Climate Change, Water Scarcity, and Economic Performance through 2050 in Italy: A Hydrologically Integrated Dynamic MRIO Model

Topic: Hydrologically Integrated Inputâ€“Output Models (HIIO): An Emerging Interdisciplinary Approach
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As climate change intensifies hydrological variability, water scarcity is expected to evolve unevenly across regions, amplifying territorial disparities in socio-economic development. Simultaneously, endogenous macroeconomic dynamicsâ€”such as growth trajectories, structural change, and interregional tradeâ€”act as additional systemic forcings shaping water demand and socio-economic vulnerability. Italy, characterized by pronounced regional heterogeneity in climate conditions, production structures, and water endowments, provides a compelling setting to investigate how climate and macroeconomic forcings jointly influence the evolution of the waterâ€“economyâ€“society nexus through mid-century.

This paper develops a dynamic multiregional inputâ€“output integrated assessment model that extends the EUROGREEN framework by embedding a spatially explicit hydro-economic module within a demand-driven macroeconomic structure. The approach is inherently interdisciplinary, integrating climate science, statistical downscaling, hydrological modeling, regional economics, and macroeconomic dynamics into a unified analytical framework. Climate forcings are derived from CMIP6 projections, combining historical simulations for 1950â€“2014 (baseline) with projections for 2015â€“2050 under four Shared Socioeconomic Pathways (SSP1â€“2.6, SSP2â€“4.5, SSP3â€“7.0, and SSP5â€–8.5). A statistical downscaling technique translates global climate outputs into regionally consistent hydrological variables, ensuring coherence between large-scale climate scenarios and subnational water availability.

The model captures interregional production linkages, differentiated sectoral water intensities, and region-specific hydrological constraints. It endogenizes blue, green, and grey water demand, incorporates stochastic hydrological variability, and computes a region-specific Extended Water Exploitation Index (EWEI). By integrating dynamic macroeconomic feedbacks with multiregional trade networks, the framework projects how interacting climate and macroeconomic shocks propagate across regions via supply chains, productivity adjustments, employment dynamics, income distribution, and public finances.

Simulation results reveal pronounced regional asymmetries. Although national aggregates suggest a moderate increase in water stress, several regionsâ€”particularly those highly dependent on irrigated agriculture and exposed to declining precipitationâ€”approach critical EWEI thresholds. The interaction between climate-induced productivity losses and endogenous growth dynamics generates heterogeneous impacts on regional GDP, unemployment, and inequality, potentially exacerbating pre-existing territorial imbalances. While improvements in water efficiency and adaptation policies mitigate stress in some areas, their effectiveness varies significantly according to local economic structures and interregional trade dependencies.

These findings demonstrate that national-level indicators may conceal emerging regional vulnerabilities. By combining downscaled CMIP6 climate projections with a dynamic MRIO macroeconomic framework, this interdisciplinary assessment offers a spatially explicit perspective on the waterâ€“economyâ€“society nexus under interacting climate and macroeconomic forcings, highlighting the need for differentiated and integrated policy strategies to safeguard long-term socio-economic stability through 2050.