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Going against the flow:

A critical analysis of virtual water trade in the context of India's National River Linking Programme

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GOING AGAINST THE FLOW

A CRITICAL ANALYSIS OF VIRTUAL WATER TRADE IN THE CONTEXT OF INDIA'S NATIONAL RIVER LINKING PROGRAMME

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Summary

Virtual water trade has been promoted as a tool to address national and regional water scarcity. In the context of international (food) trade, this concept has been applied with a view to optimize the flow of commodities considering the water endowments of nations. The concept states that water-rich countries should produce and export water intensive commodities (which indirectly carry embedded water needed for producing them) to water-scarce countries, thereby enabling the water-scarce countries to divert their precious water resources to alternative, higher productivity uses.

While progress has been made on quantifying virtual water flows between countries, there exists little information on virtual water trade within large countries like India. This report quantifies and critically analyzes inter-state virtual water flows in India in the context of a large inter-basin transfer plan of the Government of India.

Our analysis shows that the existing pattern of inter-state virtual water trade is exacerbating scarcities in already water scarce states and that rather than being dictated by water endowments, virtual water flows are influenced by other factors such as "per capita gross cropped area" and "access to secured markets". We therefore argue that in order to have a comprehensive understanding of virtual water trade, non-water factors of production need to be taken into consideration.

1. Introduction: India’s National River Linking Programme

Water infrastructure projects have always caught the fancy of planners and policy makers around the world. From the Hoover dam in the United States to the Aswan dam in Egypt, Nurek in Tajikistan, Bakun in Malaysia, Tarbela in Pakistan, Itaipu in Brazil, and India’s Bhakra and Sardar Sarovar dams have been hailed as marvels of modern society and have been a source of national pride to many. Pandit Jawaharlal Nehru, India’s first Prime Minister, famously described the Bhakra Nangal project – independent India’s first large dam – as a “new temple of resurgent India”. It is not surprising therefore that India has the third largest number of large dams in the world, after China and the United States (Economist, 2003).

Water transfers between river basins are at least as old as the Roman Civilization. However, the past century has witnessed some exceptionally large inter basin water transfer (IBWT) schemes and plans. In all there exist around 155 IBWT schemes spanning 26 countries and with a total capacity to transfer around 490×10^9 m^3/yr of water. In addition, there exist plans for around 60 proposed schemes with a total capacity to transfer $1,150\times10^9$ m^3/yr – almost three times the existing capacity! Eighty-two of the existing schemes – with a total capacity of 178×10^9 m^3/yr – are situated in North and South America; with Canada having the highest capacity of existing IBWT schemes at 138×10^9 m^3/yr. Asia has 22 existing schemes with a total capacity of 181×10^9 m^3/yr. The majority of the rest lie in Europe (30 schemes; 120×10^9 m^3/yr) with a lot fewer instances in Africa and Oceania (ICID, 2006).

While somewhat similar plans in the United States and the former Soviet Union failed to take off, China’s massive South-North Water Transfer Project, with an estimated cost of US$ 50 billion, is perhaps the largest and costliest water transfer project in the world. The Government of India, on directions from the Supreme Court in 2002 and advice from the National Water Development Agency, plans to go a step further and has proposed an estimated US$ 120 billion National River Linking Programme (NRLP) which envisages linking 37 Himalayan and Peninsular rivers (Figure 1; NCIWRD, 1999). Doing this will form a gigantic south Asian water grid which will annually handle 178×10^9 m^3/yr of inter-basin water transfer; build 12,500 km of canals; generate 34 Giga-watts of hydro-power; add 35 million ha to India’s irrigated areas and generate inland navigation benefits (IWMI, 2003; NWDA, 2006; Gupta and Van der Zaag, 2007).

The prime motivation behind the grand plan is India’s growing concern about the need to produce additional food for its large and rapidly increasing population. The National Water Development Agency cites that India will require about 450 million tonnes of food grains per annum to feed a population of 1.5 billion in the year 2050 (NCIWRD, 1999) and in order to meet this requirement, it needs to expand its irrigation potential to 160 million hectares, which is 20 million hectares more than the total irrigation potential without NRLP.

Considering that large parts of the Ganga-Brahmaputra-Meghna basin face recurring floods and a number of Western and Peninsular states face severe droughts, the National Water Development Agency contends that “one of the most effective ways to increase the irrigation potential for increasing the food grain production, mitigate floods and droughts and reduce regional imbalance in the availability of water is the Inter Basin Water Transfer (IBWT) from the surplus rivers to deficit areas" (NWDA, 2006).

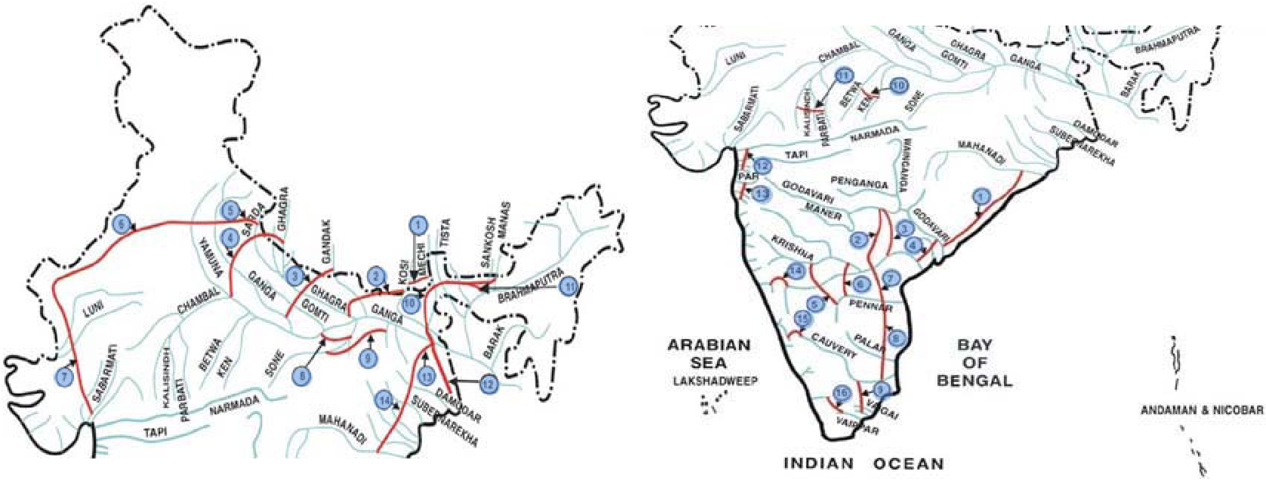

Figure 1. India's proposed National River Linking Programme (NRLP), with the Himalayan component (left) and the Peninsular component (right). Source: Reproduced from NCIWRD (1999).

However, representatives from civil society, the media and academia have strongly criticized the plan (Iyer, 2002; Vombatkere, 2003; Vaidyanathan, 2003; Bandyopadhyay and Perveen, 2004; Patkar, 2004). Besides voicing concerns about the potential negative environmental impacts of the mega-project, critics have argued that the decision to go ahead with the plan has been hasty. They argue that the NRLP is only one of the alternatives to ensure India's food and water security and alternative – local, cheaper and greener – options should have been given more serious consideration. A number of alternatives have been suggested including decentralized water harvesting and artificial recharge of aquifers, improving the productivity of agriculture in water scarce regions (which, it is claimed, continue to waste precious water resources), improving the efficiency of India's public irrigation systems through involvement of stakeholders in the management of irrigation, and using virtual water trade, instead of physical water transfers, to tackle the high spatial variation in water availability across the country.

While a number of these options seem plausible, all of them require further scientific exploration and study before any one of them (or more than one, in combination) can form a feasible answer to India's impending and formidable water crisis. While the Government of India has failed to share with the public its detailed studies and plans for the proposed inter-basin transfers, the opponents of NRLP also do not have a studied programme of action to present. The lack of such analyses has led to a polarized and opinionated debate which is preventing the nation from forming a scientific opinion about the NRLP and its various alternatives (Verma and Phansalkar, 2007).

One of the alternatives to NRLP that has been discussed is virtual water trade within the country. Proponents of this alternative have argued that instead of physically transferring large quantities of water from the flood-prone east to the water scarce west and south, it would be desirable to transfer virtual water in the form of food grains. This report explores the factors that influence inter-state virtual water trade in India; provides a preliminary assessment of the potential of virtual water trade to act as an alternative to the proposed IBWT; and assesses policy options for promoting and enhancing water saving trade within the country (Verma and Van der Zaag 2007; Verma, 2007).

2. Virtual water trade and international trade theories

The term ‘virtual water’ was introduced by Allan (1993, 1994) referring to the volume of water needed to produce agricultural commodities. The same concept has differently been referred to as ‘embedded water’ (Allan, 2003), ‘exogenous water’ (Haddadin, 2003) or ‘ultra-violet’ water (Savenije, 2004). When a commodity (or service) is traded, the buyer essentially imports (virtual) water used in the production of the commodity. In the context of international (food) trade, this concept has been applied with a view to optimize the flow of commodities considering the water endowments of nations. Using the principles of international trade, it suggests that water-rich countries should produce and export water intensive commodities (which indirectly carry embedded water needed for producing them) to water scarce countries, thereby enabling the water-scarce countries to divert their precious water resources to alternative, higher productivity uses.

The concept was later expanded to include other commodities and services (Allan 1998; Hoekstra, 2003). Several researchers (Hoekstra and Hung, 2002; Hoekstra, 2003; Chapagain and Hoekstra, 2003; Oki *et al*., 2003; Renault, 2003; Zimmer and Renault, 2003; Fraiture *et al*., 2004; Chapagain *et al*., 2005; Chapagain, 2006, Hoekstra and Chapagain 2007, 2008) have investigated the role that international trade in virtual water can play in attaining global water saving and in ensuring food security in regions facing acute physical and economic water scarcity especially in the Middle East and North Africa region and in southern Africa.

Chapagain and Hoekstra (2004) employed the concept of ‘water footprint’ to compute nations’ dependence on virtual water in the global trade system. Hoekstra and Hung (2002, 2005) quantified the scale and extent of virtual water crop trade globally while Chapagain and Hoekstra (2003) developed the methodology for similar calculations in the context of trade in livestock and livestock products. The two results were then combined to get a comprehensive picture of the total agricultural virtual water trade (Hoekstra and Chapagain 2007, 2008; Chapagain and Hoekstra 2008). Global water saving from this trade was estimated to be of the order of 455 Gm^3 per annum (Oki *et al*. 2003; Oki and Kanae, 2004). However, policy conclusions from these results were suitably moderated by Fraiture *et al*. (2004) who noted that global water savings are caused as a result of productivity differences between importing and exporting countries and are only an unintended by-product of international trade in agricultural commodities. Following the same logic, it is also possible to argue that virtual water trade can lead to wastage of water in the situation where countries with low water productivity export virtual water to high water productivity regions.

While a lot has been said about the scope, benefits and limitations of virtual water trade between countries, studies on virtual water movement within countries are, at best, sparse. As mentioned above, for countries such as India and China, it might be misleading to account for them as single entities. This is because even within these huge countries, there are wide disparities in water endowments. In addition, they demand special attention since while they are big players in the international food trade, as percentage of their domestic consumption trade is negligible and both of them are close to food self-sufficiency (Fraiture *et al*., 2004).

It is important to assess the direction and quantum of virtual water trade within these countries. Ma and others (Ma, 2004; Ma *et al*., 2006) quantified the virtual water trade within China against the backdrop of the South-North Transfer Project. The study found that north China exports 52×10^9 m^3/yr of virtual water to south China, a volume which is more than the maximum proposed water transfer volume along three routes ($38 - 43\times10^9$ m^3/yr) in the South-North Transfer Project. The study therefore concludes that if the "perverse" direction of virtual water trade in China can be reversed, it can act as a better alternative to physical transfer of water across basins. It is with a similar logic that the idea of virtual water trade within India is being proposed as an alternative to the NRLP.

Box 1: The economic logic behind virtual water trade.

Theory of comparative advantage
Hoekstra (2003) referring to Wichelns (2001), observed that "*the economic argument behind virtual water trade is that, according to international trade theory, nations should export products in which they possess a relative or comparative advantage in production, while they should import products in which they possess a comparative disadvantage.*" Thus the logic of virtual water trade follows Ricardo's theory of comparative advantage which focuses on trade based on differences in production technologies and factor endowments. It states that each country should specialize in the production of and export to other countries such goods and services in the production of which they enjoy a comparative advantage by virtue of their factor endowments.

Heckscher-Ohlin (H-O) model of international trade
The direction and patterns of virtual water trade should, therefore, be predictable and in agreement with the Heckscher-Ohlin (H-O) model of trade. Developed by Eli Heckscher and Bertil Ohlin, the H-O model builds on Ricardo's theory to predict patterns of trade and production based on the factor endowments of trading entities. Broadly, the model states that countries (or regions) will export products that require high quantities of abundant resources and import products that require high quantities of scarce resources. Thus, a capital rich (and relatively labour scarce) country would be expected to export capital intensive products and import labour intensive products or services and vice-versa (IESC, 2007; Antras, 2007; Davis, 2007). In the context of virtual water trade, this translates to water-rich regions exporting water-intensive products and vice-versa.

Leontief paradox
However, even in the case of trade of goods and services, the H-O model has been found wanting in terms of empirical evidence to support its logic. In 1954, Prof. W.W. Leontief attempted to test the H-O model by studying trade patterns between countries. To his surprise, he found that the US, possibly the most capital abundant country in the world, exported labour-intensive commodities and imported capital-intensive commodities. This was seen to be in contradiction with the H-O model and came to be known as the 'Leontief Paradox'.

Linder effect
Several economists have, ever since, tried to resolve this paradox. In 1961, Staffan Burenstam Linder proposed the Linder Hypothesis as a possible resolution to the Leontief paradox. Linder argued that demand, rather than comparative advantage, is the key determinant of trade. According to him, countries (or entities) with similar demands will develop similar industries, irrespective of factor endowments; and that these countries would then trade with each other in similar but differentiated goods. For example, both the US and Germany are capital-rich economies with significant demand for capital goods such as cars. Rather than one country dominating the car industry (by virtue of factor-endowment based comparative advantage), both countries produce and trade different brands of cars between them. This Linder Effect has also been observed in other subsequent examinations. However, it does not account for the entire pattern of world trade (See Linder, 1961; Bergstrand, 1990).

New trade theory
Similarly, proponents of the New Trade Theory (Paul Krugman, Robert Solow and others) argue that factors other than endowments determine trade. New trade theorists base international trade on imperfect competition and economies of scale – both of which are realistic but assumed away in the H-O model. Gains from increasing returns to scale at the entity level are understood intuitively but gains from industry level scale economies (external economies of scale) often get ignored. Such gains are particularly important in the case of agriculture where the scale of production of an individual farmer is very small compared to the size of the market. However, several factors such as the agricultural extension services, specialized machinery markets and fertilizer markets, marketing channels for outputs etc. contribute significantly in determining where agricultural commodities are produced.

3. Inter-state virtual water trade in India: Quantum and direction

Kampman et al. (2008) have estimated that the virtual water flow as a result of inter-state crop trade in India is 106×10^9 m^3/yr or 13 per cent of total water use. This estimate covers virtual water flows as a result of trade in 16 primary crops which represent 87 per cent of the total water use, 69 per cent of the total production value and 86 per cent of the total land use. The estimates do not include virtual water flows as a result of trade in fodder, milk and milk products. Verma (2007) estimated that at the current level of production and consumption, milk and milk products are unlikely to significantly add to the inter-state virtual water flows since India as a whole is milk surplus and consumption levels in states that produce less milk are much below the prescribed standards for nutritional security. However, if we consider a scenario of nutritional security (where minimum nutritional standards are met in every state), we can expect inter regional virtual water flows of the order of 40×10^9 m^3/yr. Under such a scenario, the inter-state virtual water flows will be still higher since there would also be some inter-state flows within each of the four regions (North, East, West and South).

Based on certain assumptions about inter-state movement of agricultural products, Kampman et al. (2008) estimated the mean annual import (or export) of virtual water between states (see Figure 2). As per these estimates, the states of Punjab, Uttar Pradesh and Haryana are the largest exporters of virtual water while Bihar, Kerala, Gujarat, Maharashtra, Jharkhand and Orissa are the key importers. Aggregating the flows at the regional level, Kampman et al. (2008) found that eastern India, India's wettest region and prone to annual floods, imports large quantities of virtual water not only from the north, west and south but also from the rest of the world (Figure 3).

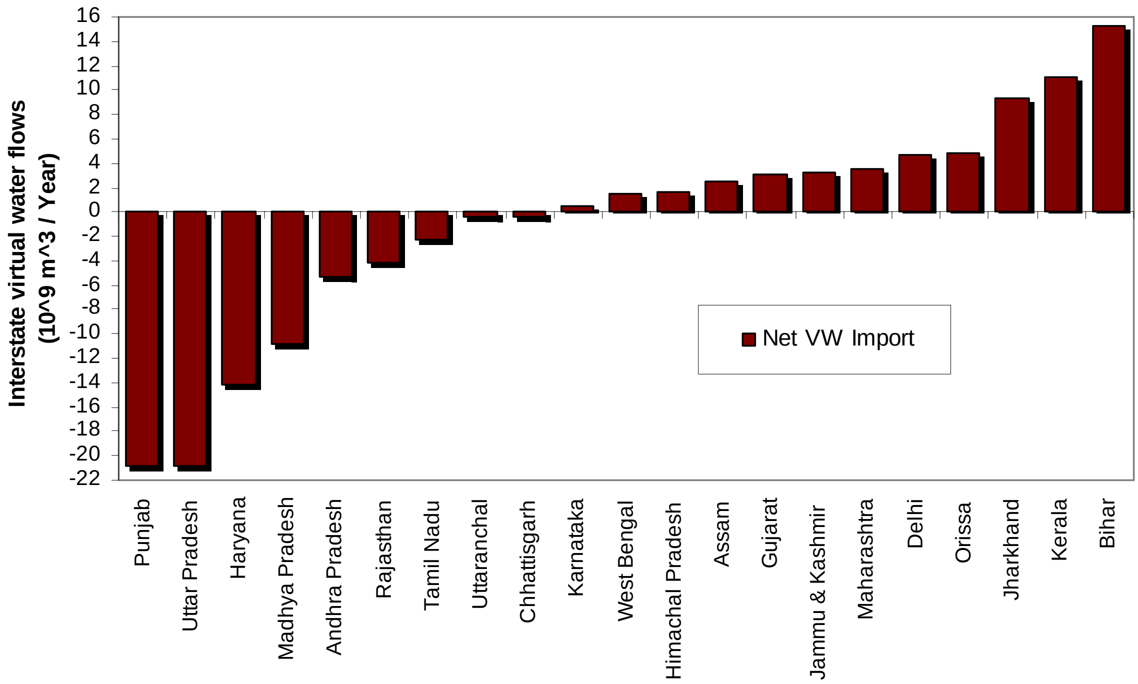

Figure 2. Inter-state virtual water flows (10^9 m^3/yr), as estimated by Kampman et al. (2008).

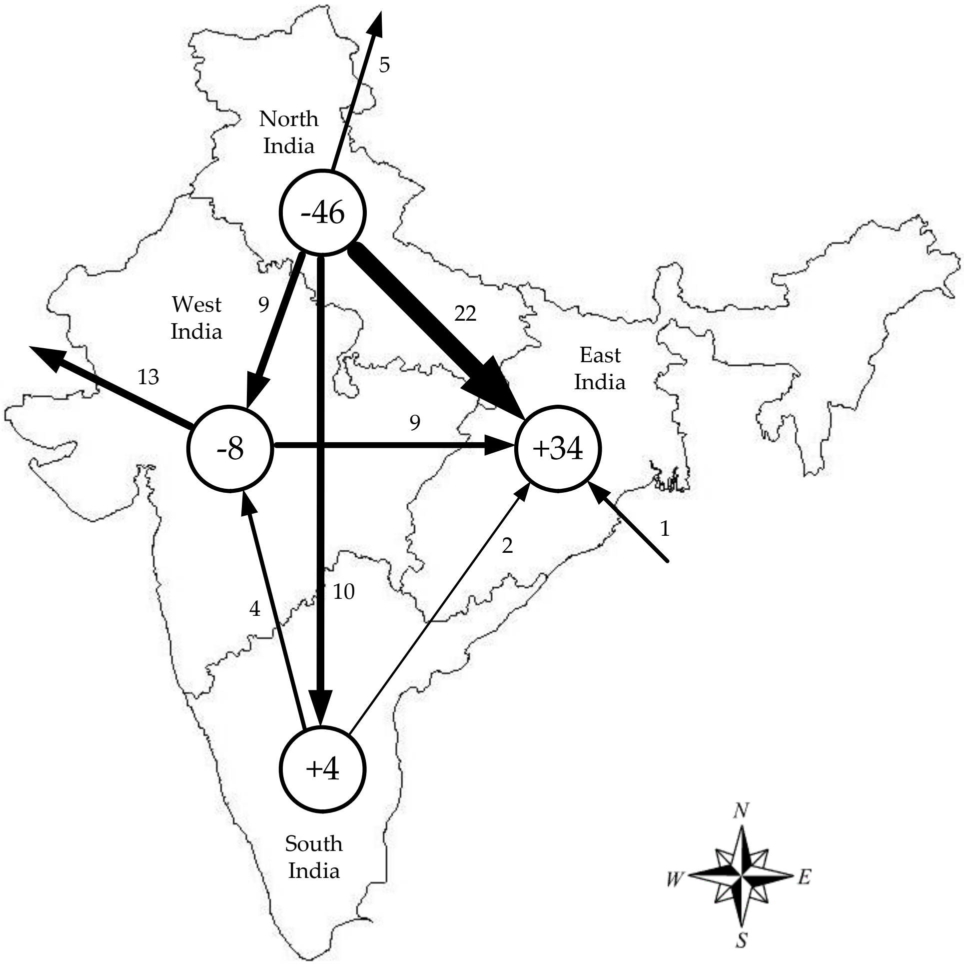

Figure 3. Inter-regional virtual water flows (10^9 m^3/yr), as estimated by Kampman et al. (2008).

The key virtual water importers – the eastern Indian states of Bihar, Jharkhand and Orissa – enjoy a comparative advantage over the key virtual water exporters – the northern states of Punjab, Uttar Pradesh and Haryana – if we look at the per capita water availability. The per capita water availability in all the three eastern Indian states is significantly higher than that in the northern states (see Table 1). Thus, we can see that the states which enjoy a natural comparative advantage in terms of water endowments actually have a net import of virtual water.

The NRLP proposes to transfer excess flood waters from the eastern states such as Assam, Bihar, West Bengal, Chattisgarh etc to the water scarce regions which produce the bulk of the food thereby ensuring India's national food security. However, the proponents of the virtual water trade argument have repeatedly claimed that such a transfer would only accentuate what they term as the "perverse" direction of virtual water trade in India. They argue that going by theories of trade, water rich states in eastern India should be producing much of India's food requirements and exporting food grains to the water scarce states. However, as we can also see from the figures above, at present, the reverse is happening. Rather than having surplus produce to export to relatively water scarce regions, the deficit in eastern India is so high that it even requires imports from outside India.

Table 1. Virtual water trade balances and per capita water resources, as per Kampman et al. (2008).

States	Per Capita Water Resources					Net virtual water import
	Green (G)	Blue (B)			Total (B+G)	
		Internal	External	Total		
	m^3/capita/year					10^9 m^3/yr
Major virtual water exporters						
Haryana	1,121	391	663	1,055	2,176	-14.1
Uttar Pradesh	863	575	1,485	2,059	2,922	-20.8
Punjab	1,102	193	2,260	2,452	3,554	-20.9
Major virtual water importers						
Jharkhand	2,082	1,970	528	2,498	4,580	9.3
Bihar	789	628	5,482	6,109	6,898	15.3
Orissa	3,446	3,079	2,185	5,264	8,710	4.8

Critics of the NRLP argue that such a "perverse" direction is the result of food and agriculture policies that have been biased in favour of states like Punjab and Haryana where farmers receive highly subsidized agricultural inputs (including water for irrigation) and are assured high prices for the wheat and rice they produce through the procurement policies of the Food Corporation of India (FCI). The proponents of the virtual water trade argument contend that if these policies were to be revised in favour of the wetter states, the so-called "perverse" direction of food trade would get "rationalized" and the water rich states would no longer have to import virtual water from water scarce states.

4. Determinants of inter-state virtual water trade in India

Why do water rich states import even more water (in virtual form) from relatively water scarce states? In order to test the relationship between the water resources endowments of states and their behaviour in the virtual water trade arena we checked whether the type of water endowment mattered. Figures 4 (a) to 4(d) plot net virtual water imports (or exports) against per capita green water availability (a); per capita internal blue water availability (b); per capita total blue water availability (c); and per capita total [internal blue + external blue + (internal) green] water availability (d) as estimated by Kampman et al. (2008). We use Figure 2 as a starting point but omit states with net inflow or outflow less than 2×10^9 m^3/yr, given the approximate nature of the estimates of Kampman et al. (2008).

If water endowments were to influence virtual water trade, we would expect that as we move along the plots from left to right, moving from the largest exporters to the largest importers, the water resource endowments would show a declining trend. None of the four trend lines depict strong correlations (R^2 in the range of 0.004 to 0.060) and do not point to any such trend. Thus clearly, in the case of inter-state virtual water flows, better water endowments do not lead to higher virtual water exports.

International trade in agricultural commodities depends on a lot more factors than differences in water scarcity in the trading nations, such as differences in availability of land, labour, knowledge and capital and differences in economic productivities in various sectors. Also the existence of domestic subsidies, export subsidies or import taxes in the trading nations may influence the trade pattern. As a consequence, international virtual water transfers can not at all or only partially be explained on the basis of relative water abundances or shortages (De Fraiture *et al*., 2004; Wichelns, 2004). Yang *et al*. (2003) demonstrated that only below a certain threshold in water availability, an inverse relationship can be established between a country's cereal import and its per capita renewable water resources. As shown here, trade of agricultural commodities between Indian states is not governed by water scarcity differences between the states.

If it is not water endowment that determines the direction of virtual water flow, then what does? In a recent paper analyzing data for 146 countries across the globe, Kumar and Singh (2005) have argued that a country's virtual water surplus or deficit is not determined by its water situation. They concluded that no correlation exists between relative water availability in a country and the virtual water trade or the volume of water embedded in the food and food products traded. Several water rich countries including Japan, Portugal and Indonesia recorded high net virtual water imports. Further analysis of 131 countries in the same paper showed that "access to arable land" can be a key driver of virtual water trade. We test this "access to arable land" hypothesis using per capita gross cropped area data for the Indian states (Figure 5). As can be seen from the figure, per capita gross cropped area does seem to assert a strong influence on net virtual water exports. The correlation coefficient (R^2 = 0.39) is much higher than that those related to water endowment.

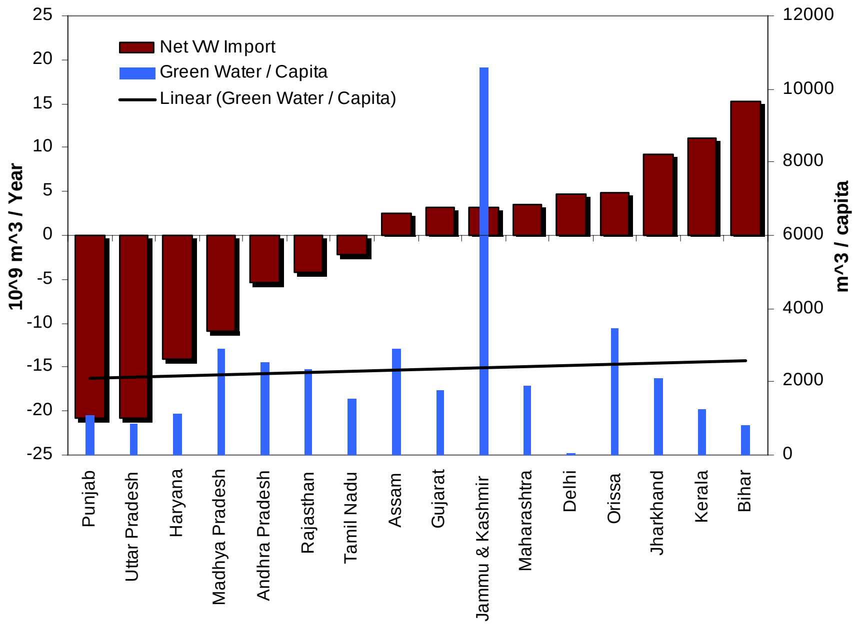

Figure 4(a). Virtual water trade and per capita green water availability (R^2=0.004), as estimated by Kampman et al. (2008).

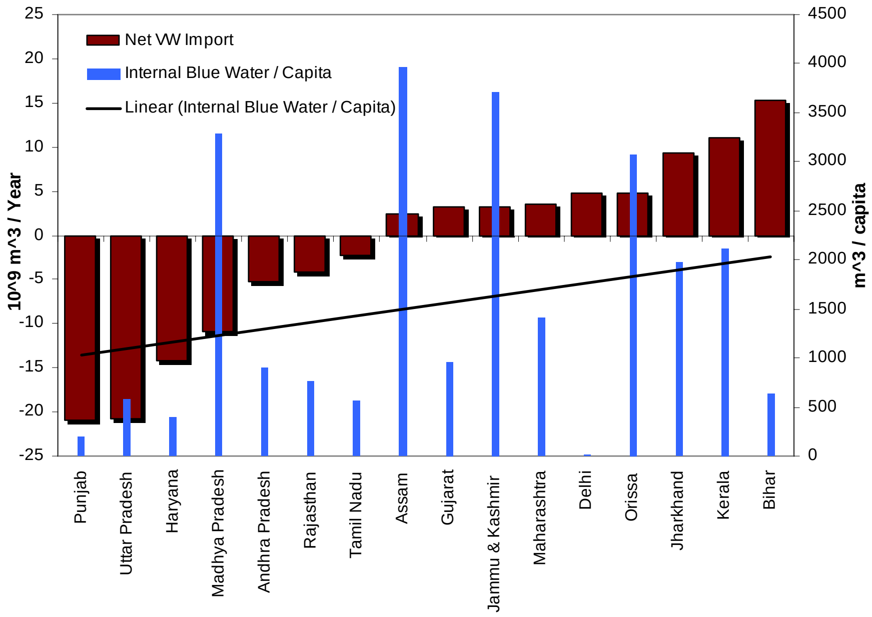

Figure 4(b). Virtual water trade and per capita internal blue water availability (R^2=0.058), as estimated by Kampman et al. (2008).

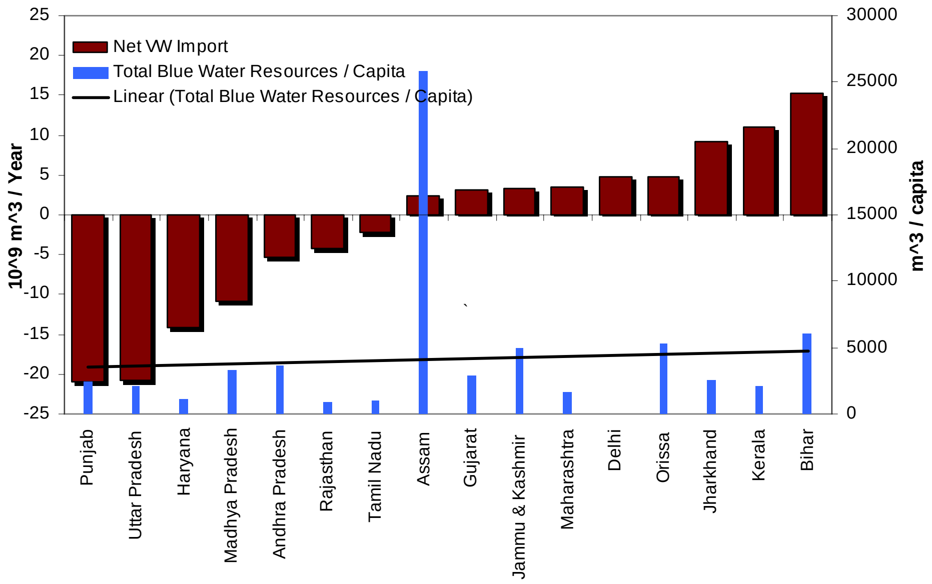

Figure 4(c). Virtual water trade and per capita total blue water availability (R^2=0.004), as estimated by Kampman et al. (2008)

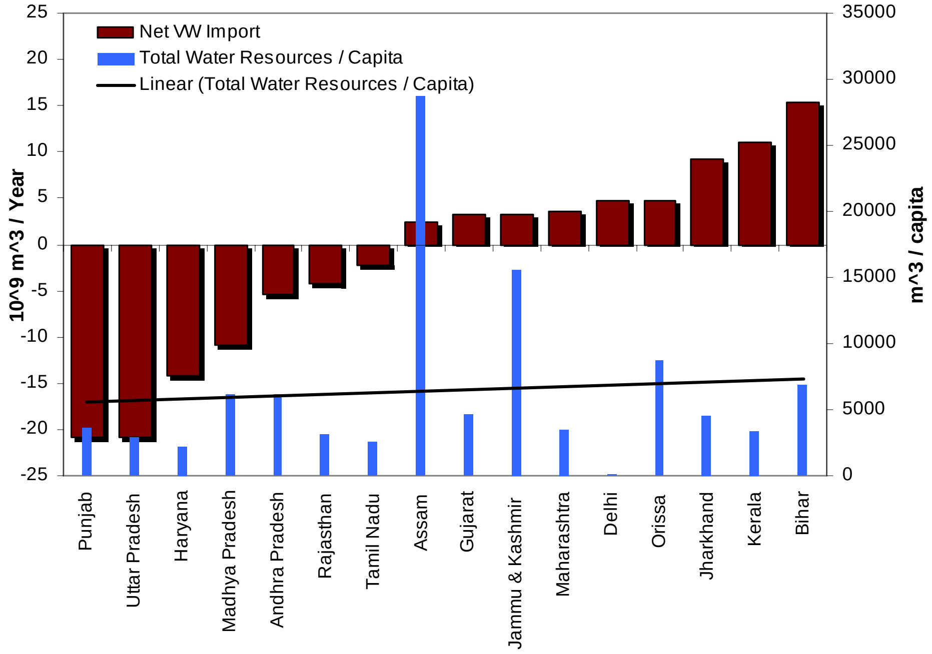

Figure 4(d). Virtual water trade and per capita total water resource availability (R^2=0.006), as estimated by Kampman et al. (2008)

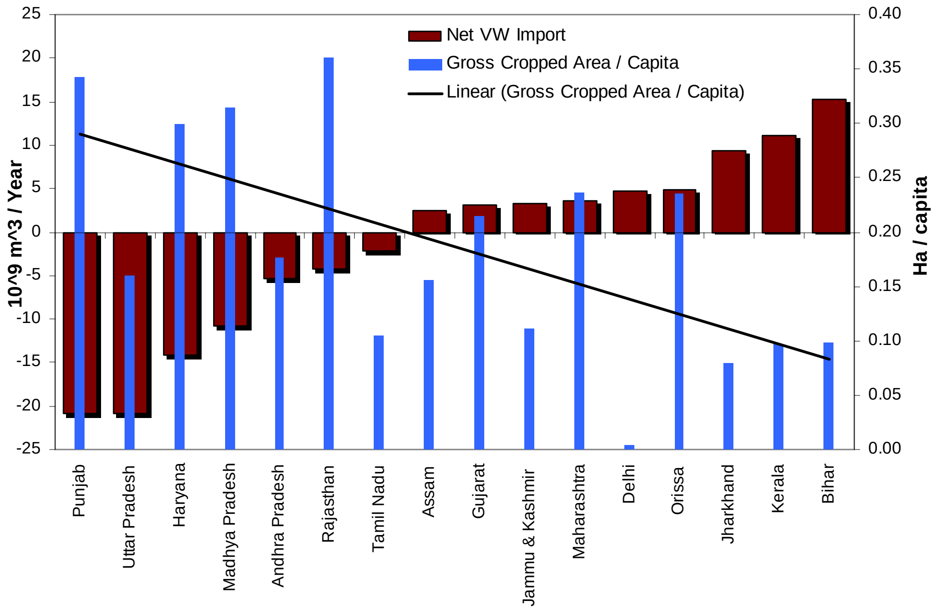

Figure 5. Virtual water trade, as estimated by Kampman et al. (2008) and per capita Gross Cropped Area (GCA) (R^2=0.39). Data source: Ministry of Agriculture, Government of India; accessed from http://www.indiastat.com.

In our analysis of high food exports from the northern Indian states, it was suggested that “access to secure markets” could be a key determinant of why Punjab continues to produce food grains. We therefore also test “access to secure markets” across virtual water importing and exporting states by using the proxy variable of ‘percentage of rice production procured by the Food Corporation of India (Figure 6). We find that this percentage correlates well with net virtual water exports (R^2 = 0.47). Thus we see that while the correlation between water endowments and virtual water surplus / deficit is absent, access to arable land and access to secure markets are correlated with virtual water exports.

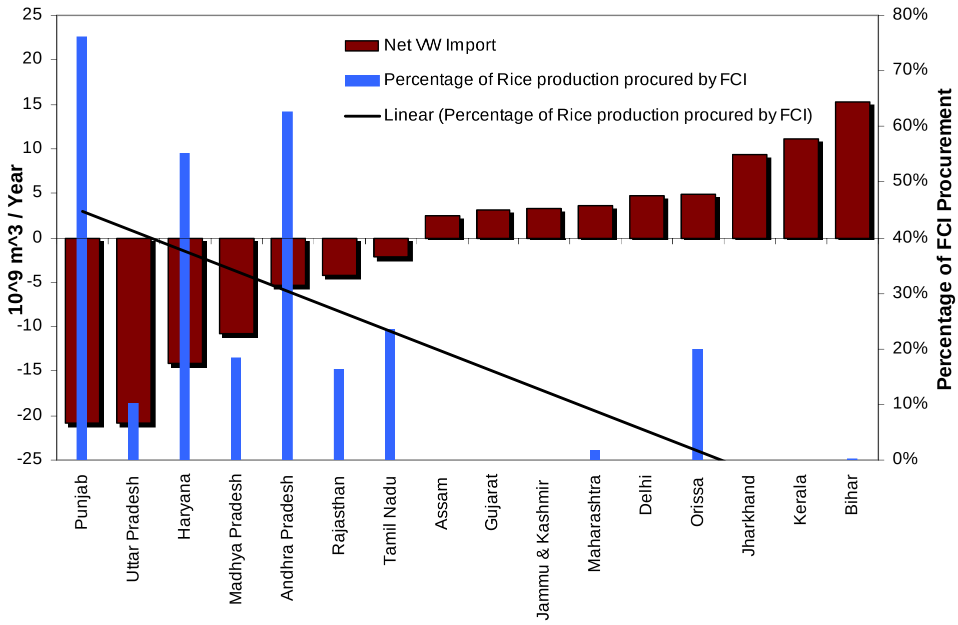

Figure 6. Virtual water trade, as per Kampman et al. (2008) and percentage of Rice production procured by Food Corporation of India (FCI) (R^2=0.47). Data source: Ministry of Agriculture, Government of India; accessed from http://www.indiastat.com.

5. Discussion: Why H-O does not work for H_2O

If the H-O model of international trade was able to explain the quantum and direction of trade, we would have expected water endowments to be strongly and positively correlated with a region's virtual water exports. However, our estimates of inter-state virtual water trade clearly do not match with such a pattern. One of the reasons for this could be the method Kampman et al. (2008) applied for estimating inter-state trade. Kampman et al. assumed that trade (import or export) is equal to the difference between production and consumption within a state. Thus, only surplus states export and only deficit states import. Such an estimation procedure implicitly assumes that all traded agricultural goods are undifferentiated commodities. But we know that products such as basmati rice, branded dairy products and other differentiated (or branded) agricultural commodities negate this assumption. However, in comparison to the total volume of virtual water traded, the proportion of virtual water embedded in branded products is perhaps small.

Another reason why the H-O model fails to apply is that it requires pre-trade resource prices to be in relation to resource endowments. In the case of water, this does not happen, especially at the farm level. Farmers in water rich states such as Bihar face a much steeper price for using water for irrigation compared to water scarce states like Punjab. This can be attributed to the public policy biases in favour of regions such as Punjab. Thus while a region might be facing physical water scarcity, the farmers do not face any economic scarcity while the reverse is true for wetter regions.

Thus, though intuitively appealing as a concept, the idea of using virtual water as a tool for water saving, or as an alternative to physical water transfers, has limited applicability in the current scenario. It has often implicitly and erroneously been assumed that water abundant countries (or regions) necessarily enjoy comparative advantage in the production of water intensive commodities. The patterns of inter-state virtual water trade in India and global food trade trends discussed by De Fraiture *et al*. (2004) show that water endowments alone are unable to explain the direction and magnitude of trade. The Leontief Paradox holds as much in the case of virtual water trade as it does for other goods. The implicit assumption behind measuring every commodity by its virtual water content is that water is the most critical and scarcest resource input. However, this assumption does not always hold. There are several key inputs that go into the production of food and these other 'factors of production' might tilt the balance of decisions against the logic of virtual water which dictates water saving as the sole criterion.

Thus, the H-O model will work to efficiently allocate water resources if and only if they constitute the most critical resource in the production process. If, on the other hand, another resource such as land becomes the critical constraint, efficient allocation will optimize land use and not water use. By importing food grains from a land rich state, a land scarce region is economizing on its land use. Following the virtual water trade logic, this can be termed as *virtual land trade*. A land-scarce region (such as Bihar) would import crops from regions where land productivity is higher (for instance, Punjab). In order to produce the same amount of food in Bihar, Bihar would have to employ more land than Punjab (Aggarwal *et al*., 2000). If, and as long as, land is the critical constraining resource, Bihar would like to economize on its land use, even at the cost of inefficient or incomplete utilization of its abundant water resources.

6. Conclusions and implications for India's National River Linking Programme

Mean annual inter-state virtual water trade as embodied in agricultural commodities in India has been estimated to be 106×10^9 m^3/yr for the years 1997 – 2001 (Kampman et al., 2008). While these estimates are neither precise nor comprehensive, they do illustrate that the quantum of inter-state virtual water trade is comparable to the proposed inter basin water transfers proposed by the Government of India under the NRLP (178×10^9 m^3/yr). Significantly, the estimates also show that the direction of virtual water trade runs opposite to the proposed physical transfers. While physical water transfers are proposed from 'surplus' to 'deficit' basins, inter-state virtual water flows move from water scarce to water rich regions.

The existing pattern of virtual water trade is exacerbating scarcities in water scarce regions and our analysis has shown that rather than being dictated by water endowments, trade patterns are influenced by factors such as per capita availability of arable land and more importantly by biases in food and agriculture policies of the Government of India as indicated by the Food Corporation of India's procurement patterns. Given that the desperation of the 1960s and 1970s with respect to national food security no longer persists, there is a strong case for reversing this trend through changes in food procurement and input subsidy policies.

According to international trade theory, there are five basic reasons why trade takes place between two entities: (1) differences in technological abilities, as explained by Ricardian model of comparative advantage; (2) differences in resource endowments, as explained by the H-O model; (3) differences in demand, which partly explains trade between surplus entities, as explained by the Linder effect; (4) existence of economies of scale, as enumerated by the new trade theory; and (5) existence of government policies which might create new comparative advantages and disadvantages that are different from natural advantages and disadvantages (Suranovic, 2007).

Much of the literature on virtual water trade so far has focused almost entirely on differences caused by water endowments or on the Ricardian logic of trade. However, this report argues that in order to have a comprehensive understanding of the behaviour of agents in trade, all other reasons including endowments of non-water factors of production (such as land) and the impact of government policies need to be taken into consideration.

The NRLP is often wrongly portrayed as a solution only to the problem of national food security. However, its promises go much further. For instance, if the promise of flood protection in the east is achieved through careful implementation, it might free up scarce land resources by preventing water logging. This will boost food production potential in the water-rich but food-deficit regions. Another significant potential benefit of the NRLP could be hydro-power generation. The NRLP promises to add 34 Giga-watts of largely CO_2-neutral hydro-power capacity to a fast-growing, energy hungry economy. On the other hand, on top of the implementation costs, additional costs of the NRLP will include potential adverse environmental and social consequences for affected ecosystems and communities.

Finally, while our analysis based on estimates of trade balances at the state level provides a conceptual picture of the conflict between the two alternatives of virtual water trade and physical inter basin water transfers, the same can more accurately be evaluated by carrying out an empirical study of the potential of virtual water trade in a particular proposed river link. Three of the 30 odd links proposed under the NRLP are independent links and the first one most likely to be implemented is the Ken-Betwa link between two adjoining sub-basins in central India. Carrying out such an analysis at that scale with data on actual (as opposed to estimated) trade and better estimates of water resources in the donor and recipient basins will be a useful exercise to further our understanding of virtual and physical transfers across river basins, and their possible tradeoffs.

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