

The Balance of Trade in virtual water in the Countries of South America

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Abstract—The aim of this paper is estimate the balance of virtual water trade of all the countries of South America with the rest of the world from 2003 to 2011. The South American continent is the region where is located the main rivers basins in the world. Virtual water trade is an application of water footprint, which is a concept derived of ecological footprint, which means the water used to produce goods and services, and those products are traded between countries. The data were retrieved from Food and Agriculture Organization and combined with data of specific requirement for water for each product. Using the quantities exported and imported products of the top twenty and data of specific requirement for water for each product (green water), was calculated the export and import virtual water in each country. The results highlight three different groups of South American countries and indicate that there is heterogeneity in the same virtual water trade for those countries.

Keywords—virtual water, South America, Green Water.

I. INTRODUCTION

It is well known that the amounts of water differ widely between countries, as well as all other natural resources, whether renewable or not. Taking this into consideration, Allan (1997) asks, referring mainly to the countries located in arid or semi-arid regions, the reason for the absence of war between them for access to water, because, as we know, these countries account for over half of water they need for their survival. The answer to this question, explains, comes from the so-called virtual water trade. This same response also appears to be relevant to another question: how could certain countries have a population growth over the availability of water existing in their territories?

The above questions are relevant, precisely because of increased population pressure on resources, and also because of the externalities that human activities generate on the environment, which mostly consist of negative. A second argument is given by Allan (1997, p. 4) that “the huge volumes of water utilized by agriculture are not counted as part of the national water budget. Such water is a free good”. Moreover, the concept of rule indicated by the weak sustainability of Hartwick (1977), that natural capital may be replaced by any other type of capital is far from being applied to the case of water. Therefore, even when water is a renewable resource, although finite, changes in availability and environmental impact on water quality, affecting their different purposes and, therefore, that the population uses it does.

The answer to both questions is grounded initially proposed the so-called virtual water trade. Virtual water is

the volume of water used to produce goods and services (Aldaya, Allan & Hoekstra, 2010). But the trade in virtual water can be understood as the amount of water used throughout the production process of an asset that is traded internationally.

Therefore, to measure and different flows of international trade through the monetary value becomes equivalent water. This is not to establish a complementary view to the measures in force measurement, but in an alternative way to understand the exploitation of natural resources, particularly water, which the traditional understanding of the economic models are purely neglected or are not adequately addressed. “Virtual water adds a new dimension to international trade, and brings along a new perspective about water scarcity and water resource management” (NOVO, GARRIDO, VARELA-ORTEGA, 2009, p. 1454).

In these sense, the aim of this paper is estimate the balance of virtual water trade of all the countries of South America with the rest of the world from 2003 to 2011. The South American continent is the region where is located the main rivers basins in the world, like the Amazon basin, La Plata and Orinoco, for instance, and accounts for about 25% of all freshwater on the planet. However, not all countries located there face situations comfortable in relation to water availability. Trinidad e Tobago is, for example, a country with the lowest water availability on the continent, about 3,130 m³ per year per person. Have other countries, like Argentina, Bolivia, Brazil, Chile, Colombia and Venezuela are faced with per capita amounts between 19,000 and 60,000 m³ per year per person. And Guyana,

whose abundance of fresh water is one of the largest in the world, is faced with more than 320,000 m³ per year per person. This means that water is, for the most countries in South America, an abundant resource and it offers opportunities to use in different ways, like transport, power generation or crops and livestock productions. Therefore, it is expected that the exports of high water endowment countries exceeds the imports of virtual water, featuring a surplus in virtual water. This study justify due the context of water scarcity, international virtual water trade can reallocate the production to countries with more available water. To address these questions, the paper covers, beyond the introduction, literature review, material and method, results and conclusion.

II. LITERATURE REVIEW

In the last years, there is a growing body of literature focusing on the concept of virtual water (HOEKSTRA AND HUNG, 2005; ALDAYA, ALLAN & HOEKSTRA, 2010, CHAPAGAIN AND HOEKSTRA, 2011). All these papers have emphasized the potential contribution to saving water and the appropriated use of it. And a special attention has been devoted to virtual water in international commodity trade, because "international trade can save water globally if a water-intensive commodity is traded from an area where it is produced with high water productivity (ton/m³) to an area with lower water productivity" (ALDAYA, ALLAN & HOEKSTRA, 2010, p. 887).

The interest in this subject is due agriculture and trade have the functions to serve humanity by eradicating hunger and poverty. Nevertheless, these functions "have recently been challenged by emerging forces including climate change, water scarcity, the energy crisis as well as the credit crisis" (Hanjra and Qureshi, 2010, p. 365).

Hanjra and Qureshi (2010) address the main challenges for water quality and quantity: decrease the competition for water between and within sectors; decrease inequity in water access; control the incidence of water borne diseases; keep natural conditions of freshwater ecosystems; diminish the tension over the use and control of water and its potential for conflict in different levels and control climatic conditions to avoid extreme wet and dry events.

Virtual water trade is based on evidence that "high water scarcity will make it attractive to import virtual water and thus become water dependent. One would logically suppose: the higher the scarcity within a country, the more dependency on water in other countries" (Hoekstra and Hung, 2005, p. 46).

Hoekstra (2008) states that the environmental footprint of water was originally introduced in 2002 and derives from

the broader concept of ecological footprint, which originated in the early 1990s. Thus, the ecological water is the amount of water (measured in cubic meters per year) needed to sustain the population. The concept of eco-paid water also relates to the "Human Appropriation of the earth's resources relates to the carrying capacity of the earth" (Hoeksra, 2008, p. 1964).

At this point, it is important to note the terminology used in water use (ALDAYA, ALLAN & HOEKSTRA, 2010). Chapagain and Hoekstra (2011) point out that the blue water refers to water that evaporates during the process of producing goods and services and that comes from surface water and groundwater. Green water is the volume of water which evaporates from rain water stored in the soil. And the gray water is the volume of water used in the production process and, after being used, was polluted.

Aldaya, Allan & Hoekstra (2010, p.887) say that, "green water generally has a lower opportunity cost than blue water. Even if it is more and more upheld that green water represents the largest share of virtual water in the international trade of agricultural commodities, with exports going from green water rich countries towards generally blue water based economies, hitherto, green water volumes have rarely been estimated".

Regardless of the availability or not of water, Pimentel (2004) states that the water use incorporated into human nutrition has increased significantly in recent years due to the change in food choices, especially for meat, which requires large volumes of water (Fraiture and Wichelns, 2010). And the consensus is that the change in food consumption patterns in countries with low abundance of water depends on the trade in virtual water. Hanjra and Qureshi (2010) analyzed the climate change, water scarcity, the energy crisis and population growth and how these forces redefining the global water supply and demand, specially on global food security.

In a globalized world, where the transactions are possible, all countries produce and export crops and livestock goods, as well processed and industrialized foods, like orange juice, preparations of beef meat, soybean oil and sugar confectionery, for instance. The exports depend on availability of natural resources and the production systems, and imports depend on the domestic demand and also the availability of natural resources.

An important consideration about the overuse of water was highlighted by Goswamia and Nishad (2015, p1); these authors said that "estimates show that export of embedded water alone can lead to loss of water sustainability". They also predicted that, due to virtual water trade, India will lose its available water in less than 1000 years. This period can be considered a short time trend taking account the

entire history of India country. Goswami, Nishad, and Sushravya (2016) projected a declining trend related to water resources and the different uses of water have an increasing trend, such as agriculture, domestic, and industrial purposes for the next decades.

Water, among other resources, can be thought as a production factor, such as labor, capital or land; and the availability of these factors defines the pattern of the international trade. The Heckscher-Ohlin model (H-O model) explains the trade among the countries when the transactions are free and under the hypothesis that there are no transaction costs. The core of the HO model is that each country specializes in international trade in the good intensive in the factor of production. Extending the Ricardian model of international trade for various factors of production, the H-O model states that the specialization in trade is determined by the relative cost of factors of production (GANDOLFO, 1998). Thus, countries with abundant natural resources, will specialize and export goods intensive in these resources

The use of H-O model to explain the virtual water trade is adopted by some authors (Hoekstra and Hung, 2005; Guan and Hubacek, 2007). The main idea is that high water endowment countries export intensive water goods. In the other hand, Ansink (2010) uses the H-O model to refuse the two main claims about this subject: (i) virtual water trade levels uneven water distribution and (ii) virtual water trade reduces the potential for water conflict. The author complements that “both claims are based on an incorrect understanding of comparative advantage in the production of water-intensive goods. The results show that both claims only hold under certain conditions, but do not necessarily follow from the Heckscher-Ohlin trade model” (ANSINK, 2010, p. 2027).

The researches about this subject aim evaluate the virtual water exportation and importation and the balance of the trade. Aldaya, Allan and Hoekstra (2010), for instance, estimated the green and blue virtual-water content of maize, soybean and wheat exports for the main exporting countries of these crops (Argentina, Australia, Canada and the USA). Guan and Hubacek (2007) evaluated the Chinese inter-regional trade structure, using virtual water flows, and its effects on water consumption and pollution. Hanasakiet al. (2010) simulated the virtual water content of major crops consistent with their global hydrological simulation.

Papers on virtual water trade have focused on water quantity. Dabrowskiet. al (2009) investigated the impacts of water quality on virtual water trading. A proxy for water quality impacts was created by calculating the amount of water required to dilute nonpoint-source agrochemical

inputs to relevant water quality guideline values. The results suggest that in virtual water trading scenarios the impacts of agriculture on water quality need to be considered, due the “volume of water required for dilution is compared to the volumes of blue water used. The relative importance of water quantity and quality use is dependent on the specific water requirements of the particular crop” Dabrowskiet. al (2009, p. 1080).

Fraiture and Wichelns (2010) analyzed four scenarios taking account variations on investments in rainfed agriculture and irrigation. The most striking result to emerge from the study is that there are water and land resources available to supply global food demands during the next fifty years. The restriction is that only water is managed correctly and effectively in agriculture.

Guan and Hubacek (2007) evaluated the China inter-regional trade structure and its effects on water pollution and consumption using virtual water flows. The results point out that the domestic trade structure is misallocated and inefficiency. Novo, Garrido, Varela-Ortega (2009, p. 1454) showed that Spain is a “show that Spain is a net virtual water importer through international grain trade”, and it is consistent with relative water scarcity.

III. MATERIALS AND METHODS

Through the data on agricultural and livestock production retrieved from FAO were selected the top twenty exports and imports goods that generate the most value to the external accounts of every country in South America. Data were collected during the period covered the years 2003 to 2011 totaling thus nine years of observations. It is noteworthy that the top 20 products in 70.1% to 99% of all commercial transactions involving agricultural goods, which can be fresh, lightly processed or prepared for human consumption.

Using the quantities exported and imported products of the top twenty and data of specific requirement for water for each product (green water), was calculated the export and import virtual water in each country. Specific requirement for water data for crops were obtained from Mekonnen and Hoekstra (2010, a), and for farm animals and animal products from Mekonnen and Hoekstra (2010, b).

The methodology adopted in this study take account geographical location and water productivity for all countries analyzed. In this way, the virtual water export (VWE) of goods is expressed as follows:

$$VWE_{it} = \sum_{j=1}^m \sum_{i=1}^n q_{jit} w_{ji} \quad (1)$$

where q denotes the quantity of goods exported (crop, livestock goods and, processed and industrialized foods)

and w denotes specific requirement for water data for crops and animals and animal products. The subscripts j, i and t denote good, countries and year.

The virtual water import (VWI) of goods is expressed as follows:

$$VWI_{it} = \sum_{j=1}^m \sum_{i=1}^n q_{jit} w_{ji} \quad (2)$$

For a given year, the balance of virtual water (BVW) is the difference between virtual water export and virtual water import.

$$BVW_{it} = VWE_{it} - VWI_{it} \quad (3)$$

The results are explained below.

IV. RESULTS

Although South America has 14 countries, were considered for this study only 13. This difference is due to the fact that French Guyana is considered integral to the French territory, and whose statistics are not available in disaggregated form.

The Table 1 shows the area of all countries of South America totalizes 15,779,575 Km², in which Brazil, the largest country, has 53.9%. Argentina, the second largest, has about 2.78 millions of Km². In contrast, Trinidad and Tobago and Suriname are the smallest countries in South America.

Table 1: Total renewable water resources for country

	TOTAL RENEWABLE WATER RESOURCES km ³ /year	POPULATION	AREA (Km ²)	WATER AVAILABILITY PER PERSON (m ³ /person)	WATER AVAILABILITY PER AREA (m ³ /Km ²)
Argentina	814	42,192,494	2,780,400	19,292.53	292,763.63
Bolivia	622.5	10,290,003	109,858	60,495.61	5,666,405.72
Brazil	8233	199,321,413	8,514,877	41,305.15	966,895.94
Chile	922	17,067,369	756,102	54,021.21	1,219,412.20
Colombia	2132	45,239,079	1,138,910	47,127.4	1,871,965.30
Ecuador	432	15,223,680	283,561	28,376.84	1,523,481.72
Guyana	241	741,908	214,969	324,838.1	1,121,091.88
Paraguay	336	6,541,591	406,752	51,363.65	826,056.17
Peru	1913	29,549,517	1,285,216	64,738.79	1,488,465.75
Suriname	122	560,157	16,382	217,796.1	7,447,198.14
Trinidad e Tobago	3.84	1,226,383	5,128	3,131.15	748,829.95
Uruguay	139	3,316,328	176,215	41,913.83	788,809.13
Venezuela	1233	28,047,938	91,205	43,960.45	13,518,995.67

Source: FAO (total renewable water resources) and CIA (Population and Area)

The Table 1 also shows the quantity available of water in each country. To be comparable, the total of renewable water was pondered by population and area data. Taking

into account the water per person, we can see that Guyana is an exception, more than 320 thousands m³ of water available per person. Most countries have between 28

thousands of m³ and 65 thousands of m³ of water available. On the other hand, Trinidad and Tobago is the country which has less water available, about 3,131 m³ per person. With reference to the quantity of water per area, it is possible to see that Venezuela is the country which has the most availability water per area, about 13 millions of m³ per Km². Suriname and Bolivia are the second and third countries which have most availability water per area (7.4 million of m³/Km² and 5.6 million of m³/Km², respectively). In contrast, Argentina has the less availability, approximately 290 thousand of m³ per /Km².

Table 2 shows the quantity of water embedded in the twenty products that were exported by each country from South America. The two main countries were Argentina and Brazil. The quantity of water available in Argentina is very different from Brazilian situation. While Brazil has a huge water resources, Argentina has about just 10% of Brazil, however, it was the second exporter country. The reason for that was, as discusses above, Argentina is the second largest country, and has great quantity of area available for agriculture and animals. Chile, Colombia and Venezuela have more water available than Argentina, but these countries export less than Argentina.

Table 2: Virtual Water Exportation of South America Countries (km³)

	2007	2008	2009	20	2007	2008	2009	2010	2011	Average
Argentina	101,25	100,78	121,78	121,74	157,31	148,85	111,37	148,68	157,69	129,94
Bolivia	5,02	5,25	5,39	5,79	5,61	5,02	6,53	5,65	5,32	5,51
Brazil	122,79	134,12	134,52	142,77	154,95	149,03	163,07	176,82	186,5	151,62
Chile	1,37	1,59	1,99	1,84	2,33	2,32	2,09	2,5	2,77	2,09
Colombia	10,62	10,89	11,6	11,09	12,4	12,64	10,37	8,03	8,8	10,72
Ecuador	5,47	5,89	6,4	6,48	6,61	6,7	8,54	7,93	10,46	7,16
Guyana	0,74	0,88	0,74	0,7	0,7	0,68	0,2	0,2	0,61	0,61
Paraguay	11,4	14,79	16,76	17,3	22	23	20,18	21,55	24,39	19,04
Peru	2,28	2,87	2,42	3,67	2,88	3,64	3,26	4,28	5,28	3,40
Suriname	0,03	0,04	0,06	0,05	0,06	0,07	0,04	0,1	0,05	0,06
Trinidad e Tobago	0,27	0,31	0,32	0,32	0,3	0,18	0,18	0,17	0,12	0,24
Uruguay	6,96	8,33	10,04	10,9	10,21	10,62	12,59	14,03	12,76	10,72
Venezuela	1,3	0,86	0,76	0,69	0,89	0,45	0,28	0,25	0,24	0,64

Source: Own elaboration

Economic theory shows that the most important variable that explains import is domestic income, which is influenced by population. In this way, is expected that populated country, as Brazil, have huge demand on

imports, and virtual water import as well. In fact, during the period analyzed, Brazil had higher level of import (Table 3). Curiously, Venezuela, which has the fifth population, was the second and Chile was the third.

Table 3: Virtual Water Importation of South America Countries (km³)

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Argentina	3.02	3.40	3.78	3.91	7.11	8.37	7.30	8.73	10.20	6.20
Bolivia	1.43	1.01	1.03	1.12	1.29	0.96	0.66	0.82	1.15	1.05

Brasil	20.15	14.43	14.69	16.54	19.51	18.76	16.32	24.79	30.63	19.53
Chile	7.29	7.58	8.24	8.82	11.30	9.63	10.65	16.18	19.23	10.99
Colômbia	6.98	7.31	8.13	9.50	9.79	9.94	5.50	6.63	9.67	8.16
Equador	2.09	2.40	2.55	2.74	2.93	2.84	2.27	2.59	3.82	2.69
Guiana	0.20	0.22	0.20	0.16	0.16	0.23	0.25	0.28	0.31	0.22
Paraguai	0.35	0.41	0.48	0.48	0.53	0.61	1.06	1.24	1.48	0.73
Peru	5.31	6.14	6.79	7.09	7.60	7.62	3.80	5.47	7.07	6.32
Suriname	0.19	0.18	0.18	0.18	0.19	0.16	0.28	0.28	0.32	0.21
Trinidad e Tobago	0.65	0.68	0.60	0.50	0.57	0.65	0.85	0.90	1.24	0.73
Uruguai	1.12	0.89	0.93	1.48	1.04	1.73	1.33	1.74	2.95	1.46
Venezuela	6.80	8.33	6.02	8.26	10.61	12.49	28.13	15.29	13.73	12.18

Source: Own elaboration

The difference between virtual water export and virtual water import results the balance. First of all, it is important clarify that the countries analyzed can be clustered in three

different groups. The first one is formed by Brazil and Argentina, which had had approximately the same surplus in virtual water trade (Table 4).

Table 4: Balance of Virtual Water Trade of South America Countries (km³)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Argentina	98.22	97.38	118	117.83	150.21	140.47	104.08	139.95	147.49	123.74
Bolívia	3.59	4.23	4.35	4.67	4.32	4.06	5.88	4.83	4.17	4.46
Brasil	102.64	119.69	119.83	126.23	135.44	130.27	146.74	152.02	155.86	132.08
Chile	-5.91	-5.99	-6.25	-6.98	-8.98	-7.31	-8.56	-13.67	-16.47	-8.90
Colômbia	3.63	3.58	3.46	1.59	2.61	2.7	4.87	1.4	-0.86	2.55
Equador	3.38	3.49	3.84	3.74	3.67	3.86	6.27	5.34	6.64	4.47
Guiana	0.54	0.65	0.54	0.53	0.54	0.45	-0.06	-0.07	0.3	0.38
Paraguai	11.04	14.38	16.28	16.82	21.46	22.39	19.12	20.31	22.92	18.30
Peru	-3.03	-3.27	-4.37	-3.41	-4.72	-3.98	-0.54	-1.19	-1.79	-2.92
Suriname	-0.16	-0.14	-0.12	-0.13	-0.13	-0.09	-0.24	-0.18	-0.27	-0.16
Trinidad e Tobago	-0.39	-0.37	-0.28	-0.18	-0.27	-0.47	-0.67	-0.72	-1.12	-0.50
Uruguai	5.84	7.44	9.11	9.42	9.17	8.89	11.26	12.29	9.81	9.25
Venezuela	-5.5	-7.47	-5.26	-7.56	-9.73	-12.03	-27.85	-15.04	-13.49	-11.55

Source: Own elaboration

In average, the largest surplus country is Brazil. Additionally, how can be seen, in 2011 Brazilian surplus reached the equivalent of 155.86 km³ of water. During the period analyzed, Argentina had, in average, surplus of 132.08 km³.

The second group is constituted by countries with small, but positive, surplus, as Bolivia, Colombia, Ecuador, Paraguay and Uruguay. The exception is Paraguay, which had, in average, a surplus of 18.3 km³. In 2011, the surplus of Paraguay was 23 km³.

Additionally, the third group is formed by countries that import more than export, yielding deficit. Five countries are in this group: Chile, Peru, Suriname, Trinidad and Tobago and Venezuela. What is interesting in this data is that Venezuela and Suriname are countries which have the most availability water per area, respectively, about 13.5

million of m³ per Km² and 7.5 million of m³ per Km² (Table 1). The explanation about Venezuela may be concerned with political decisions, including oil export dependence and, as consequence, a special kind of Dutch disease.

Table 5 exhibits the correlation between trade (export, import and balance) and countries characteristics. All the measures of trade are correlated with renewable water resources, population and area. Concerning with water available per person, the correlation is negative for all measures of trade. And with respect to water available per area, the correlation is negative taking account export and balance, and a positive correlation was found with. This means that water availability per area is not a decisive factor for trade, due the presence of others elements, such as domestic markets, for instance.

Table 5: Correlation matrix

	Export Average	ImportAverage	Balance Average
TOTAL RENEWABLE WATER RESOURCES km ³ /year	0.7045	0.8330	0.6324
POPULATION	0.8010	0.8297	0.7366
AREA (Km ²)	0.8839	0.7602	0.8336
WATER AVAILABILITY PER PERSON (m ³ /person)	-0.2592	-0.3407	-0.2202
WATER AVAILABILITY PER AREA (m ³ /Km ²)	-0.296	0.1259	-0.3122

Source: Own elaboration

The three figures below exhibits the evolution of trade balance from 2003 to 2011. Taking account the first figure, formed by Argentina and Brazil, the surplus has a tendency of increasing. The figure also shows in 2009 a huge decrease of surplus of Argentina. This signalizes the impact of international crises in Argentina export, diminishing its surplus.

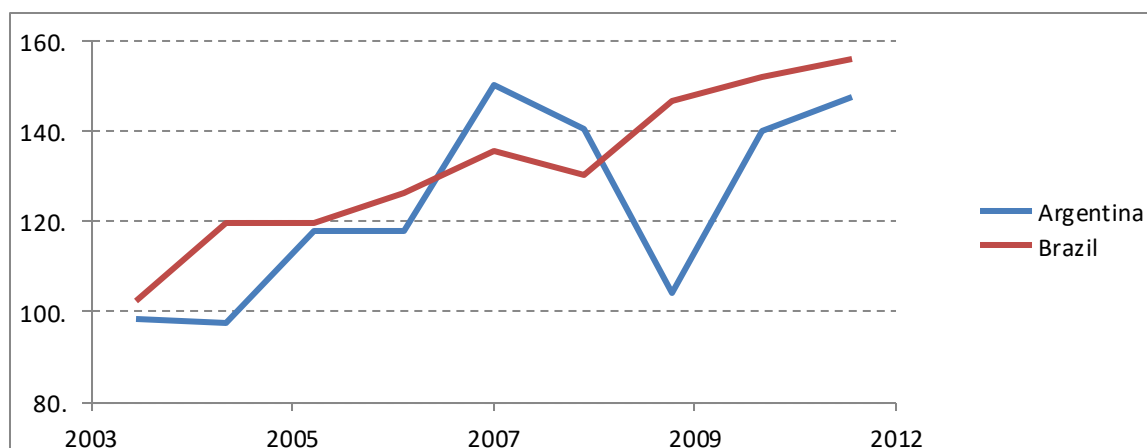


Fig.1: Surplus to the main countries on virtual water trade.

Source: Own elaboration

The second figure shows a clear tendency of increase of Paraguay and Uruguay surpluses. Colombia, had a small decrease, followed by a little increase and, after 2009, a severe decrease. The others countries (Ecuador, Bolivia and Guyana) keep moving at constant tendency.

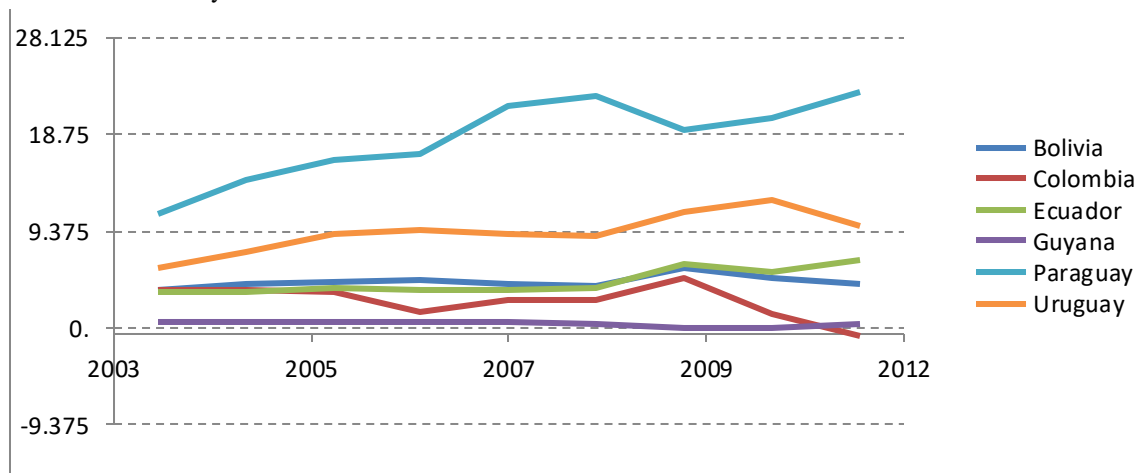


Fig.2: Surplus on virtual water trade.

Source: Own elaboration

And the third figure exhibits countries with deficits; this means that the level of import is bigger than export. Countries such as Suriname and Trinidad and Tobago face to small deficits. After 2009, Peru had diminished its deficit. And finally, Chile and Venezuela are countries

with huge deficits; and for both there are a tendency of increasing. The figure shows that Venezuela had a strong impact from international crises in 2009; but in 2011 it has recovered the same level in 2008.

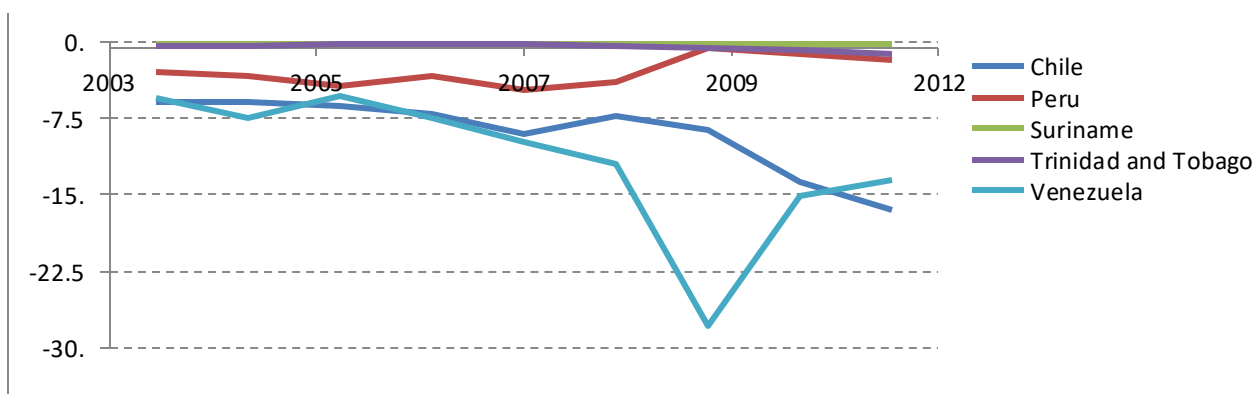


Fig.3: Surplus on virtual water trade.

Source: Own elaboration

V. CONCLUSION

The results indicate that there is heterogeneity in the same virtual water trade for those countries with abundance, as is the case of Venezuela, which should be a surplus, as shown by the theoretical assumptions of the H-O Model and the great quantity of water available. In this sense, the results not refute Ansink (2010) arguments.

Furthermore, taking account proportions, Brazil, which, given their territorial and climatic conditions, should

provide the highest surplus of the continent is behind Argentina, whose water availability and other resources is lower than the Brazilian case. In a way, this shows that Argentina uses resources more intensively than Brazil.

The growth of world income has a positive impact on demand for food requires intensive water and the producing countries, both in quantity and composition, more use of their water sources. Even water being a renewable resource, this feature depends on a broad and

complex set of other environmental services that are increasingly committed to the advancement of economic activities on other natural resources, such as the conversion of forest areas into agricultural systems. The absence of certain services environmental causes the water from becoming poor and inappropriate for certain uses. Moreover, the water lends itself to many purposes, and having exhausted their capacity for renewal, all-purpose, economical or not, become compromised, affecting significantly the very conditions of life of local populations.

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