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THE YANGTZE RIVER'S REGIONAL WATER FOOTPRINTS: AN INTERREGIONAL INPUT–OUTPUT APPROACH

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ABSTRACT

The multi-regional input–output (MRIO) method has recently been used to water footprint (WF) analysis by academics. To study regional problems, the idea of interregional input–output (R-MRIO) was created. The creation of global or international input–output (N-MRIO) tables has been the focus of research. The N-MRIO and R-MRIO approaches may be used to investigate global and regional problems, respectively. The WF is a trade indicator that is affected by commerce between countries and regions. However, whether foreign imports are segregated or integrated in an R-MRIO method varies in how they are treated. The consequences of the differences between these models are assessed, and policy implications for the Yangtze River in China are discussed. The WF estimated with the combined type model is 11% higher than the WF obtained with the separated type model. International imports, mostly domestic consumption and interregional commerce, is to blame for this disparity. We discovered that this disparity had an impact on social equality in water-rich regions.

KEYWORDS: *Multi-regional input–output approach; Social equity; Water footprint; Regional analysis; Yangtze River*

1. INTRODUCTION

An environmental input–output analysis (EIOA) (Leontief, 1970; Duchin and Szyld, 1985; Duchin, 1992) is a method for calculating cumulative environmental impacts over a product's life cycle, and it can be extended to greenhouse gas emissions and air toxicity (Lenzen et al., 2004; Suh et al., 2004; Wiedmann et al., 2007; Peters, 2008; Wiedmann,[1] 2009; Su and (Lenzen and Murray, 2001; Turner et al., 2007)[2]. Using the production- and consumption-based methods, EIOA enables us to estimate the direct environmental loads from industrial sectors as well as the indirect environmental loads generated by end products and services. Many scientists have recently tried to adapt the MRIO method to water foot printing. The interregional input–output (R-MRIO) method for a single country (Lenzen, 2009; Yu et al., 2010; López-Morales and Duchin, 2011; Feng et al., 2012) and the international input–output (N-MRIO) approach for several countries (Feng et al., 2011) are two types of this technique. The R-MRIO approach was created for regional issues, whereas the global or international MRIO (N-MRIO) tables, which are currently being developed, can aid researchers in their studies of the role of international trade in environmental issues (Isard, 1951; Murray and Lenzen, 2013; Tukker and Dietzenbacher, 2013). Thus, the N-MRIO method aids understanding of global environmental problems (Su and Nag, 2010; 2011; Su et al., 2010), while the R-MRIO approach utilized in this work is appropriate for investigating regional issues, particularly those involving water. This is due to the fact that water resource distribution varies by area, even if the regions are part of the same country. As a result, most studies have favored the R-MRIO method for regional water resource management water footprint (WF) study.

WF is a metric that accounts for both domestic and imported water consumption (Hoekstra and Hung, 2002; 2005; Renault, 2003; Chapagain and Hoekstra, 2007; 2011; Hoekstra and Chapagain, 2007a; 2007b; 2008; Chapagain and Orr, 2009; Hoekstra and Chapagain, 2007a; 2007b; 2008; Chapagain and Orr, 2009). Input–output tables (IOTs) may be divided into two types based on how foreign imports are handled (Matuszewski et al., 1963; UN, 1999; Dietzenbacher et al., 2005). Thus, EIOA methods for water are categorized into the two major kinds described above: the 'combined type model' (CTM) and the 'separated type model' (STM) (Lenzen and Foran, 2001; Hubacek and Sun, 2005; Guan and Hubacek, 2007, 2008; Hubacek et al., 2009; Zhang et al., 2011; Feng et al., 2012). For the R-MRIO, for example, international commerce may be assimilated into regional transactions or a distinct "rest-of-the-world" area might be defined. Guan and Hubacek (2007) employed the CTM, while Lenzen (2009) used the STM with distinct import tables in earlier R-MRIO investigations of WF. Cazcarro et al. (2013) recently developed the STM [3]by including foreign import data. Thus, WF based on the R-MRIO method varies depending on the model employed (CTM or STM), although the impact of foreign imports on WF is still being investigated.

As a result, we show that the WF calculated using the R-MRIO method may vary depending on the kind of model (combined or separated) utilized to compute it. The remainder of the paper is laid out as follows. First, we'll go through the process for defining the WF, as well as the data requirements. We next use the R-MRIO method to compute the WF using the combined and STMs, show the findings, and conduct a decomposition analysis. Finally, we provide our findings and analyze the policy implications, sensitivity, and uncertainty of the WF estimates using the models. Products and industries There are 38 crops in all. 6 agriculture 23 industries 48 industries 40 industries Products from 20 different industries China has eight distinct regions. China is divided into four areas. 30 provinces divided into two regions Note: n/a indicates that the researcher did not compute the amount (s). For the year 1995, the following are the results for China. These data were re-aggregated using Feng et a criteria .'s and findings (2012)[2]. Imports from other countries are included. Overseas and interregional trade is included in the values. North China and South China are denoted by the letters NC and SC, respectively. For a variety of reasons, we chose the Yangtze River (area 1.8 million km2) as the target region, which spans 15 Chinese provinces and municipalities. To begin with, water stress varies by area, based on water supplies and population density. The Yangtze River's water resource per capita (2,553 m3) is lower than China's average (YRYCC, 2003), although the numbers vary widely among areas, ranging from 208 to 5,329 m3 (MWR, 2003).

In addition, the WF is linked to water extraction and consumption. Thus, considering the WF on a basin-wide scale may provide valuable insights into water resource management. Matching economic and water statistics is difficult, but it may be avoided by looking at the basin as a whole (Feng et al., 2011). Second, the R-MRIO method is appropriate for a big nation like China

(Su and Ang, 2010), where regional disparities in the economy and distribution of water resources occur. Third, the Yangtze River is China's primary water supply, accounting for 36% of total water use (MWR, 2001). Furthermore, the river contributes for 53 percent of China's GDP (YRYCC, 1999), thus foreign imports are expected to have a major impact on WF. Finally, several studies have estimated China's WF, which ranges between 489 and 1,304 billion m3 every year (Table 1). Although the requirements for water data, techniques used, geographical units, and target years vary across the research, the number of studies makes it simpler to validate the findings. Regional WF Definition Hoekstra and Chapagain, 2007b) The WF is made up of water needs inside the nation (internal WF, IWF) and those linked to imported products and services (external WF, EWF). The IWF and EWF are computed by multiplying the virtual water contents (VWCs) by domestic production while excluding exports, and multiplying the VWC by imports (Hoekstra and Hung, 2002; Zhao et al., 2009).On a regional basis, the IWF represents the water demand inside the area, while the EWF represents the demand for imported products and services from other nations, as well as the rest of the country's regions[4].

2. DISCUSSION:

The Yangtze River IOT is being developed utilizing a hybrid method (Miller and Blair, 2009), which is based on China's interregional IOT (IDE-JETRO, 2003). (see Appendix A). Each area is divided into 30 sections (TableA1). China is divided into five regions: the upper Yangtze area (UYA), which includes Chongqing, Shanxi, Sichuan, Guizhou, Gansu, Yunnan, and Qinghai; the central Yangtze area (CYA), which includes Jiangxi, Hubei, Hunan, and Henan; the lower Yangtze area (LYA), which includes Shanghai, Jiangsu, Zhejiang, and Anhui; South China (SC) (except Tibet and Hong Kong). Although the classification of provinces according to the Yangtze River's upper, middle, and lower regions is widely disputed, we stand by it because it is based on the climates, hydrologist, geographies, and economies of the regions, as well as the regional classifications provided in the Yangtze River Yearbook (YRYCC, 1999). The Yangtze River's border is based on administrative boundaries; therefore it does not precisely match the watershed's. 3 However, since we are focusing on various models inside the same system boundary, this should not be an issue. The statistics on water usage in China mostly refers to agricultural, industrial, and residential water withdrawals by province (MWR, 2001).Irrigation water and withdrawals for other agricultural sectors make up agricultural water. The irrigation water ratio (MWR, 2001) separates irrigation water from provincial agricultural water, however it does not include green water for crop cultivation. Provincial livestock, forestry, and fisheries withdrawals are computed.3 Feng et al. were the first to use geographic information systems to adjust discrepancies between administrative and watershed borders (2011).by dividing the withdrawal of other agricultural sectors (MWR, 2001) by their individual shares of gross domestic output of cattle, forestry, and fisheries, respectively, against other agricultural sectors' gross domestic outputs (NBSC, 2001).

By calculating province industrial withdrawal water by the sectoral proportion of drainage against total industrial drainage, provincial industrial withdrawals by sector may be determined (CEYCC, 2001). We calculate the provincial water utilized by all 30 sectors' workers by multiplying the number of sector employees in each province (NBSC, 2001)[5] by the water consumption per capita in urban and rural regions. Domestic water consumption per capita (MWR, 2001; NBSC, 2001) in urban and rural regions is calculated using a working time factor of 8 hours per day. Although water used by livestock (cattle, swine, and fowl) is included in the household water demand in rural regions, there are no comparable Chinese statistics. As a result, we calculate the amount of water used by livestock by multiplying the number of provincial livestock by the water consumption coefficient of each head of livestock (Oradea et al., 2006), assuming that the water requirements of cattle in Japan and China are similar. The EWF from abroad may be computed using the CTM (Equation 8) if the foreign nations' VWCs and Leontief inverse matrices are the same for the Chinese area importing goods and services (Lenzen, 2009; Zhao et al., 2009).This assumption helps ease data accessibility problems since it is usually difficult to match data for water needs from various industrial sectors and IOTs across the globe. Furthermore, the EWF[6] indicates water needs for domestically produced products and services that utilize the same production processes and intermediary transactions as foreign nations, and has the same meaning as virtual water in our instance (Allan, 1997; 1998; Oki and Kanae, 2004).In contrast, we can easily differentiate the VWC and Leontief inverse inside and exterior to an area using the STM (Equation 2). As a result, the EWF from outside the country is the same as the so-called actual water (Oki and Kane, 2004). As a result, some researchers assumed that the VWC or Leontief inverse for the EWF of international imports equals those for a country or region (Lenzen, 2009; Zhao et al., 2009), whereas others used the N-MRIO approach to estimate the VWCs of all targeted countries using international water databases (Feng et al., 2012; Lenzen et al., 2013).

We calculate the VWC in this research by multiplying the regional VWC by the adjusting parameter4 (0.26) (MWR, 2001; Pacific Institute, 2011; World Bank, 2012). The Leontief inverse matrix of foreign nations is also established based on intermediary transactions between Indonesia, Malaysia, the Philippines, Singapore, Thailand, Taiwan, Korea, Japan, and the United States (IDE-JETRO, 2006).We estimate Equations 2 and 8 using the importation coefficients (sr I = 4) since the IOT organized in this research involves international imports of intermediate and final products and services. The global withdrawal per GDP (0.17 m3/USD) is about 26% of China's (0.46 m3/USD). We also utilize statistics on freshwater extraction from 92 nations (excluding China) I by the values of the intermediate transaction and final demand by region, the regional intermediate and final products and services as international imports are defined. Furthermore, we use the importation coefficients to construct the Leontief inverse matrix of the STM by eliminating foreign imports (Miller and Blair, 2009)[7].International imports are defined differently by provincial IOTs. While some provincial tables (for example, those for Shanghai) provide detailed information by defining foreign imports and exports from foreign countries separately[8], others (for example, those for Shandong) only provide ‘net export,' with the values of interregional and overseas trade not separately recorded. As a result, we estimate the regional international imports vector by sector using province IOTs, which only offer ‘net exports' from provincial statistics import and export data. 5 Furthermore, each province's foreign trade statistics was modified to be consistent with the national IOT.

According to the STM, China's WF (f R) is 412.5 billion m3, with the IWF (f R I), EWF for domestic imports (f SR E), and EWF for international imports (f R E) accounting for 77 percent, 22 percent, and 2%, respectively .The Yangtze River is responsible for half of China's WF. The IWF and EWF for domestic imports along the Yangtze River account for 50 percent and 52 percent of China's IWF and EWF, respectively. The Yangtze River's EWF for international imports accounts for 31% of China's EWF for international imports. The LYA contributes for the majority of the Yangtze River's WF (38%) while the EWFs for domestic and foreign imports account for 45 and 72 percent, respectively. The CYA, on the other hand, makes up the largest portion of the Yangtze River's IWF (36 percent). FIGURE 1 Discloses The Areas Under Study[4].

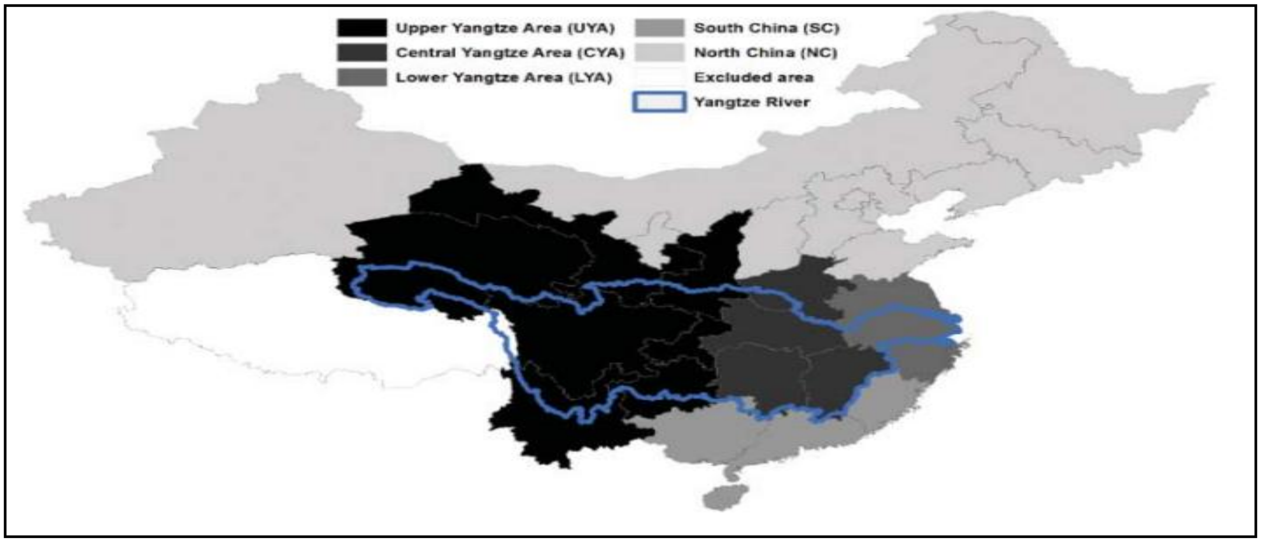

FIGURE 1: Areas under Study.

3. CONCLUSION:

For the Yangtze River, we used the MRIO method to compute the differences between the WFs by the combined and STMs. The STM calculated China's WF to be 11% lower than the CTM's. This result, which is due to differences in how international imports are treated, highlights a problem with the accuracy of the calculated results: neither model can be used by decision-makers in isolation, as this would lead to incorrect/biased policies, with one model providing an overly optimistic view and the other providing an overly pessimistic view. Furthermore, this finding indicates that the environmental consequences of WFs would differ depending on the model employed, which would have an impact on the feasibility of policy choices such as the South–North Water Transfer Project in China, which allocates water resources to water-scarce areas. Some studies discovered that 19 percent of China's WF originates from water-scarce sources using a revised WF and a water scarcity indicator (Lenzen et al., 2013). Furthermore, earlier results that water-scarce regions in China practically export to water-abundant areas in China (Ma et al., 2006; Guan and Hubacek, 2007) are significant since it is obviously not efficient, effective, or fair for the latter to use the former's water resources. The social equity of water imports by water-abundant regions is affected by these variations by model type, and the STM is more sensitive to changes in regional international imports, according to our findings. In summary, decision-makers in a water-abundant area should carefully examine the social justice of water imports from water-scarce regions, since the environmental effects of water usage in the latter are greater than in the former. We also proposed a novel hybrid method for dealing with uncertainty, in which the Leontief inverse matrix of the CTM was used in the STM. We expect that this proposal will lead to more accurate findings in WF studies and that it will ultimately evolve into a WF-relevant standard, such as ISO/DIS 14046[9].

Finally, with the addition of global MRIO datasets, more researchers are expected to use the N-MRIO method for WF analysis. Because of the regional disparities in water resource distribution, we think that further study is needed to validate the method's usefulness at a regional level. As a result, we believe that our work will be useful as additional research in projects using the N-MRIO method[10].

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