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ANALYSIS

Assessment of regional trade and virtual water flows in China

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ABSTRACT

The success of China's economic development has left deep marks on resource availability and quality. Some regions in China are relatively poor with regards to water resources. This problem is exacerbated by economic growth. Flourishing trade activities on both domestic and international levels have resulted in significant amounts of water withdrawal and water pollution. Hence the goal of this paper is to evaluate the current inter-regional trade structure and its effects on water consumption and pollution via 'virtual water flows'. Virtual water is the water embedded in products and used in the whole production chain, and that is traded between regions or exported to other countries. For this assessment of trade flows and effects on water resources, we have developed an extended regional input–output model for eight hydro-economic regions in China to account for virtual water flows between North and South China. The findings show that the current trade structure in China is not very favorable with regards to water resource allocation and efficiency. North China as a water scarce region virtually exports about 5% of its total available freshwater resources while accepting large amounts of wastewater for other regions' consumption. By contrast, South China a region with abundant water resources is virtually importing water from other regions while their imports are creating waste water polluting other regions' hydro-ecosystems.

1. The 'economic miracle' and virtual water flows

1.1. Water shortage and its competing usage

The latter half of the 20th century is considered the period of the 'economic miracle' for East Asia, achieving industrialization and urbanization in a relatively short time period. China, in particular, accelerated its economic development with an annual GDP growth rate of almost 10% after economic reforms were started in 1978. In comparison, the world average was 3.3% during the same period. By 2005, China's GDP had reached 1.13 trillion US dollars, which put China among the four largest economies in the world. China's economic reform has created very competitive and favorable circumstances for domestic and foreign investors in terms of cheap labor costs, a huge domestic market, low workers safety standards and environmental standards. These and other reasons, such as the undervalued Yuan, have led to large amounts of capital flowing into China, especially in the southern and eastern parts, which has made China one of the largest manufacturers and exporters in the world. However, Deng's 'ladder-up' strategy of economic development has increased income inequality between regions and urban and rural areas. This is also reflected in differing regional development policies, economic production structures, unequal spread of foreign direct investment, and huge differences in people's lifestyles pattern.

These developments have left deep marks on China's natural resource availability and especially with regards to water resources. China is trying to support the needs and

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wants of a population of 1.3 billion. This amounts to 22% of the total world population with only 7% of the world's arable land, and 6% of the world's fresh water resources. Water is already considered the most critical natural resource in many parts of China in terms of the low availability of per capita volume. The average water availability is about 2300 m^3, which is roughly about 1/3 of the world's average value. But China's water resources are also unevenly distributed: North China has only about 20% of total water resources in China, but is supporting more than half of the total population. As a result, per capita water availability in North China is as little as 271 m^3 or 1/8 of the national level and 1/25 of the world average. Furthermore the rapid economic development in this region has been extracting significant amount of water from the environment, and it is also discharging pollution to the water supply sources, which further contributes to water-scarcity. Flourishing trade activities on both domestic and international levels have contributed to ever increasing levels of water consumption.

These socio-economic and environmental issues facing China in the 21st century call for careful evaluation of China's resource consumption caused by its present production and consumption and associated trade structure. Due to these trade activities, significant amounts of 'virtual water', i.e. water embedded in products and used in the whole production chain, are traded between regions or exported to other countries. Hence the goal of this paper is to evaluate the current regional economic structure and the resulting inter-regional trade patters in China and its effects on water consumption and pollution via 'virtual water flows'.

1.2. *Virtual water flows*

The idea of virtual water was derived from the concept of 'embedded water' applied to agriculture in Israel by Fishelson (1994). Their study pointed out that exporting Israeli water embedded in water intensive-crops was not sustainable. The term 'virtual water' was first proposed in 1994 by J. Anthony Allan (Allan, 1994). Allan defines virtual water as the water used to produce food crops that are traded internationally. He found that a few countries characterized as water-scarce have secured their food supply by importing water-intensive food products, rather than producing all of their food supply with inadequate water resources. Limited water resources should be used efficiently by not allocating the majority of the water resources to the production of water-intensive products (e.g. crops, paper etc.) but rather water should be made available for other economic purposes that can contribute more to regional value added by consuming less water (Allan, 1998, 2002).

Most of the studies on virtual water flows have been conducted for drought areas such as the Middle East and North Africa and have emphasized the amount of water embedded in different agricultural products related to food security, with agriculture being the largest water consumer.

Similarly, in China, agricultural irrigation has accounted for the majority of water use in the past, however, along with the large-scale industrialization and urbanization since 1980, domestic, municipal, and industrial water consumption joined the competition for limited water resources. Many industrial products also carry substantial amounts of virtual 'freshwater' as well as contaminated 'wastewater' from the production of paper, fertilizer and cement, which are then exported to other regions or countries.

Due to increasing importance of other industrial products and services and their effects on water consumption, we extend the concept of virtual water flows to comprise all types of commodities including agricultural goods, industrial products and services. We distinguish between two categories of virtual water: freshwater and wastewater. Virtual freshwater is the amount of freshwater consumed during the production for exports. Virtual wastewater is the amount of polluted water discharged to the ecosystem, i.e. the amount of emissions generated and left in the respective region in order to feed consumption in other regions or countries. Due to the importance of the agricultural sector in terms of water consumption we further differentiate between rainfed and irrigated agricultural products. This is based on the rationale that rain water used for agricultural products would not be readily available for any other economic production.

1.3. *Virtual water as a factor of production*

The notion of virtual water as necessary input to production and consumption activities leads us to the notion of factors of production or factor endowments. In our case we focus on water as a special input to production but are also interested in the question of how production and associated trade structures affect the availability of water resources. Early economic theorists such as Adam Smith (1909) and David Ricardo (1817) were concerned with differences in factor endowment, 'the comparative advantage', as one of the main reasons for trade and regional inequalities and as a source for the wellbeing of nations. The focus shifted to the negative sides of trade; and only rather recently, scholars started to advocate re-designing trade structures from the perspectives of social and environmental sustainability. In the following we will look at certain selected key publications to see how factor endowment and environmental resources have been treated in the trade literature and how that links to our question.

Heckscher (1919) and Ohlin (1933) incorporated the endowment of factors of production into the principle of comparative advantage, and consequently was referred to as the Heckscher–Ohlin (HO) theorem. The HO theory of international trade was able to explain that the differences of productivity in various countries are dependent on relative factor endowments. Leontief (1951 and 1954) calculated the labor and capital content of the exports of the United States to test the HO theory. The US seemed to be endowed with more capital relative to labor than any other country at that time. Therefore in terms of the HO theory, the US should have exported capital-intensive products and imported labor-intensive commodities. However, Leontief's test surprised the academic field as he reached a paradoxical conclusion that the US exported relatively more labor-intensive commodities and imported capital-intensive goods. These results received a great deal of attention and became known as the Leontief Paradox and have led to numerous studies discussing and critiquing the approach (see, for example, Stolper and Roskamp, 1961; Bharawaj, 1962).

If we apply classical trade theory to environmental studies, a country may have a comparative advantage if it