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Water footprint assessment for service sector: A case study of gaming industry in water scarce Macao

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ABSTRACT

Although numerous studies have been carried out to investigate the water footprint of different economies at global, national and regional scales, the research on water footprint of individual economic sector, which is the elementary part of each economy, is still lacking. To fill the gap, this paper for the first time employs a hybrid method to evaluate the water footprint of gaming industry in water scarce Macao, based on the latest statistics and most exhaustive embodied water intensity databases. The results show that direct water use only accounts for extremely small fraction of the gaming industry's water footprint, indicating that the exchange of water embodied in product and service between different sectors is also a useful mean to satisfy individual sector's demand for water resources. As Macao's demand for water is growing, integrated plans including economic instruments and measures like reducing the scale of commission input and promoting efficiency would ease Macao's water pressure. Water footprint assessment in this study brings along new perspectives on gaming industry's water management and encourages wise use of goods, materials and services in a sustainable way.

1. Introduction

Water footprint is defined as the total volume of water needed to produce the goods or services consumed by a country, region, business or an individual person (Hoekstra, 2009). This concept is closely related to the concept of virtual water, or the more general one of embodied water (Chen et al., 2012), referring to the total amount of water (including direct and indirect water input) embodied in a product or service (Allan, 1998). Despite these "young" academic concepts, they have become the hot spots in the research fields and lots of works have been carried out to analyze water footprint and virtual water issues at different scales.

Global water footprint has been estimated and moreover, international virtual water flows between nations have been calculated based on the trade statistics (Carr et al., 2013; Chen and Chen, 2013; Dalin et al., 2012; Hoekstra and Mekonnen, 2012; Lenzen et al., 2013; Yang et al., 2012). These global scale water footprint analyses point out that some countries have significantly externalized their impacts on water resources in other countries via importing water-intensive goods. At the national scale, water footprint of some key countries, such as China (Chen and Chen, 2010; Guan and Hubacek, 2007; Zhao et al., 2009), France (Ercin et al., 2013), Spain (Cazcarro et al., 2011) and UK (Yu et al., 2010), have been explored. Most of the national water accounting studies first find out the target nation is a "net importer" or "net exporter" of virtual water and then help decision-makers develop well-informed national water policy. At the regional scale, the analysis has been focused toward the topic that how virtual water transfers between regions affect each region's water footprint (Mubako et al., 2013; Lenzen, 2009). Recently, the water footprint of sub-national regions like river basins (Feng et al., 2012; Zhao et al., 2010), provinces (Dong et al., 2013) and cities (Wang et al., 2009, 2013; Zhang et al., 2011; Zhou et al., 2010) raise more and more concerns with the purpose to support local governments to develop appropriate regional water strategies. Besides, to help determine optimal production, water issues receive interests from plants, factories and business leaders (Ene et al., 2013; Meng et al., 2013; Shao and Chen, 2013). All these previous studies on virtual water of economies at different scales have provided with much insight into water issues formulating water policies.

For each economy, the sustainable consumption of water will depend on the amount of products and services its economic sectors consumes. In fact, the definitions of water footprint and virtual water become more relevant if it links to the exchange of commodities and services since the water virtually transfers between sectors in various regions (Velázquez, 2007). For instance, agriculture produces food such as rice and meat, whose production process consumes large quantity of physical water. Service sectors need to purchase large amount of food to satisfy its demand.

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Therefore, when service sector consumes food from agricultural sector, virtual water starts to flow from agricultural sectors to service sectors and consequently has effect on service sector's water footprint. That means a certain proportion of direct water used by agricultural sectors is induced by the demand of service sectors.

However, the statistic figures just focus on the 'on-site' or 'direct' water used by service sectors. According to previous study (Wiedmann et al., 2013), environmental impacts are allocated to the immediate producers and the influence of final consumers is not reflected. Even though some studies have evaluated consumer-focused water use by global, national and regional economies as aforementioned, there is an important omission that no study has ever been carried out to exploit individual economic sector's water use driven by its consumption. As a matter of fact, the total water footprint of economies can be considered as the sum of the water footprint of each economic sector, as they constitute the whole economy. Moreover, the water footprint assessment of economic sector can provide more comprehensive information to guide appropriate water management practices, which will contribute to helping the economy to use water resources in a more sustainable way. Given these reasons, this study chooses a typical service sector—Macao's gaming industry as a case to evaluate its water footprint.

Gaming industry has been existed in Macao since the 16th century. With over 400 years' development, Macao's gaming industry has made striking progress in its scale and profit. As the pillar industry, gaming industry contributed to three fourths of Macao's GDP in 2011 (DSEC, 2011) and moreover, making Macao one of the richest regions in Asia (Wang, 2010). However, price has to be paid; Macao inevitably suffers from various problems, such as inequality, pollution caused by gaming industry (Tang and Sheng, 2009). Especially, Macao is an extremely water-starving region; more than 95% of Macao's freshwater is imported from mainland China. Moreover, its freshwater resources are subject to increasing pressure, due to the growing residents as well as large number of tourists attracted by gaming industry (MSAG, 2013). Inevitably, the resource-intensive gaming industry has brought about great pressure to extreme resource-scarce Macao (Wan and Li, 2013).

In the recognition of these problems, concerns on Macao's sustainable development arise, striving for a better society and environment. A series of studies have made efforts to evaluate Macao's consumption's impact on socioeconomic issues such as energy use and greenhouse gases emissions (e.g., Li and Chen, 2013; Li et al., 2013; To et al., 2011). More specifically, gaming industry has been the focus in some recent academic studies, due to its vital role in Macao's entire economy (e.g. Lei et al., 2010; Sheng and Tsui, 2009). All of the efforts have contributed greatly to tackle the challenge of the sustainable development of Macao's gaming industry. Despite these previous studies, it should be pointed out that the key element water has been absent in the studies on Macao's gaming industry. As Macao's pillar industry, no doubt gaming industry has significant influence on Macao's water footprint and water management. As a consequence, appreciating the detailed information on gaming industry's water use can be of prime importance for solving some of Macao's most urgent water shortage problems.

This paper attempts to for the first time provide an explicit accounting procedure to assess the water footprint of a special service sector—gaming industry. Our object is to find out how much direct and indirect water is needed to sustain Macao's gaming industry in the period of 2005–2011 during which the data are available, by the means of water footprint calculation and more importantly, to figure out water reduction potential and possible solutions to save water, based on the detailed findings of this study.

2. Methodology and data

2.1. The hybrid method

Generally, there are two widely adopted methods for water footprint accounting: one is bottom-up approach and the other is top-down approach. The bottom-up can collect dispersive process information through the research target's whole lifecycle and then aggregate all the information into the target's whole virtual water profile. Providing intuitively detailed information is bottom-up approach's most attractive merit, while at the same time; it is also this approach's disadvantage. As Macao's gaming industry has various products and service inputs, striving for such details is time-consuming and inevitably suffers from truncation errors, due to the difficulty in covering each input in a unified base (Chen et al., 2011; Chen and Chen, 2013). On the contrary, the top-down approach, usually presented as input–output analysis, can not only avoid the truncation error but also cover different activities in the whole economic network, as the input–output table is a high level aggregation of all economic sectors. However, just because of the aggregation of data, the results obtained by the most prevalent top-down approach are doomed to be too rough to analyze specific products or services inputs in individual economic sectors. And more importantly, it should be noted that no Macao economic input–output table exists currently, making it impossible to employ input–output analysis on Macao's gaming industry.

Under this circumstance, a method attempting to incorporate the merits of methods outlined above and at the meantime reducing their disadvantages is needed in the current study. A hybrid method which describes procedures for combining input–output analysis with process analysis is firstly proposed by Bullard et al. (1978) to calculate energy required directly and indirectly to produce goods and services. On the basis of the averaged macro-economy data supported by the input–output analysis with the process analysis, the hybrid method has been successfully applied to evaluate ecological endowments consumed by different systems, such as embodied energy of building materials (Alcorn and Baird, 1996; Han et al., 2013), embodied greenhouse gas emission of renewable resources (Li et al., 2012), virtual water of constructed wetlands (Chen et al., 2011), embodied energy and water footprint of wastewater treatment plant (Shao and Chen, 2013). Moreover, as for Macao's gaming industry, this hybrid method was also successfully employed to investigate its embodied energy consumption as well as greenhouse gas emission (Li et al., 2014). In light of the previous hybrid method based studies, water footprint of Macao's gaming industry can be calculated by the following steps.

First, as the hybrid method begins with the readily input data, this study classifies the various inputs required by Macao's gaming industry into four major categories, namely, operating inputs, labor, commission and goods purchased, then compiles a detailed input inventory. It should be noted that the amount of direct water input into gaming industry can be calculated in this step. Based on the monetary cost of water input and the water price, the amount of direct water input is obtained. Second, choose suitable embodied water intensity databases. Embodied water intensity for an economic sector refers to the average amount of water consumed in the supply chain to produce one monetary unit of goods or services based on the current technology. According to Macao's trade statistics, the majority of goods and services consumed by gaming industry are imported from different countries/regions. For instance, energy products like electricity and diesel are imported from mainland China, while the electrical machines are mainly purchased from Germany. As a result, choosing comprehensive databases cover embodied water intensities of various sectors in different countries/regions has the fundamental meaning for water footprint calculation.