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Review

Unfolding the potential of the virtual water concept. What is still under debate?

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ABSTRACT

The concept of virtual water refers to the volume of water used in the production of a commodity or a service. The concept was identified by the geographer Tony Allan in the early 1990s, to draw attention on the global economic processes that ameliorate local water deficits in the MENA region and elsewhere. Since its inception, the virtual water concept has inspired a flourishing literature on how to address global water resource scarcity vis-à-vis commodity production and consumption in a variety of disciplines, but also has been the object of a number of critiques. Against this backdrop, the aim of the study is, first, to conduct a thorough review of the conceptual definition of the concept, its critics and applications. Secondly, to analyze its theoretical underpinnings and, in particular, its relationship with economic theory. The study argues that, despite not being a policy tool itself, the virtual water concept can reveal aspects related to production, consumption and trade in goods which monetary indicators do not capture. Its potential as an indicator for informing decision-making in water management and policy, as well as commodity trade policy, still has to be fully unfolded.

1. Introduction

In the early 1990s, the geographer Tony Allan coined the term "virtual water" in order to draw attention on the global economic processes that ameliorate local water deficits in the Middle East and North African region as well as elsewhere (Allan, 1993). Since then, it has steadily gained prominence as an *indicator*[1] that relates water inputs and industry outputs as well as for analysing commodity trade flows in terms of water resources. Any products have in fact a virtual water content, that is, the volume of water that is actually used to produce that good.

The exchange of water as 'embedded' in traded goods brings about the so-called *virtual water trade* (VWT) (Chapagain and Hoekstra, 2003). If a country exports water-intensive

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[1] In what follows, the words 'indicator' and 'concept' will be used as synonymous when referred to virtual water.
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products to another country, it also 'exports' in fact the volumes of water 'embodied' in those products.[2] Commodity exports (imports) fundamentally act as channels to transfer substantial amounts of water (from) abroad in the form of an input 'embedded' in the exported (imported) commodities via trade. It has been shown that this market-mediated mechanism have enabled water-scarce regions, such as the Middle East and North Africa, to cope with water scarcity over the past few decades without implementing major changes and reforms in water allocation, management and policy, while avoiding conflicts over water (Allan, 2001, 2002, 2003a; Antonelli et al., 2014). VW steps beyond traditional accounts of 'real' water flows, to include a traditionally invisible dimension that links global and national economies (Warner and Zeitoun, 2008). By making visible the linkage between consumers in water-deficit countries and producers and water resources in distant water-surplus economies (Allan, 2003a), VW reveals the global dimension of water resource scarcity (Hoekstra, 2011; Hoekstra and Mekonnen, 2012).

The concept of VW has been used as a novel quantitative indicator for the study of water resources use in agriculture and livestock production worldwide, and has provided the conceptual ground for the development of the *water footprint* indicator, developed by Arjen Hoekstra in the early 2000s (Hoekstra, 2003). The two concepts are often erroneously used as synonymous although the perspective they bring to water resources management policy is dramatically different (Velázquez et al., 2011).

Finally, the use of the VW concept has drawn attention on the different sources of water 'embedded' in agricultural products and, more specifically, emphasized the role that soil water – also referred to as 'green water' – invisibly plays in underpinning global water and food security. Green water was first identified by Falkenmark (1995), but its importance has been neglected in water resources assessments until very recently. It supports rainfed agricultural production as opposed to 'blue water', which is the water source for irrigated agriculture, as well as for industrial and municipal use.

Despite the VW concept has been very helpful in gaining the attention of public officials and policy makers, the extent to which it can be used as a policy criterion is still under debate (Wichelns, 2010). Several authors have conducted empirical analyses of VW 'flows' between countries, by comparing water requirement of crops and livestock products involved in international trade, concluding that some countries are net importers of VW, while others are net exporters. On the basis of these results, combined with the 'prescriptions' of traditional international trade theories, these studies suggest that water short countries should import water intensive goods and services, whereas water abundant countries should export water intensive products. Other scholars claim instead that this line of reasoning is not based on a legitimate conceptual framework and that it can lead to inaccurate or even misleading policy recommendations. These issues will be addressed in detail in Sections 3 and 5.

Another source of critique regarding the reliability of the concept as a policy criterion comes from the usefulness of the distinction between the *green* and the *blue* water components of VW and water footprints. While agreeing that such dichotomy has helped to increase public awareness of an important dimension of water resource management, some authors say that the notions do not establish a new conceptual framework that can be used alone to guide policy decisions. Other authors, supporting the importance of the distinction, legitimate their thought on the basis of the different opportunity cost of the water sources, proposing the 'trade' of green VW (which has a lower opportunity cost) in exchange of blue VW (which has a higher opportunity cost) when possible, to generate meaningful water savings. Yet, there is no a common legitimate conceptual framework regarding how to compute the opportunity costs of water. These issues will be addressed in detail in Section 4.

The criticism against the VW concept mainly originated from two interrelated aspects: on the one side, there still exists some ambiguity associated with the meaning of the VW concept itself, that is, ''what is VW and what is not'', generated by its trans-disciplinary nature; on the other side, *virtual water* suffers from being inevitably associated with one of the most complex good from a physical, social, ethical and economic point of view, that is water.[3] There is no other comparable concept, with maybe the exception of concepts of virtual carbon and more recently virtual land, which has generated a similar vast body of (debated) literature.

The present review aims to address these critical aspects regarding the VW concept/indicator and its applications, providing a comprehensive and discussed review of: (i) the debate on the economic foundation of the concept; (ii) the contributions which distinguish between the sources of water, when computing the VW 'flows'; (iii) and the relevance and the reliability of this indicator in guiding policy decisions. Compared to other surveys available in the literature, our work adds a novel contribution to the literature, as it goes beyond the mere water footprint concept critique (Chenoweth et al., 2014; Perry, 2014) and the policy purpose limitations of the concept (Frontier Economics, 2008).

The remind of the article proceeds as follows. Section 2 provides a brief introduction on the origin of the VW indicator, clarifying what it is intended for, how it is computed and its main field of applications. Section 3 discusses the strengths and flaws of the concept found in the current economic literature. Section 4 reviews the strands of literature on virtual

[2] This mechanism is not only limited to water, but can be extended to any other input factor employed in the production process. Potentially, one might compute the virtual labour, the virtual land, the virtual oil, and the many other ''virtual factors'' embedded in any good.

[3] From a physical point of view, water is a partially renewable resource, whose renewability differs over space and time. From an economic point of view, unlike other scarce goods, water does not typically possess a formal market in which prices can be formed and used as information signals in the allocation of resources. Overexploitation, unsustainable economic development, lack of efficient coordination among economic agents are all unavoidable consequences. All these issues, together with those regarding the socio-ethical considerations about the water right and security, generate ideological thoughts and subjective judgments, which unavoidably affect and alter the meaning and the usefulness of the VW concept.