Evaluating the vulnerability of physical and virtual water resource networks in China's megacities

Topic: Input-Output Analysis: Sustainable Production and Consumption Policies - IV
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The water resource networks that provide water for urban consumption consists not only of physical water supply, but also water embodied in imported goods and services i.e. virtual water supply or external water footprint. However, the dependence on external water footprint introduces a risk to cities when the water of the exporting region is overexploited. It remains unknown that if relying on external water footprint will increase or decrease the vulnerability of cities' water resource networks.

Previous studies have evaluated virtual water flows, as well as direct vulnerability (vulnerable to internal water shortages) and indirect vulnerability (vulnerable to external water shortages) for cities based on bilateral commodity flow data, However, the bilateral trade data has the limitation of being unable to distinguish between intermediate and final demand products, thus is difficult to trace the life cycle processes of water use along complex supply chains. In contrast, the accounting framework based on the multi-region input-output (MRIO) table has the advantage of showing whole industry supply chain effects, and provides relatively more detailed sector disaggregation for industrial products. However, to best of our knowledge, there is no study applying a MRIO analysis approach to evaluate and compare the direct and indirect vulnerability of physical and virtual water resource networks in different megacities.

Here, we evaluate the vulnerability of urban water resource networks for China's six megacities i.e. Beijing, Tianjin, Shanghai, Chongqing, Guangzhou, and Shenzhen. The vulnerability index was developed through combining a refined MRIO table with both water footprint and water scarcity footprint analysis. The Chinese MRIO table formally contains four Chinese provincial-level megacities: Beijing, Tianjin, Shanghai and Chongqing. Accordingly, existing relevant studies within China using the MRIO approach tend to have only considered these four megacities, and have ignored two other recognized megacities; Shenzhen and Guangzhou. In order to give a comprehensive analysis of the water footprint of China's megacities, we have thus extended the existing Chinese MRIO table to include Shenzhen and Guangzhou using a gravity model.

The results showed that megacities need to import large volumes of virtual water embodied in food related sectors to balance their physical water shortages. The external blue water footprint (BWF) of the six megacities accounted for 80.7% of their total BWF, and was almost twice their physical water supply. The large share of external BWF helped Beijing, Tianjin, and Shanghai, which suffer extreme water stress in their urban areas, to decrease their total vulnerability by 39%, 33%, and 28% respectively, but conversely increase their vulnerability to external water shortages i.e. indirect vulnerability. Establishing megacity physical and virtual water resource networks based on input-output analysis provides an opportunity for urban water planners to internalize the risk of their external water footprint. Avoiding import water-intensive products from regions suffering extreme water stress, or managing indirect vulnerability through cooperation with those regions are suggested as viable water management approaches.