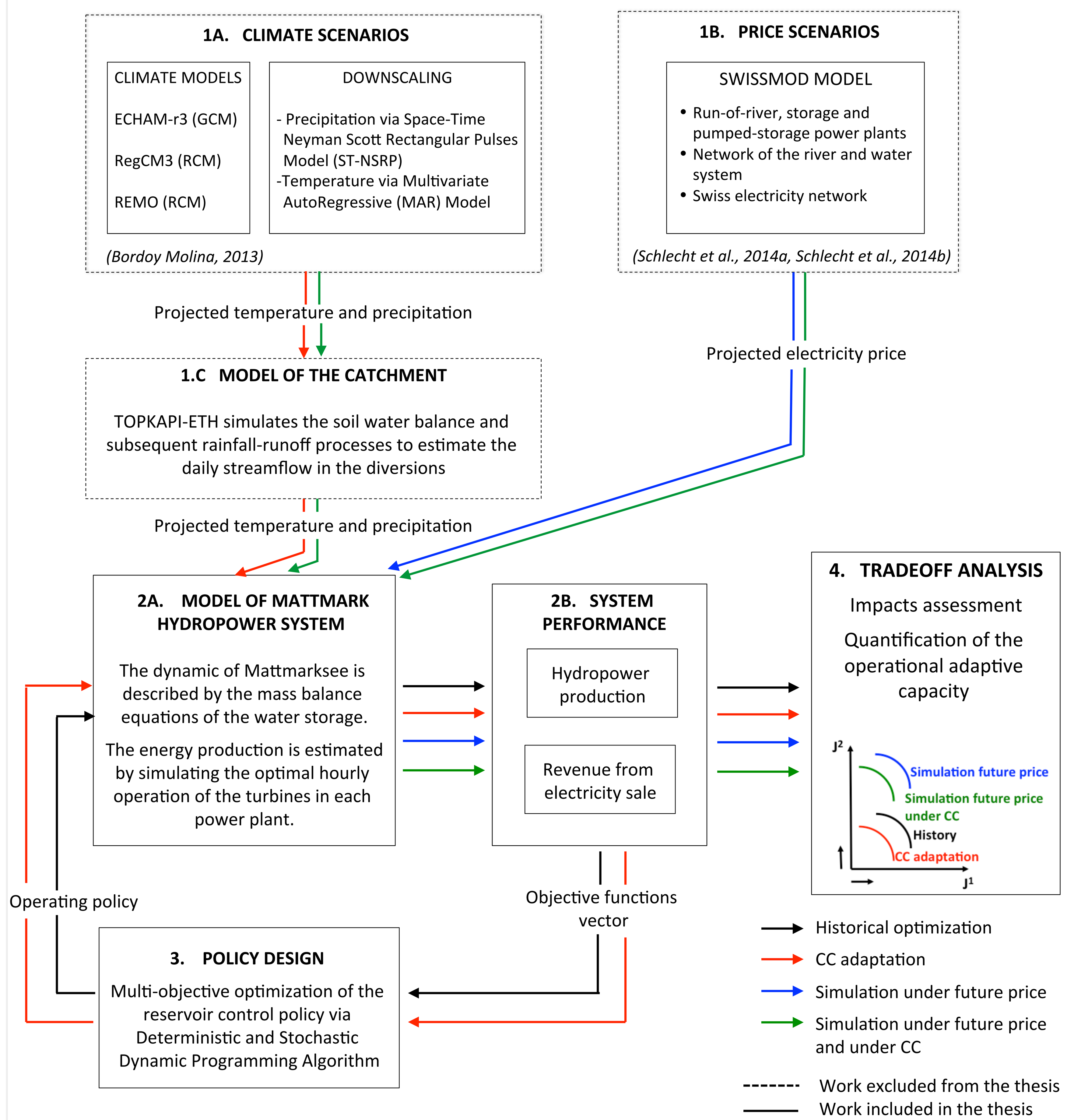

Figure 3. The simulation framework adopted in this study consists into four phases:

1. Generating water availability and price scenarios,
2. Modelling the hydropower system,
3. Designing the Mattmarksee operating policy,
4. Simulating and analysing the system performances

The procedure is run under different combinations of water availability and price scenarios.

(4) SCENARIOS

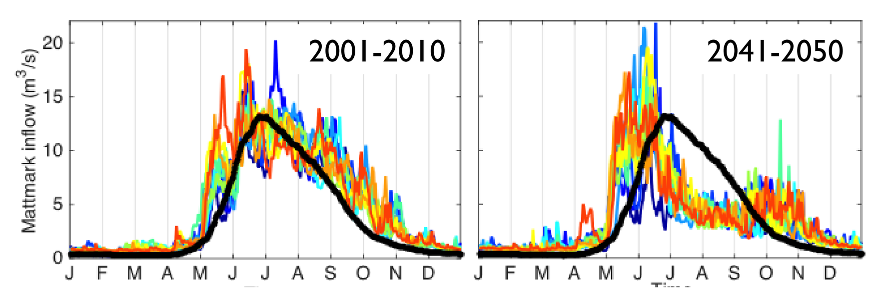

Figure 4.
Climate scenarios: Colored lines represent different realization of the stochastic downscaling procedure (*Bordoy Molina, 2013*). Black line represents the mean historical inflow.
Future inflow shows a shift of the peak inflow due to changed snow-melt dynamics and glaciers retreat.

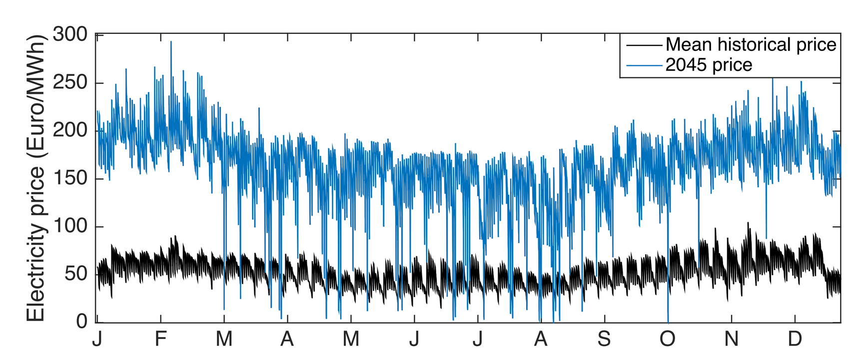

Figure 5.
Energy price scenarios: Historical and Future price scenarios in 2045 (*Schlecht at al., 2014a, Schlecht et al., 2014b*).
Future prices show increasing mean and variance due to higher share of renewables.

(5) RESULTS

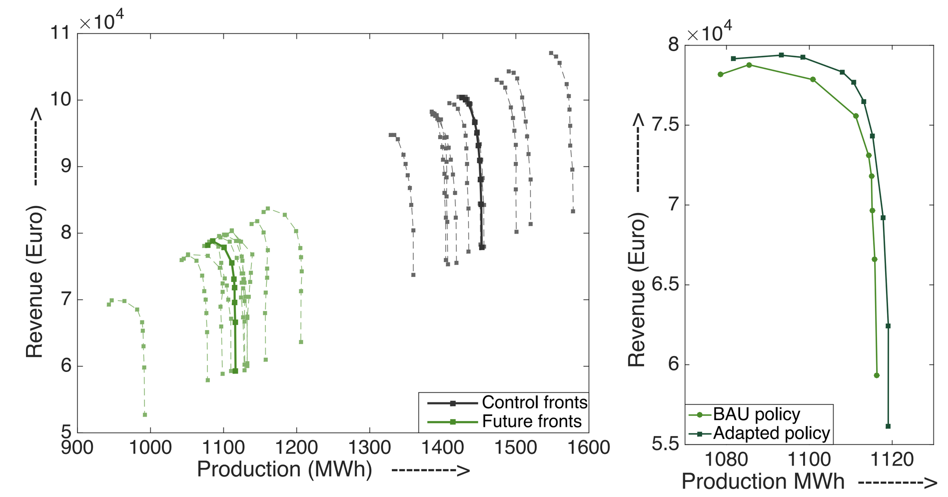

Figure 5.
CC impact assessment:
Left panel: Shift from the black Pareto fronts (control period, 2001-2010) to the green fronts (future period, 2041-2050)

Loss of about 23% in terms of production and of 21% in terms of revenue

Right panel:

- Reduced water availability (glacier retreat) → Limited adaptive capacity of the system
- Exacerbated conflict between the objectives: +2% of productivity → -8% of profitability

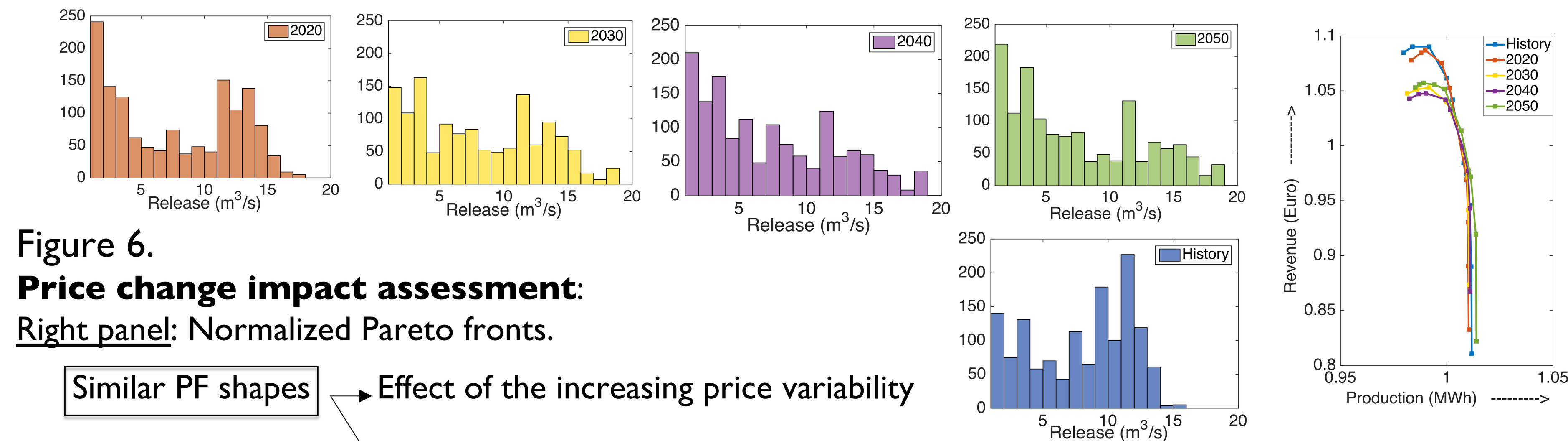

Figure 6.
Price change impact assessment:
Right panel: Normalized Pareto fronts.

Similar PF shapes → Effect of the increasing price variability

History and 2020 price scenarios VS 2030-2040-2050 price scenarios

Left panels:
Higher price variability → more extreme releases in the system operation

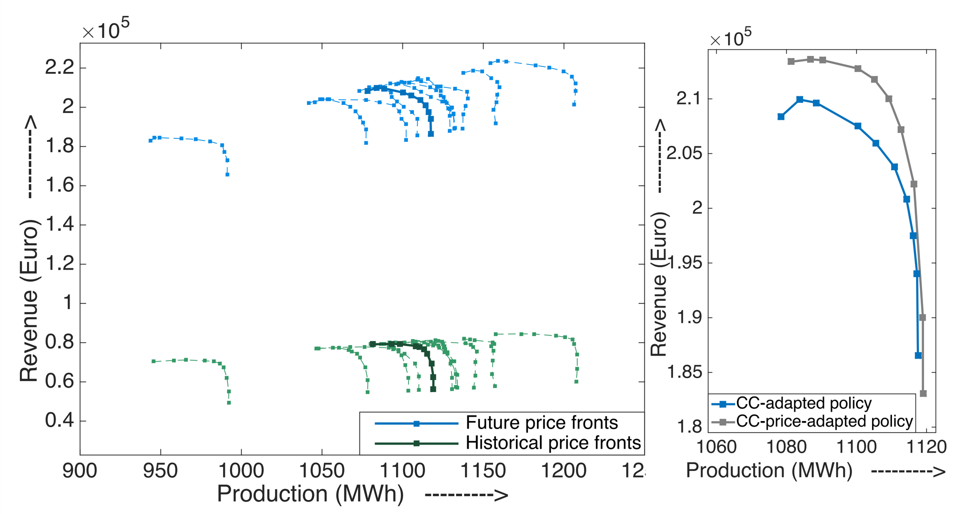

Figure 7.
Co-varying climate and price impact assessment:
Left panel: 2045 inflow and price time series.
Higher future price → increase of profitability

Right panel: Adaptive capacity of the system:

- Increase of profitability (+2.5%) when considering profitability objective only.
- Loss of profitability (-2%) when considering the productivity objective only.

Higher price variability → more important to allocate production when the price peaks.

(6) CONCLUSIONS

- CC impacts could cause a loss of about 21% of productivity and about 23% of profitability.
- The increasing mean of future price increases the future revenue and the future-price-adapted operating policy is expected to register more extreme releases, because of the higher variability of the future prices.
- The adaptive capacity of the system is quite limited by system physical constrains.
- Under future inflow and price scenarios the conflict between productivity and profitability is expected to increase because the efficient allocation of the water resource becomes more important.

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