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A review on the virtual water theory

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ABSTRACT

The concept of virtual water originated in Europe in 1993. As a brand-new perspective, the theory means significantly for the expansion of our horizons on the management of water resources. Building on a systematic study of such ideas as virtual water, water footprint and its measurement, virtual water trade and strategy, this thesis is intended to establish a sound understanding of the current research developments, analyze the possible deficiencies and put forward a projection of the future research direction.

KEYWORDS

Virtual water; Water footprint; Virtual water trade; Virtual water strategy.

DEFINITION AND MEASUREMENT OF VIRTUAL WATER

Definition

In 1993, Professor Allan proposed the concept of “Virtual Water”[1], which originally meant the quantities of the water resources that have been consumed during the agricultural production. This idea has been further extended by scholars like Qadir. M and Hoekstra. It was not until 1996 that Professor Allan had perfected the concept and gained wide recognition among scholars, meaning the quantities of water resources that have been consumed during the goods production and service provision[2]. In the field of the theoretical study of virtual water, Chapagain maintains that it be classified into green water, blue water and dilute water[3]; while Dabo Guan contends that it break up into categories of fresh water and waste water[4].

Measurement of virtual water

The measurement of virtual water in the production and services has constituted the premise and basis of the study of it. Water volumes for agricultural use accounts for about 80% of the total global water consumption. Owing to the unavailability of data, complicated computerization as well as the lack of research on industrial goods[5], the measurement of virtual water is now mainly based on the agricultural produce. Presently, the database of virtual water of agricultural and livestock products has already been established[6]. There are general two methods of the measurement of virtual water. One is what Chapagain proposed to study the production trees of products[7]; the other is what Zimmer. D suggested to measure in accordance with different product types[8]. The Penman Equation recommended by FAO, has been generally applied in the classified counting of agricultural produce for its convenience and practicability[9]. An input-output analysis could easily reflect the flows of resources during the processes of goods production and consumption. Consequently a more comprehensive measurement of virtual water could be established. Hence, this method has been widely adopted among scholars in China[10-12].

Deficiencies

At present, all research findings available show the lack of detailed metrological information and accurate water consumption data leaves us no option but to base the measurement of virtual water of agricultural produce on the volume of water demand of an average drought year. What’ more, the standard virtual water content given by FAO is ideally obtained and the configuration is not accurate, thus leading to big errors in the measurement of the virtual water content. Despite the improvement on the measurement method of input and output, there still remains the following problems:

First, The virtual water content of products obtained this way is still not completely tantamount to virtual water;

Second, With green water conveniently ignored, the virtual water content obtained this way is actually the consumption volume of blue water, and therefore the validity and reliability of the method is deteriorated;

Third, The input-output model of water resources is a value model. There is obviously a lack of homogeneity by incorporating water for agricultural use and other industrial uses into the same table. Currently the measurement of virtual water is far from being perfect and demands more intensive study.

VIRTUAL WATER TRADE AND STRATEGY

Virtual water trade

Virtual water is tradable and can flow in the import and export of goods in international and domestic trading activities. Crops contain a higher content of virtual water. Some scholars have constructed a connection between food safety and virtual water trade[1]. S. Suweis has started a regulation study of the global virtual water trade[13]. Over the recent years, the empirical research range of virtual water trade has been extended all over the world including Middle East, South Africa, Japan, India, and China[2,14]. Some scholars even go further to study the impact the virtual water trade has on the quality of water resources[15]. Based on AHP approach, Dongsheng Li has appraised the application conditions of the virtual water trade of agricultural produce[16]. By applying input-output model, Changbo Qin has made an analysis of the virtual water trade volume in Shaanxi Province China[17]. Among the researches in which virtual water trade volume is obtained by comparing the production and consumption data, only a few scholars consider the storage of it[18]. Currently there are two major research directions about the virtual water trade: one is the measurement based on the water footprint, the other the measurement based on the input-output of water resources.

Virtual water strategy

As the result of the virtual water trade research comes the virtual water strategy, which refers to the activities in which the water-rich countries and regions export the water-intensive products to the water-poor countries and regions by means of barter arrangements[19]. Zhongmin Xu has questioned and redefined it[20]. The research of virtual water strategy concerns two parts : one is the virtual water strategy and water safety, the other is the impact study of virtual water strategy on the management of water resources, ecology and economy[4], both of which have embodied the political and social function of the virtual water[21]. Jimei Li has given an analysis of the virtual water strategies in different contexts and their impact on the water resources and ecological environment of Tarim river Basin. The application of virtual water strategies will conserve the water resources to restore the natural vegetation and partially reverse the ecological environment of the basin[19]. Applying the comprehensive AHP-GRA approach, Liping Liu has given a quantitative assessment of the suitability of virtual water strategies to be taken in Zhang Ye[22]. In view of national security and food safety, the strategy on national level is not preferred by the Chinese scholars and they hold that the virtual water strategy should be carried out among regions like south and north to promote reasonable configuration of water resources.

Deficiencies

To sum up, major problems about the research of virtual water trade and strategy lie in:

First, The research of resource effects, ecological effects and economic and social effects is done, but not deep enough[23];

Second, Most of the virtual water strategy researches focus on the measurement to the volume of virtual water trade. Except for several foreign scholars[24], there are rarely any relevant studies on the negative effects of the application of virtual water strategy in China;

Third, There is a lack of feasible approaches to appraise the environmental effects of virtual water strategy[25];

Forth, The whole system of application conditions, methods and result assessment of virtual water strategy still remains weak;

Fifth, A more thorough research is still needed on the regulation and maintenance mechanism of virtual water trade;

Sixth, In the general environment of virtual water strategy, there is currently no relevant study on the ecological compensation mechanism of agriculture, basins, and cities and so on. Owing to the special nature of virtual water, there are a lot of difficulties to formulate a quantitative and value assessment. Further study is needed on how to compensate and balance ecological benefits and economic benefits and so on.

DEFINITION OF WATER FOOTPRINT AND ITS MEASUREMENT

Definition of water footprint

Water footprint faithfully reflects the demand and possession of water resources. Hoekstra defines it as the required amount of water resources in all products and services that any known people (countries, regions or individuals) have consumed within a specific period of time[26]. It studies the amount of water resources that corresponds to the resources and services man has consumed directly and indirectly. Concerned scholars have established the structural analysis and comparative study of water footprints on national, provincial and basin levels. The study of the effects of food consumption structure on water footprint is to identify the factors of water footprint and solve problems like water shortage, water and food safety as well as the ecological environmental pressure[27]. More and more international study on water footprint is done in a relatively small frame in the world[28]. However, it is focused in a larger frame such as the whole country, provinces and basins in China[29].

Measurement to water footprint

There are generally two approaches in measuring water footprint; top-down and bottom-up. The top-down approach means the water footprint equals available water resources in the region plus net virtual water inflow[30]. The bottom-up approach means the products, goods and services that residents have consumed are multiplied by their corresponding amount of virtual water per unit and then added together to obtain an amount, which then is added by the water consumption of life and ecological environment[31]. Despite the possibly different results both approached may lead to, a rough pattern of the water footprint distribution can be reflected. Some scholars have developed the calculation method of water footprint based on the input-output analysis[32]. The input-output models break up into regional input-output models and multi-regional input-output models. The former suits a specific single area, and therefore enjoys wide applications in the water footprint study[33].

Deficiencies

To sum up, current water footprint study is still in its initial stage, mainly focusing on the introduction of its definition and measurement and the application study on the regional level. There are the following deficiencies:

First, The study is limited to the impact of human activities on water resources without considering the impact to water quality.

Second, The measurement of water footprint only covers the virtual water and real water contained in the products closely related to human life without considering ecological water.

Third, The top-down and bottom-up approaches have their distinctive styles. The former is used to analyze the dependence of local residents upon the external water resourced. Confined by the difficulties to obtain the trade data and double counting involved, it could only be applied on national levels, and this method have repeated computing problems, the results are often too large; while the latter, despite its convenience in calculations, does not include the trade volumes of the deep-processing consumption goods, rain-fed agriculture and the grain reserve and export. Hence, the results tend to be smaller. The input-output calculation approach does not consider the difference between the consumption between green water and blue water in the agricultural production and therefore the error is relatively big.

DEVELOPMENTS AND DEFICIENCIES IN THE VIRTUAL WATER STUDY

The advancement and development of virtual water and water footprint has extended our horizons on the study of water resources, which gradually gained its acceptance and attention by the researchers and administrators of water resources. Guodong Cheng has pointed out the relationship between virtual water and water resource safety[34]. Dennis Wichelns has explored the policy-formulation of the water resources management[35]. Guided by the virtual water strategy, Yongqiang Cao has given an analysis of the management and regulation of the water resources in Bejing, Tianjin and

Hubei Province[36]. Based on the developments of water footprint, Rui Qi has assessed the indexes of the sustainability of regional water resources[37]. Yuping Han has studied the assessment of sustainable use of regional water resources and water safety[38]. In view of the protection of ecological system, Xue Han has proposed to reduce the green space and increase the potential, or at least protect the available farming land[39]. Changxin Xu has elaborated on the economic content of virtual water strategy from perspectives of water-saving effects and economic values and a data model is set to give an empirical study[40].

Based on the ongoing development of the empirical and extended study of virtual water, some scholars have discussed the basic rules of the virtual water flow. Seekell has analyzed the factors that affect the flow of virtual water on the global level[41]. Hongmei Liu has pointed out that the virtual water trade involves factors such as water resources, politics, economy, ecology, society and son on[42]. Ma Jing holds the virtual water trade is related to factors such as the wealth of water resources, climate and techniques. Though the above-mentioned researches touch upon the flow of virtual water, they fail to give a clear picture of the factors that affect the industries inside the regional virtual water flow, the evolution pattern, and the driving mechanism of the regional virtual water flow.

CONCLUSIONS

Research development of the virtual water theory

A review of the domestic and overseas researches of the virtual water theory shows it was noticed and studied in 1993 and the definition, measurement and research models were proposed and recognized by a few western scholars. In 2003,Guodong Cheng, the academician of the Chinese Academy of Sciences first introduced the concepts of virtual water and did the pioneering study. In 2011, Hongjun Lei has analyzed the theoretical system of virtual water and proposed the problems and solutions[43]. The virtual water study in china is better developed in the north rather than the south and most of the researches are limited to the quantification of virtual water of agricultural produce and the application of low-level strategies. Many say the virtual water study is the priority of dry and water-deficient areas and has nothing to do with water-rich areas. Presently the virtual water study in China is faced with congenital deficiency as we as well as acquired misunderstanding.

Major deficiencies of the virtual water theory

There are mainly four deficiencies in the study of virtual water:

First, The theoretical study of virtual water in China is still in its initial stage. There is rather little effort made to study the potential ecological environment and the positive externalities and the study on the development of virtual water remains unsubstantial;

Second, There is currently no systematic study of the basic rules of virtual water flow, affecting factors, driving mechanism and so on in the world. As a result, the further development of the virtual water theory is circumscribed;

Third, Weak still, is the study of resource effects, environmental effects, assessment of soci-economic effects and the regulation of virtual water flow. The scientific evaluation of the management measures can be seriously affected.

Forth, There are still no sound modeling approaches to measure virtual water and water footprint. Some calculation results are far from the reality.

Research prospects of the virtual water theory

Confronted with the regulation and management demands of virtual water in China, we have to give answers to the following questions:

First, The question of the basic characteristics of virtual water flow and its calculation, and reveal the different area, different products and services of the regional differences in virtual water content;

Second, The question of the evolvement pattern, affecting factors and driving mechanism of virtual water, regional virtual water flow pattern, the water resources optimal allocation model;

Third, The question of the principles of virtual water flow and its simulation, including the assessment of the resources, ecological and socio-economic effects of virtual water flow, the regulation model and effects evaluation of virtual water flow;

Forth, The study of regional water footprint starts from the regional consumption pattern to reveal the load capacity of water resources in different regions by means of the water footprint evaluation and finally reflects the regional supply-demand balance quantitatively;

Fifth, The strategic study of virtual water, for the virtual water strategy in different regions to establish scientific and reasonable, provides solid scientific foundation and policy support for the sustainable application of water resources.

Sixth, The question of the coupling of virtual water and real water. How to calculate quantitatively the service in the virtual water, how to make better use of virtual water for the entire social, economic and ecological system of sustainable development services, etc.

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