Carbon and Water Supply Chain in Urban Sustainability for North China Urban Agglomeration

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Author: HERAN ZHENG
Co-Authors: Dabo Guan, Jing MENG, Zhifu Mi

Urbanization has been booming at an unprecedented scale and rate, and this prosperity will continue. Global urbanization today has led to a range of concerns related to sustainability in different dimensions, scales, and fields, and global cities have come to play an indispensable role in sustainable development strategies. Recently, a new norm has emerged as urban agglomerations that cross city boundaries and encompass multiple urban areas. Urban agglomerations are expected to grow rapidly in both developed and developing countries. For example, there were 10 urban agglomerations with more than 10 million dwellers and 153 million people in 1990. By 2016, this figure rose to 31 urban agglomerations with a total population of 500 million; 24 of these agglomerations were located in the â€œGlobal Southâ€•. By 2030, 41 urban agglomerations with 710 million residents are expected to exist.

In this study, we focus on the North China urban agglomeration (or Jing-Jin-Ji urban agglomeration), which is one of the largest urbanized regions but struggles with regional disparity and environmental issues. The carbon and water supply, demand and distribution in the lens of urban sustainability are discussed by illustrating carbon and water supply networks, which reflects the most important elements for sustaining urban growth. We then evaluate the pattern of citiesâ€™ carbon and water networks in terms of potential efficiency and inequality. For our purpose, we develop a city-level multi-regional input-output dataset (MRIO) for 13 cities and 30 sectors in the urban agglomeration based on a regional input-output (IO) table, which is the first time a city-level MRIO table has been constructed.

Based on the city-level MRIO, we then apply an environmentally extended IO analysis (EEIOA) to account for the carbon and water footprint for each city by tracking carbon and water supply and demand. We show the concentrated pattern in both carbon and water supply chains from Hebei to Beijing and Tianjin, reflecting two megacities outstripping resources from the surrounding environment, and identify key supplier cities in the supply chain. The four industrial cities such as Shijiazhuang, Tangshan, Xingtai, and Handan contribute 66% of trade related carbon emissions, while The upstream water supply chain is mainly dominated by Baoding, Shijiazhuang, Xingtai, and Hengshui in terms of net flows and magnitude. However, the four cities are the most water-scarce cities; their per capita water resources are the lowest in the urban agglomeration. Of the total 1502 Mt of water embodied in net trade in the urban agglomeration in 2012, 68% (1025 Mt) is supplied by the most water-scarce cities.

Improving the efficiency of water and energy use is a core focus of sustainable development not only for water availability in arid regions but also for mitigation at the regional level. Unfortunately, carbon and water supply chains in the urban agglomeration are both inefficient, as cities with low efficiency undertake production activities for cities with higher efficiency. Meanwhile Carbon and water chains unveil the economic-environmental inequality in the urban agglomeration, of which Beijing and Tianjin are the largest beneficiaries. Identifying key sectors behind the carbon and water chain could help gain insights into the pattern.
The carbon supply chain in the urban agglomeration is largely shaped by heavy industrial production and energy generation. Half of the energy-related emissions are for construction and heavy industrial products, of which Shijiazhuang and Tangshan contribute the most, with 47% of construction-induced emissions and 40% of heavy industry-induced emissions. Beijing is

responsible for 36% of construction-induced emissions, while other upstream cities, including many industrial cities, account for 30% of emissions embodied in energy for heavy industrial production. This indicates that the infrastructure (urban sprawl, highway construction) in these megacities, especially Beijing, largely shapes the patterns of the supply chain and that industrial cities, especially Tangshan and Shijiazhuang, play the supplier role. Thus, it highlights the city linkages between Beijing and Tangshan, Shijiazhuang should be paid more attention regarding sustainability policies on both the consumption and production sides.

In the water supply chain, agriculture plays a dominant role and consumes 2532 Mt of water for trade, accounting for 78% of the water embodied in trade, of which upstream cities take 75%. On the supply side, Shijiazhuang, Baoding and Xingtai are the largest agricultural water suppliers, contributing a total of 50% agriculture-related water. In contrast, more than 70% of agriculture-related water is demanded by the light industry and agriculture, which indicates that urban residentsâ€™ daily life largely shapes the water supply chain.