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India-China Agricultural Trade Based on Virtual Water: A Heckscher-Ohlin Approach

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Aim: This paper provides the economics of Virtual Water (VW) exporting to other countries through major agricultural commodities from India. Virtual Water is interconnected with food sustainability and it is the amount of hidden water transferred to other countries through trade. India produces and exports high water-consuming products but contains only 2.56 per cent of total water available in our world. By analysing VW, the total VW export from and import to India and the comparative advantage in producing the commodity in India can be obtained.
Methodology: VW for major crops is estimated by dividing the total water required or applied for the specified crop by the total yield of the crop. In this paper, we computed the virtual water trade for the major crops in India and analysed the comparative advantage for India in producing the crop. The data required for the analysis are collected from various secondary sources like the Directorate of Economics and Statistics (DES, GoI), Indian Agricultural Statistical Research Institute (IASRI), EXIM Bank, and FAO Aqua Stat.
Results: In the years 2018-19 and 2017-18, India exported 34515 MCM and 41080 MCM of VW through rice followed by 420 MCM and 622 MCM of VW through Wheat, 276 MCM and 184 MCM of VW through Maize. When comparing the production of rice and groundnut in China and India in

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water requirement aspect, India has the comparative advantage in the production of groundnut and china has the comparative advantage in the production of rice and also shows the same in the yield aspect.

Conclusion: With the growing water scarcity in India, we should shift the focus from the high-water requirement crop to the lower crop. In the end, we sort out the water scarcity problem and can attain sustainability.

Keywords: Comparative advantage; sustainability; virtual water; water scarcity.

1. INTRODUCTION

"Ensuring the food needs of the growing population with limited water resources is a major challenge. Freshwater scarcity has been increasing at an alarming rate due to climate change and socio-economic development and threatening crop production at the local and global scale. In the Virtual Water Trade (VWT) concept, many countries could offset their limited and uneven distribution of water resources through the international trade of food commodities. This concept potentially promotes regional and global water and food security. Water is vital for all known forms of life. India has only 2.56 per cent of total available water in the world of 43750 Km^3. According to FAO, renewable freshwater availability among continents is 45 per cent in America, 28 per cent in Asia, 15.5 per cent in Europe, 9 per cent in Africa and 2.5 per cent in Australia. The details of total renewable fresh water availability of top ten countries is shown in the Fig. 1. In India, 76 per cent of the total available water are used for irrigation purpose only. Water is one of the major deciding factors in the selection of crops for cultivation and it may lead to a serious threat because of increasing water problems in India, with demand from various sectors exceeding the utilizable supplies" (Kumar, 2017). "All economies around the world which face acute water scarcity problems can and should meet their water demand in the discussions on ways of facing global water challenges" [1,2].

1.1 Virtual Water

Virtual Water (VW) is the hidden flow of water in food or other commodities traded from one place to another (Tony Allan). As agricultural products are sold and traded, the water that is used to produce them is also essentially traded. Identifying the amount of VW embedded in a product has implications for water management, practice and policy. VW is inter-connected with climate resilience, natural capital management, food safety and health, food security, sustainability, biodiversity, trade competitiveness and so on [3-5]. We can sustain the water availability by cut down the production of high crop water requirements in high water scarcity regions and otherwise by the innovation of more water-saving instruments. VW is varying among crops and region due to nature of crop, soil profile, variety and various climatic factors. VW content of various crops among the three countries namely USA, China and India are shown in Fig. 2. The figure clearly indicates that India has high VW content in almost all mentioned crops due to high tropical and sub-tropical nature of the country.

"The virtual water concept (the volume of water used in the production of a commodity, good or service) together with the water footprint (indicator of water consumption that looks at both direct and indirect water use of a consumer or producer), links a large range of sectors and issues, thus providing a potentially Virtual Water Trade as a Solution for Water Scarcity in Egypt 2439 appropriate framework to support more optimal water management practices by informing production and trade decisions" (Aldaya et al. 2009). "Measuring virtual water is a useful concept in assessing water management as it permits the comparison of crops and livestock from the perspective of embedded water" [6]. For a water-poor, but land rich country, virtual water import offers little scope as a sound water management strategy as what is often achieved through virtual water trade is improved "global land use efficiency" (Dinesh and Singh 2005).

"Approximately, VW trade among countries amounts some 15% of the total water use on earth, including rained agriculture. For example, about 1,000 l of water is needed to produce 1 kg of wheat. However, about five to ten times as much is needed for producing 1 kg of meat. Virtual water is practiced between countries as exchange of food, fiber, and manufactured goods. Trade in cereals and other crops as virtual water amounts in average to some 64% of total virtual water trade, while animal products amounts to about 25%, and other about 11%" [7]. "Several studies have emphasized the importance of the virtual water trade and its impact on water and food sustainability from regional to global scale" [8]. "Assessment of water footprint and virtual water trade are relevant for national policy planning for resource management and sustainable supply of food and water" [9].

1.2 Virtual Water and India

"According to the Water Footprint Network (WFN) database, India had the lowest virtual imports of water in the world. India is a large virtual net exporter of water because of agricultural commodities. India is exporting large amounts of virtual water despite being an extremely water-scarce country. India is also a leading producer and exporter of rice. Hence, assessing virtual water content and trade for rice is important to compute the water use efficiency of rice especially. VWE of India changed from 13 Bm3 /y in 1986 to 185 Bm3 /y in 2013. This is 14 times increase in VWE. Total VW traded is 1,652 Bm3 in 28 years. Long-term average VWE is 59 Bm3 /y" [10].

The Heckscher- Ohlin (H-O) model was used which explains international trade flows on the base of relative factors' abundance, positing that an economy will be a net importer in the goods whose production is intensive in the factors that are relatively scarce within the country.

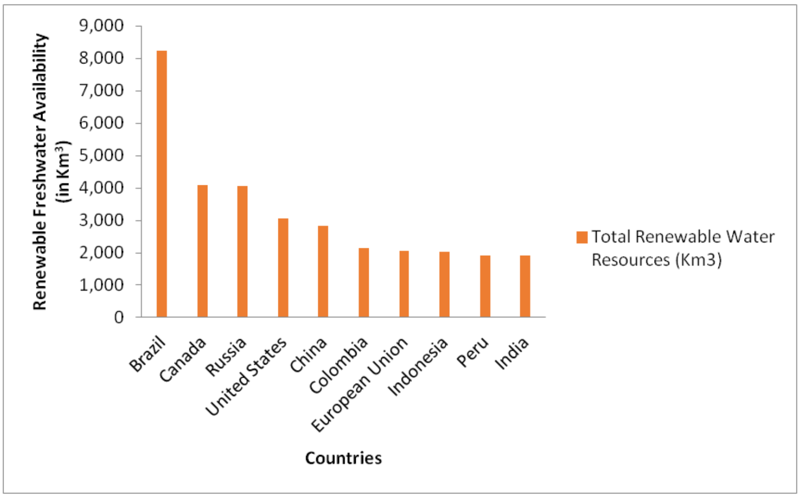

Fig. 1. Top 10 Renewable Freshwater Availability Countries in the World
[Source: 11]

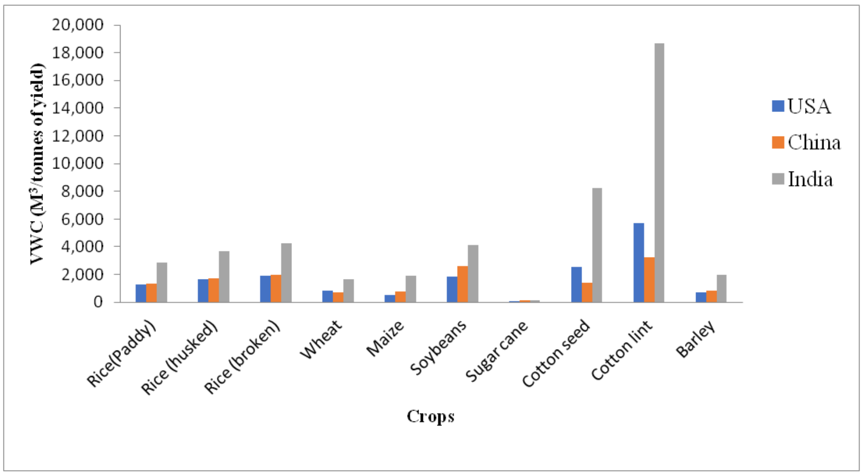

Fig. 2. VWC (M^3/ton) for various agricultural commodities among the three countries
[Source: 12]

The view of the paper is to: (1) to compute the virtual water trade for the major crops in India and (2) to test the validity of the assumption that virtual water flows out of water rich regions to water deficit regions based on analysis of global realities with regard to virtual water trade.

2. MATERIALS AND METHODS

VW is calculated for the major crops in India. Virtual Water Export from India through commodities is calculated for academic years 2017-18 and 2018-19. Table.1 depicts variables and data sources.

Table 1. Describing variables and data sources

Variables	Data sources
Area, Production and Yield	Directorate of Economics and Statistics, Government of India
Crop Water Requirement	Indian Agricultural Statistical Research Institute (IASRI)
Export and Water Parameters	EXIM bank and FAO Aqua Stat

2.1 Virtual Water Content (VWC)

VWC is defined as the volume of water used to produce one unit of a crop.

$$VWC_{C,\,J} = CWR_{C,\,J} / R_{C,\,J}$$

$VWC_{C,\,J}$ - Virtual water content
$CWR_{C,\,J}$ - Crop water requirement for crops and year
$R_{C,\,J}$ – Crop yield

2.2 Virtual Water Trade (VWT)

VWT is associated with the international food trade of corresponding agricultural commodities, and it consists of Virtual Water Import (VWI) and virtual water export (VWE). VWE was given in the Eq. (2).

$$VWE_{C,\,N,\,J} = VWC_{C,\,N,\,J} * E_{C,\,N,\,J}$$

$VWC_{C,\,N,\,J}$ - VWC for agricultural commodities C, country N and year J
$VWE_{C,\,N,\,J}$ -VWE of agricultural commodities C from country N in year J
$E_{C,\,N,\,J}$ - Export quantity of agricultural commodities C from country N in year J

2.3 Heckscher- Ohlin Model (H- O Trade Model)

Heckscher-Ohlin theory, in economics, a theory of comparative advantage in international trade according to which countries in which capital is relatively plentiful and labour relatively scarce will tend to export capital-intensive products and import labour- intensive products, while countries in which labour is relatively plentiful and capital relatively scarce will tend to export labor-intensive products and import capital-intensive products.

The assumption of this model is 2-by-2-by-2 (“Noah's Ark” model), trading goods not the factors, Constant return to scale, perfect competition. With this model assumption, Ohlin's thesis contends that countries export goods that use relatively a greater proportion of their abundant and cheap factor. While the same country imports goods whose production requires the intensive use of the nation's relatively scarce and expensive factors.

2.4 Relative Factor Intensity

At any given relative factor price ratio R/W, the L/K ratio in each sector is chosen to minimize the cost of production. Therefore, tangency between factor price ratio line slope = R/W and production isoquant, slope = MRTS = - dL/dK, in each sector. Call the Y-good relatively L-intensive (and the X-good relatively K-intensive) if the resulting ratio LY /KY is always > LX / KX (equivalently, KX / LX > KY /LY).

Two countries	:	India (I) and China (C)
Two goods	:	Rice and Groundnut
Two factors	:	Capital (K) and Irrigation Water (W)

3. RESULTS AND DISCUSSION

The Virtual Water Contents of major agricultural and horticultural commodities have been calculated for two academic years 2018-19 and 2017-18 in India are depicted in Table.2. There exists a difference in VWC between the two academic years because of the yield difference which is indirectly influenced by climatic and other factors.

The VWC (m^3/ton) and VWE (MCM) of different agricultural commodities for India are presented in Tables.2 and 3. Although the VWC of the

Cashew nut is very high if compared with other agricultural and horticultural commodities, it has higher water productivity (in terms of dollar production per unit of water) than other agricultural and horticultural crops. This is because the yield of cashew nuts is low per unit of water when compared to other crops. The VWC of staple food crop, Rice has around 4500 m^3 per ton of yield followed by wheat has 1850 m^3 per ton of yield. It implies that the cashew nut consumes more water but less in Virtual Water Export. It should be noted that the VWC of various crops will vary according to the production conditions, water management technologies, and climatic conditions. In the consideration of existing water scarcity problems all around the country, we should concentrate on water-consuming technologies to eradicate the water problem.

Table 2. Average Virtual Water Content (VWC) of various crops (*in Number)*

Crops	**VWC (m^3/t)**	
	2018-19	**2017-18**
Rice	4512.97	4658.39
Wheat	1853.44	1929.93
Maize	2698.15	2610.11
Groundnut	5025.13	3697.83
Tobacco	2589.56	2976.19
Potato	285.23	292.19
Soybean	4108.46	4725.90
Onion	295.75	303.82
Cabbage	104.17	111.11
Banana	622.14	631.11
Citrus	1600.00	1363.64
Grapes	279.07	266.67
Cashew nut	29325.51	26007.80
Garlic	586.18	925.01
Sweet potato	324.57	293.50

Table 3. Virtual Water Flows from India during 2017-18and 2018-19 through various agricultural commodities (in Number)

Crops	**Export Quantity (000 t)**	**VW Export (MCM)**	**Export Quantity (000 t)**	**VW Export (MCM)**
	2018-19		**2017-18**	
Rice	7648.0	34515.2	8818.53	41080.1
Wheat	226.6	420.0	322.79	623.0
Maize	102.2	275.8	70.60	184.3
Groundnut	489.2	2458.2	504.04	1863.9
Tobacco	189.6	490.9	185.36	551.7
Potato	367.4	104.8	395.75	115.6
Soybean	0.4	1.6	0.41	1.9
Onion	2182.9	645.6	1588.99	482.8
Cabbage	0.2	0.0	0.53	0.1
Banana	0.1	0.1	0.10	0.1
Citrus	0.0	0.0	0.02	0.0
Grapes	246.1	68.7	188.22	50.2
Cashew nut	1.5	43.4	2.87	74.7
Garlic	11.0	6.5	31.22	28.9
Sweet potato	0.7	0.2	0.40	0.1

Table 4. Comparative Advantages between India and China

Crops	India			China		
	Water Requirement (mm)	Capital Requirement (USD/T)	Yield (t/ha)	Water Requirement (mm)	Capital Requirement (USD/T)	Yield (t/ha)
Rice	1400	223	2.34	890	310	6.75
Groundnut	600	157	2.7	600	160	1.217

The VW flows from India through major commodities are shown in Table.2 depicts that Rice has the largest amount of the virtual water flows from India (34515 MCM in 2018-19 and 41080 MCM in 2017-18), followed by Groundnut (2458 MCM in 2018-19 and 1863.9 MCM in 2017-18).

India is the largest producer and consumer of rice and groundnut. In the year 2021, India's production of rice was over 122 million metric tons. Except for a few years, the production of rice in increased over the last decade. China is the largest importer of rice in the world and imported 4600 thousand metric tons of rice during 2018-19. Groundnut is largely produced and consumed in China followed by India. But there is a vast difference in the water requirement and virtual water content of both crops. With the above considerations, the H-O model was used to find out the comparative advantage in producing the commodities in both countries. Comparative advantage was estimated and shown in Table 4.

When comparing the all in Table.4, we can infer that India requires 1400 mm of water for the rice crop followed by 600 mm for the groundnut crop. But the country China requires only 890 mm of water for rice and the same water requirement for groundnut as India. Considering the other two parameters capital and yield of both crops, we can easily find out that India has a comparative advantage in groundnut and China has a comparative advantage in Paddy crop.

4. CONCLUSION AND POLICY IMPLICATION

The exports of cereal and agricultural foods to over a hundred countries from India for maintaining food security and sustainability involve virtual water trade. Production in the agriculture sector requires a heavy amount of water. When the agricultural produce is exported, it also takes water with it in the virtual form equal to the water that is consumed in producing it. Exporting high virtual water commodities is not in the long-run economic interest of India from the point of view of sustainable development. VWC must be considered while trading agricultural commodities being an agrarian economy. Because it is not favorable to export water from the country, which will lead to depletion of water resources in a country. India must regulate policies to control those commodities and should focus on water-saving technology in producing agricultural commodities [13-15]. The comparative advantage shows that India can produce more groundnut and export them to China, Similarly, China can focus on paddy production rather than groundnut which has more comparative advantage in terms of water requirement and can export to India [16-18].

Because of agricultural products, India is a big virtual net exporter of water. One policy implication is that as the country works to enhance industrial exports, effort should be made to maximize water use efficiency in order to avoid virtually exporting more water. Adjust crop structure to grow more water-efficient crops in water-stressed areas [19-21]; reduce exporting high water-intensive but low-value items through financial incentives; and increase exporting low-water-cost but high-value products.

CONFERENCE DISCLAIMER

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http://repo.lib.jfn.ac.lk/ujrr/bitstream/123456789/8230/1/A%20Quantification%20of%20Virtual%20Water%20Trade%20of%20Major%20Agricultural%20Commodities.pdf

COMPETING INTERESTS

Author has declared that no competing interests exist.

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