REGIONAL VIRTUAL WATER OF THE SHIKOKU ISLAND: INTER-REGIONAL INPUT-OUTPUT TABLE

Pongsak SUTTINON, Seigo NASU
Kochi University of Technology

ABSTRACT**:** This paper proposes the use of water-resources inter-regional input-output (WRIRIO) table as a tool to evaluate virtual water trade between Shikoku Island, one of the severe areas in water shortages, and other regions. The WRIRIO table meets the challenge of evaluating water demand to support to various economic activities such as (1) agriculture, (2) manufacturing, and (3) service sector in all regions of Japan. This approach, which combines input-output tables and water demand analysis, overcomes the shortcoming of traditional input-output tables which do not resolve the challenge of evaluating demand of natural resources to meet economic development in each region. Regional virtual water or trade of services of water is enumerated by combining a Shikoku inter-regional input-output table and water demand analysis in same industry product. The calculated results show inter-regional trade of money and water use to support each industry. The application methodology is illustrated through the case of year 2005. The paper indicates that "water-resources inter-regional input-output table" provides a tool that allows decision makers to accurately value regional trade with consideration not only of money circulations, but also of water uses.

KEYWORDS: input-output table, regional trade, virtual water

1. INTRODUCTION

Water is generally needed to produce goods and services. Hoekstra stated that the water used in the production process of an agricultural and industrial product is called the 'virtual water' contained in the product (Hoekstra, 2003). For example, (1) 1 kg of rice needs 1-4 m^3 of water (Chapagain and Hoekstra, 2003); and (2) 2 gram of a 32-megabyte computer requires 32 kg of water (Williams et al., 2002).

Virtual water, which was also known as embedded water, embodied water, or hidden water, was defined as "the volume of freshwater used to produce the product, measured at the place where the product was actually produced" (Hoekstra and Chapagain, 2007). It is certain that a country or a region exports water-consumed products to another country or region, it also exports water in a virtual form. By this definition, water is supported from countries to the other countries by a trade of goods and services.

There is little experience in the use of trade of real water among regions or countries, for a number of reasons. For example, there are the large distances between regions and associated cost. However, an illuminating real world case study is a trade in water-demanding goods and services or virtual water trade by importing products instead of domestically producing water-intensive products. On the other hand, water-rich regions or countries could get benefits from producing water-consuming products and exporting to water-scare countries.

During the 1960s, Tony Allen introduced the concept of "virtual water" (Allen, 1993; 1994). Since the early 2000s, there has been growing interest in the application of virtual water to a various products and regions. The development of virtual water has become a popular topic in the field of water management, especially in arid countries. For example, Allan described virtual water impacts in various fields such as economic, political, and social viewpoints in the Middle East (Allen, 1997; 1998; 1999; 2001; 2001; 2003). Virtual water has been also suggested as an important role to food security (Meissner, (2003); Renault, (2003); Wichelns, (2001); Yang and Zehnder, (2002); Yang et al., (2003)). Hoekstra and Hung (2002; 2003) showed a quantification of virtual water flows between nations in relation to international crop trade. Hoekstra (2008) assessed virtual water flows between nations as a result of trade in agricultural and industrial product. Verma et al. (2009) reported virtual water in the context of India's National River Linking. Aldaya et al. (2010) proposed virtual water to regional policy adaptation in Spain. From previous reviews, it is certain that virtual water can be considered as one option of water management schemes.

However, virtual water was questioned by a number of economists about a weak support by standard economic arguments. Ansink (2010) argued that the virtual water concept has been "incorrectly used to make certain claims that are not in line with empirical facts and standard economic theory." However, Reimer (2012) developed new theoretical results that place the virtual water concept on a firm economic foundation, and which corrected several misconceptions within the existing literature on virtual water economics. Reimer (2012) suggested using a phrase of "trade in the services of water," or "trade in water services", which was recognized that in trading goods across national borders, we were effectively trading the services of water that was used to produce the goods. From previous reviews, it is almost certain that virtual water is generally used to define a trade in water services to produce the goods in various goods and regions. However, the main disadvantage of virtual water is that the data for domestic and international trades; and water used in each goods is not accessible, especially in developing countries.

To overcome this shortcoming, an inter-regional input-output table that covers multiple regions at the same time, describing transaction relationships of goods and services not only in international markets but also in domestic trades between regions, is needed to illustrate the production behavior in each products and each region. This table shows "how much was consumed by which region's which industry or final demand" for goods and services produced in each region (METI, 2010). Extended input-output table with trade in water services has become a popular topic in the field of virtual water and water demand assessment (Hatano and Okuda (2004); Okadera et al. (2005); Okuda et al. (2005); Guan and Hubacek (2007); Fukuishi (2010)). From the above reviews, it is certain that the combination of input-output table and water demand analysis is a powerful valuation tool that combines economic values and water used in each industrial sector so as to value virtual water, defined as trading the services of water that was used to produce the goods.

However, there is little experience in the use of inter-regional input-output table for evaluating virtual water in each economic product such as agriculture, manufacturing, and services, for a number of reasons. For example, input-output table is an economic approach in which understanding of theories is necessary. The data for water used in each industrial sector is not accessible.

The objective of this paper is to value virtual water by means of a tool that integrates inter-regional input-output table and water demand analysis. This proposed extension of inter-regional input-output table can enable a more complete assessment of water demand in terms of intermediate and final demand with impacts of trade in the national and world market. The case study was selected from Shikoku Island in Japan. This is a basic analysis for understanding the regional level and preparedness for a further analysis of water management in the river basin inside Shikoku region.

2. METHODOLOGY

To evaluate virtual water in Shikoku region and the other regions, we develop an extended model of inter-regional input-output (IRIO) model named water-resources inter-regional input-output (WRIRIO) model by integrating a traditional IRIO table with water used under conditions of the same industrial sectors, time and regions. The steps in calculation are as follow. First, IRIO table of 9 regions of Japan is collected and aggregated from a 12-sectors IRIO table to 3-sectors IRIO table for simplicity. Next, water demand is calculated for each industrial sector. Then, the WRIRIO table is generated by inserting a set of calculated water demand as a new row of the aggregated IRIO table. Finally, virtual water or trade in the services of water is analyzed under industrial activities. The main assumptions are; (1) virtual water is defined as a trade in the services of water, shown in the rows of input-output table, describing the distribution of output or product sale structure; (2) water use is measured at the field level, not at the point of water withdrawal.

2.1 Inter-regional input-Output (IRIO) model

Input-Output (I-O) table was firstly created by Wassily W. Leontief for USA to forecast economic situation after the Second World War (Leontief, (1936; 1941)). The I-O table clarifies flows of goods and services from each industrial sector, considered as a producer or supply sector, to each of the sectors itself and others, defined as consumers or demand sector (Miller and Blair, 2009). An input-output table is illustrated in a monetary matrix (row and column) format containing inter-industry transactions. The rows of this matrix describe the distribution of output or product sale structure. The columns show input or purchase structure, the sum of raw materials and value added expenses. However, a traditional I-O table is only illustrated in one region. This means that an effect of domestic trade cannot be shown.

To overcome this shortcoming in Japan, a 2005 inter-regional input-output table that illustrates trades of goods and services in international and domestic markets of 9 regions of Japan, is published in 2010 (full details on a process of creation and application of IRIO table are given in METI (2010)). In this paper, first, IRIO table of all 9 regions of Japan is collected from published data of Ministry of Economy, Trade and Industry (METI) of Japan. We select the 12-sectors domestic products for an industrial classification as follow: (1) Agriculture, forestry and fishery; (2) Mining; (3) Beverages and Foods; (4) Metal products; (5) Machinery; (6) Miscellaneous manufacturing products; (7) Construction; (8) Public utilities; (9) Commerce and transport; (10) Finance and insurance and real estate; (11) Information and communications; and (12) Service Industries. Next, the collected IRIO table is aggregated into two regions as Shikoku and rest of

Japan to show the domestic trades. For simplicity, number of industrial sectors is also aggregated into three main sectors as (1) agriculture, (2) Manufacturing (a sum of industrial sectors from (2) mining to (6) miscellaneous manufacturing products in the 12-sectors traditional IRIO table), and (3) service sectors (a sum of industrial sectors from number (7) to (12) in the 12-sectors traditional IRIO table). Finally, the aggregated Shikoku-IRIO table in 2005 is created.

2.2 Water demand analysis

The process of water demand analysis is as follow. First, the analysis of number and type of industrial sectors of water used is the same as in the case of the previous aggregated IRIO table. Then, water used in agricultural, manufacturing, and service sectors is collected from a number of sources, such as (1) white paper of water resources in Japan, 2005 (MLIT, 2005); and (2) industrial site and water of the 2005 census (METI,2005). Finally, water used in the same three sectors as aggregated IRIO table is generated and prepared for the nest step of WRIRIO model.

From the viewpoint of water resources engineering, there are various types of water used such as: (1) agriculture; (2) manufacturing; (3) service; (4) household or residential use; (5) hydro power generation; (6) environmental preservation; and the other purposes. However, for simplicity, only three sectors of economic activities in IRIO model are considered as (1) agriculture; (2) manufacturing; (3) service. However, the further research is a combination of all water users into IRIO table. Water source is one of the most interesting issues. This is because policy makers are planning means of meeting the demand with limited water supply from each source. In this paper, for simplicity, only the sum of water from all sources is used in the process of water-resources inter-regional input-output (WRIRIO) model.

2.3 Water-resources inter-regional input-output (WRIRIO) model

The generated process of this step is as follow. First, sum of the water demand from the previous step is added as a new row of an aggregated IRIO table. The sectors of both IRIO table and water used must be the same. In this step, water use unit per monetary terms (m^3/Japanese yen) of production cost, value added, and total production can be also calculated. Finally, WRIRIO model is generated as a reliable database of economic activity and water used to meet it. Reliability and accuracy of WRIRIO table, as a descriptive device, are the most important topics until this calculation step. This is the reason why we use only secondary data published by Japanese government agencies such as METI and MLIT. All data used in this paper is collected by a survey method by METI and MLIT. However, in the further research, a non-survey method is used for downscaling to the local region or river basin.

2.4 Virtual water

The main objective of this step is to identify virtual water or trade in the services of water. The virtual water is defined as a trade in the services of water in the rows of input-output table, describing the distribution of output or product sale structure. This means not only virtual water can be illustrated, but the distribution of services of water that used to produce the goods is also shown. For example, water used to produce goods in an agricultural sector is a sum of water used in production; trade in the services of water of final demand, domestic and international exports.

3. RESULTS

Water-resources inter-regional input-output table and virtual water of Shikoku region are calculated from traditional inter-regional table and water use analysis. Table 1 shows the water-resources inter-regional input-output (WRIRIO) table of Shikoku region with three industrial sectors in 2005. There are two different parts: (1) aggregated inter-regional input-output (IRIO) table in a monetary unit; (2) water used in unit of m^3.

As can be seen in IRIO part of table 1, the status of regional economics of Shikoku region and the rest of Japan in 2005 is summarized. All input and output values in each I-O table are compared for a number of sectors; for example, intermediate demand, value added, final demand, trade, and total outputs. As shown in table 1, Shikoku Island does not play an important role in Japan economy, accounting for only approximately 3 % of total national production. However, regional production for Shikoku industry is still huge, approximately 84 % of total national production of a whole nation of a country as Thailand (NESDB, 2005).

As can be seen in part of water used of table 1, total water used Shikoku region is only 4 % of total national water used. However, water demand and supply is generally managed based on area such as river basin. In this area, there are water shortages every 3 year from year 1997 to a present time in Yoshino river basin, which is a biggest river basin in Shikoku Island located in 4 prefectures (SWRRC, 2011). The calculation result shows that water-used structure in each sector of Shikoku region and rest of Japan is the same: (1) 65-75 % in Agriculture sector; (2) 15-20 % in both manufacturing and service sectors.

Table 1 also shows water use unit in each industrial sector. This is defined as a quantity of water to meet 1 million yen of each product. For example, agriculture sector in Shikoku region needs 3,054 m^3 of water to produce 1 million yen of agricultural product. It is certain that agricultural products generally need water greater than manufacturing and service goods. This is because physical needs for plant in each step of growing and low economic value of agricultural production.

Water use unit in both regions is compared in table 1; however, it is not correct to inform that agriculture product in Shikoku needs less water than rest of Japan to produce 1 million of goods. This is because different types of crop inside each region. For example, rice is a major crop in rest of Japan which consumes much water for growing, at the same time, Shikoku concentrates in planting the other crops consuming less water. It should be carefully considered in each crop such as rice, grain, and the others to compare water use unit.

Table 2 shows virtual water or trade in the services of water using three regions, (1) inside Shikoku, (2) rest of Japan, and (3) international market. All regions use the data from aggregated IRIO table and water used from Japanese government agencies. As can be seen in table 2, trade in the services of water in intermediate demand (production process) is greater than final demand (private and governmental consumption) and international trade (exports and imports) for both regions of Shikoku and rest of Japan, accounting for approximately 70 % of total water used in each region. This is because production process generally needs water to produce goods and services. As can be seen in table 2, trade in the services of water of international market indicates that Japan imports goods across national border greater than exports.

This means Japan also trade the services of water from the other countries outside Japan that is used to produce the goods.

Figure 1 shows trade in the service of water in a case of only agricultural sector in Shikoku region, illustrated in the first row of table 2. As can be seen in figure 1, according to domestic market, it is almost certain that half of service of water is traded to the rest of Japan, located outside Shikoku region. At the same time, there are water shortages every three years inside Shikoku region, especially in Yoshino river basin. This means half of water used in agricultural sector in Shikoku is traded in form of service of water to other regions under water-scarce conditions.

From the viewpoint of virtual water considering, much-water-consumed products such as rice should be moved to outside Shikoku or we should import rice form other region and international market to reduce water use inside Shikoku area. However, from the other viewpoints such as engineering and socio-economics, it is only one option of various water demand and supply measures. By using this option, policy makers should carefully consider the impacts of social and cultural change in that community also. Future research should focus on how to utilize this option in decision support system by using a number of methods such as real option analysis (Suttinon and Nasu, 2010) and option games (Suttinon et al., 2012).

4. CONCLUSION

The Water-resources inter-regional input-output (WRIRIO) table can be used to quantify the virtual water or trade in service of water in each region and each industrial sector. The main advantage of the WRIRIO table is that it combines the traditional inter-regional input-output table and water used by comparing on the same industrial sectors. WRIRIO table allows policy makers to clearly understand the path and type of virtual water or trade in water services. The WRIRIO approach presented here is a descriptive device that is workable with various regions and industrial sectors. It is one of powerful tools for considering route of water service between regions, especially in water-scare region such as Yoshino river basin in Shikoku, where water is limited. Future research should focus on: (1) the river basin scale; (2) international scale, with uncertainties of water demand and supply in the future.

Table 1. Water-resources inter-regional input-output (WRIRIO) table of Shikoku region with 3 industrial sectors in 2005.

Part 1: IRIO table Unit: 10^6 Japanese yen			Intermediate demand						Final demand		International trade		Total Output
			Shikoku region (SKK)			Rest of Japan (RoJ)			SKK	RoJ	Exports	Imports	
			Agr.	Man.	Ser.	Agr.	Man.	Ser.					
Intermediate transaction	SKK	Agr.	65,381	187,883	30,861	11,008	157,142	62,883	104,322	164,290	8,130	-68,430	723,470
		Man.	80,751	1,953,225	922,396	30,183	1,993,263	1,374,017	1,106,283	1,193,954	1,449,526	-2,134,233	7,969,365
		Ser.	65,305	945,959	2,880,015	14,707	477,064	636,857	10,458,934	1,311,139	350,259	-168,392	16,971,847
	RoJ	Agr.	17,976	60,943	12,300	1,548,652	7,392,769	1,303,158	30,265	4,184,125	54,334	-2,173,417	12,431,105
		Man.	72,412	1,546,336	1,088,739	2,495,534	138,695,007	63,445,763	1,677,293	92,511,449	54,658,906	-57,109,400	299,082,039
		Ser.	43,465	709,816	1,368,632	1,757,831	59,336,725	163,400,686	1,879,334	376,120,601	17,075,897	-10,677,439	611,015,548
	Value added		378,180	2,565,203	10,668,904	6,573,190	91,030,069	380,792,184					
	Total input		723,470	7,969,365	16,971,847	12,431,105	299,082,039	611,015,548					
Part 2: Water demand, 10^6 m^3.			2,209	695	507	52,576	10,393	13,452					
	Water use unit, $m^3/10^6$yen		3,054	87	30	4,229	35	22					

Note: Agr is Agriculture, Man is Manufacturing, and Ser is Service sector.

Table 2. Inter-regional virtual water or trade in the services of water of Shikoku region with 3 industrial sectors in 2005. Unit: 10^6 m^3.

		Intermediate demand						Final demand		International trade		Total Output
		Shikoku region (SKK)			Rest of Japan (RoJ)			SKK	RoJ	Exports	Imports	
		Agr.	Man.	Ser.	Agr.	Man.	Ser.					
SKK	Agr.	200	574	94	34	480	192	319	502	25	-209	2,209
	Man.	7	170	80	3	174	120	96	104	126	-186	695
	Ser.	2	28	86	0	14	19	312	39	10	-5	507
RoJ	Agr.	76	258	52	6,550	31,267	5,512	128	17,696	230	-9,192	52,576
	Man.	3	54	38	87	4,820	2,205	58	3,215	1,899	-1,985	10,393
	Ser.	1	16	30	39	1,306	3,597	41	8,281	376	-235	13,452

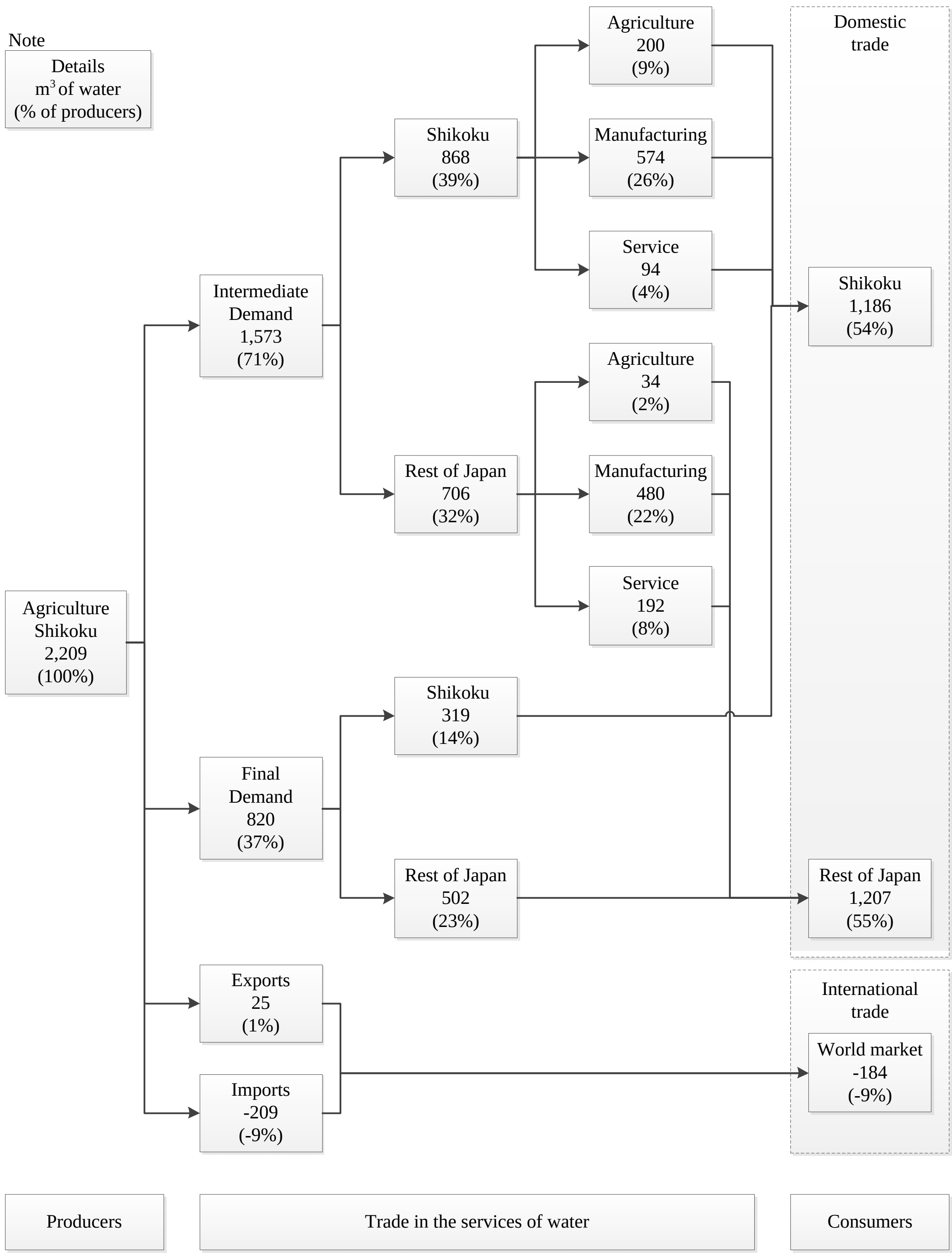

Figure 1. Trade in the service of water in a case of agricultural sector in Shikoku Region

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