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Water Consumption in Brazilian Economic Sectors – An Application from a General Equilibrium Model

By Lucas Souza Beppler[*] & Gustavo Inácio de Moraes[±]

The manufacture of all products requires water, either directly or indirectly. Due to its peculiar nature, water is a unique input. Global economic growth and international trade put pressure on the demand for water in industrial and primary sectors. This paper seeks to analyze the total water consumption in Brazil by economic sector in scenarios of greater external demand for domestic products, considering especially the shift in the current national export profile. A typical computable general equilibrium model (CGE) based on the 2015 Brazilian Input-Output Table and the 2013-2015 System of Environmental-Economic Accounts for Water in Brazil are used for this analysis. The changes in total water consumption in the proposed scenarios are elastic in relation to the variations in demand for the other primary factors of the model (capital and land) and activity level. The extractive industry was the one with the highest increase in water consumption. The agricultural sector, which represents a large share of Brazilian exports and is the largest water consumer in the world, surprisingly had a variation in water consumption when compared to other sectors.

Keywords: *water consumption, CGE models, Brazilian economy, international trade, basic inputs*

Introduction

Fresh water is a natural resource with a unique economic characteristic due to its presence in almost all manufactured products, in addition to its importance to the biological aspects of the human, animal and, plant life. These resources and their availability are under intense pressure in terms of quantity and demand, given the economic growth, population growth, and human intervention in several areas (Ponce et al. 2012). The result of such practices is the position of water as a major concern among the environmental issues of the 21st century. Brazil in particular has a vast water reservoir both in absolute and per capita terms, when compared to the reservoir of other countries, even larger or less populated countries. Hence, the country's geographic features have a significant comparative and competitive advantage in the economic context, especially in the production of basic and industrial commodities. Such advantages, however, should not mask the possibility of social and economic problems involving the resource.

The relationship between economic growth and water availability is complex and gradually becomes more apparent (Hertel and Liu 2016). International trade is

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currently a determining factor to measure economic growth and it increases the demand for basic inputs such as fresh water, energy and land. In particular, there has been a growing interest in the literature on the relationship between water availability and international trade in recent years (Hoekstra 2010). This paper proposes to analyze the total consumption of fresh water in the Brazilian economic sectors, simulating some changes in international trade for the country, an important player in the global market of basic commodities, a sector which consumes a lot of water.

Brazilian economy benefits from an extensive fresh water reservoir, a large comparative advantage for its economic sectors. Total consumption is higher than in any other major country, in absolute and relative terms. In 2017, 18.9 million cubic hectometers were removed from the territory, with the average annual replacement for the same year being 13.3 million cubic hectometers (ANA and IBGE 2020). In this sense, the balance between supply and demand is a permanent object of study.

In order to contribute to this growing literature, this work aims to analyze the changes in total water consumption by the Brazilian economic sector from a hypothetical rise in the world demand for Brazilian products at different levels and different compositions. This increase would aim to generically reflect, for simulation purposes, the constant global economic growth observed in the last decades, since only in 2009 the overall real GDP growth was negative (IMF 2018). Methodologically, a typical Computable General Equilibrium (CGE) model was used, the ORANI-G, modified to adapt to the water input as primary input and its implications. The data were collected from the 2015 Input-Output Table from Brazil and the 2013-2015 System of Environmental-Economic Accounts for Water in Brazil. After the literature review, the methodology is presented and the results are discussed in connection with the scenarios created. A final considerations section ends the paper.

Literature Review

There are several estimates regarding the amount of fresh water available. One of these estimates was made by Shiklomanov (1999), and it shows that the total volume of water on Earth is approximately 1.4 billion km³, of which 35 million km³ (2.5%) correspond to fresh water and, of this total, 200 thousand km³ correspond to the part available for abstraction (Tomasoni et al. 2009). The total annual precipitation on the soil is about 119,000 km³, of which 72,000 km³ evaporate, leaving about 47,000 km³ of flow (4,000 km³ are collected annually). Brazil has a large fresh water reservoir, representing about 12% of the total amount of fresh water on the planet (Bicudo et al. 2010). The permanent growth of global and national demand for goods and services, however, puts pressure on this large reserve, and the risk of negative economic and social impacts are imperceptible due to water abundance. In addition, despite having made advances in the management of its water resources, the country's current structure is flawed. Furthermore, the distribution of water in the country is quite irregular. According to Silva et al. (2016), the Brazilian Water Scarcity Index is 5%, which masks the high scarcity in several regions. The Northeastern states, for example, have an average of 76.7% water scarcity. Finally, in Brazil, there is a false notion of water abundance, secondly, in crises such as power outages are frequent. In 2001, for instance, there was a drought in dams in the Center-South region of Brazil; a drought in water reservoirs in the largest metropolitan area of South America, Sao Paulo, in the 2014/15 season; and great economic losses in the Northeast region in 2012-17, among others cases (ANA et al., p. 9).

In addition, according to Buriti and Barbosa (2014), quoting Granziera (2001), in the twentieth century, water came to be treated as "a scarce resource that could generate conflict of interest not only between human beings, citizens of the same country, but also between states and nationalities" (Buriti and Barbosa 2014, p. 239). This reality made it necessary to establish rules for the use and consumption of this unique and vital natural resource. Although it has existed in Brazil since 1930, Brazilian rules for national waters have undergone important changes since the end of the 20th century. Before the Federal Constitution of 1988, the existence of public and private waters was recognized. With the new Constitution, however, all the water resources of Brazil were recognized as public. In 1997, the Water Law (or “Lei das Águas”) was established and, most importantly, created the National Water Resources Policy. It has established tools to manage federal resources (i.e., across more than one state or border) and created the National Water Resources Management System.

According to the National Water Agency - ANA (2018), the National Water Resources Policy has two fundamental aspects: decentralization, by creating a national system that integrates the Federal Government and the federal states; and participatory, by setting up water resources management committees that unite the public authorities in three instances (federal, states and municipalities), resource users and civil society. According to ANA (2018), the evolution of water resources management at the national level is assessed by means of the Report on Water Resources, published every 4 years.

Amaral (2008) states that the Water Law represents an important initiative in favor of the rational use of water and the depollution of rivers and seas. In legal terms, as detailed by Buriti and Barbosa (2014), the National Water Resources Policy was enacted based on the following grounds, according to first article of the Water Law:

> "Water is a public property (Item I); water is a limited natural resource endowed with economic value (Section II); in situations of scarcity, the priority use of water resources is human consumption and animal nutrition (Section III); the management of water resources must be decentralized and have the participation of the Government, users and communities (Section VI)."

According to Buriti and Barbosa (2014), the Water Law created, as mentioned above, the National Water Resources Management System, a set of legal and administrative instruments, formed by "laws and institutions that have a set of instruments or management tools whose function is to enable the implementation of the National Policy and State Policies for Water Resources." (Buriti and Barbosa 2014, p. 245).

This model of water management, according to Portela and Braga (2006), was inspired by a model developed in France. The cultural and territorial differences between countries present enormous challenges to the Brazilian management system, such as challenges of federal coordination, as well as the "permanent tension between centralization and decentralization that has been characterizing the country in the last 20 years" (Portela and Braga 2006, p. 75). These include vertical conflicts between the three levels of government (Country, States and Municipalities) and horizontal conflicts between governments of the same level of power, civil society organizations and business organizations (Portela and Braga 2006).

With the economic value attributed to water (item II, article 1), it is only natural to charge for its use, as can be observed in Article 5 of the Water Law. According to Amaral (2008), this charge can be considered one of the main instruments for the implementation of the National Water Resources Policy (of which the Water Resources Management System is part).

The economic activity most influenced by the establishment of the Water Law, given the charging bias, is the industry sector. A price is put on the use of water to establish it as an economic good. Attributing this role to the water radically changes its role in society, since the rationalization of water use and the obtaining of financial resources for the financing of water programs and policies become more feasible. Thus, its environmental aspect is expanded thanks to the "new" economic character, and vice versa.

The System of Environmental Economic Accounts (SCEA) of Water in Brazil was developed by the National Water Agency (ANA), the Brazilian Institute of Geography and Statistics (IBGE) and the Department of Water Resources and Environmental Quality (SRHQA). The system has information on the balance between the availability of water resources and water demands of the economic sectors on a national scale. The SCEA complements the System of National Accounts (SNA) using the same accounting principles as the latter for environmental resources. The SCEA thus allows a joint analysis between environmental data and economic information (in physical and monetary terms). They are considered "the relations between the economic, social and environmental dimensions of the countries in order to guarantee a truly sustainable economic growth. In this way, political decisions about economic growth, investment in social level and environmental management are increasingly sensitive to the value of natural resources" (ANA et al. 2018, p. 10).

In order to collect data on the water resources in Brazil, Tables of Uses and Resources (TRU) of the System of Environmental Economic Accounts of water were compiled. The composition of the Environmental Economic Accounts for Water in Brazil addresses the years 2013, 2014 and 2015 of the Water TRU and considers "the interrelations of water in quantitative terms and with physical representation (units of volume in time-flow) in the economy and between the environment and the economy." (ANA et al. 2018, p. 15). It is possible, therefore, to evaluate the flows of water use by the Brazilian economic sectors in a certain temporal cut. In sum, total water withdrawal, total water uses from other economic activities, total supply to other economic activities, total resurfacing water, and total water consumption are quantified. For simplification purposes, only the 2015 values will be shown here.

The study, by separating the information by economic activities, grouped these sectors in a similar way to the hierarchical level of the National Classification of Economic Activities (CNAE). The activities of the CNAE, "agriculture, silviculture, forestry, fishing and aquaculture", "extraction industry", "electricity and gas" and "water and sewage" kept the same title and concept in the Environmental Economic Accounts of Water in Brazil. On the other hand, the sectors of the CNAE "processing industry" and "construction" were aggregated in the Environmental Economic Accounts of Water in Brazil, being named "processing and construction industries", a large and, unfortunately, generic sector. The rest of the sectors present in the CNAE were grouped in only one sector in the Environmental Economic Accounts of Water in Brazil, receiving the name of "other activities".

Table 1 shows the different water flows in Brazil in the 2015 economy. The total water withdrawal encompasses the volumes collected by the economic sectors directly from the environment, either for their own consumption or for the transfer to other sectors. Extremely high values for the electricity and gas sector are observed, since these values "(...) contemplate the turbine flows used for power generation in hydroelectric plants, considered a non-consumptive use, and the flows used in thermoelectric plants" (ANA et al. 2018, p. 32). It is necessary to clarify the difference between use and consumption. Water use refers to the use of the resource that does not waste it and may be returned or redistributed, otherwise, consumption refers to the use that waste the product.

The use and supply of water reflects the interaction between sectors and volumes of water, including wastewater to the sewage system and the supply of treated water to or from other economic activity. In both cases, the values of the "water and sewage" activity are highlighted, mainly due to the volumes of sanitary sewage and stormwater drainage of the CNAE 37 (Sewage and related activities) and the flows destined to the distribution to other economic activities by the CNAE division 36 (Water collection, treatment, and supply) (ANA et al. 2018).

The total return includes the releases to internal water resources. The expressive numbers of "electricity and gas" are given because "turbine flows for power generation" are fully returned to the environment by hydroelectric plants and thermoelectric plants have a significantly small consumption" (ANA et al. 2018, p. 43). The "water and sewage" sector returns water through the flows of collected sewage and rainwater. The sector "agriculture, silviculture, forestry, fishing and aquaculture" returns water to irrigation activities.

Table 1. *Water Flows by Economic Activity – Brazil 2015 – in Cubic Hectometers*

Sector /Water	Retirements	Use from other sectors	Supply for others	Total Return	Water Consumption
Agriculture	32.05	1.14	0	9.94	23.70
Extractive Industry	1.04	0.01	0	0.76	0.28
Industry and Construction	6.11	0.28	0.18	2.77	3.45
Eletricity and gas	3114.29	0.01	0	3114.20	0.10
Sewage and Water	47.09	7.16	10.86	41.11	2.27
Other Activities	0.70	2.05	1.30	0	0.75

Source: Research in ANA et al. (2018).

Total consumption and total use, as mentioned, have different values. Total usage is the sum of the Total Withdrawal and Usage columns coming from other sectors. Total consumption is Total use subtracted from Supply for other sectors and Total Return. Brazil's largest water consumers are irrigation and animal feed activities in the "agriculture, silviculture, forestry, fishing and aquaculture" sector with 77.6% of total consumption, followed by the "manufacturing and construction industry" (11.3%) and "water and sewage" (7.4%) (ANA et al. 2018). Table 2 summarizes these results.

Table 2. *Total Consumption by Economic Activity – Brazil 2015 – in Cubic Hectometers*

Sector /Water	Total Consumption	Share of Total (%)
Agriculture	23.70	77.6
Extractive Industry	0.28	0.9
Industry and Construction	3.45	11.3
Eletricity and gas	0.10	0.3
Sewage and Water	2.27	7.4
Other Activities	0.75	2.4

Source: Research in ANA, IBGE e SRHQA (2018).

Macroeconomic dynamics relates to the availability of natural resources in different ways. As a consequence of continued economic and population growth, demand for water is increasing worldwide:

> “Potential for greater political instability, population growth of underdeveloped countries and the growing need for natural resources caused by the increasing destruction of the natural environment, lead the world in the period that could be characterize by the conflicts for the natural resources.” (Kurecic et al. 2014, p. 2)

According to Hoekstra (2010), there is a growing interest of trade and water experts in the relationship between international trade and water scarcity. This relation has two characteristics: first, the water commodity itself is hardly sold. It is different from other physical commodities in this respect. The types of water trade as a product are the bottled water trade and the beverage industry, and even these are not very relevant in the international scenario. Second, the relevant water transfers are those in the form of "processed” products, either exported or imported.

When a country consumes its water to produce an export good, water is virtually transferred to the importing country. (Hoekstra 2010).

The concept of virtual water is defined as "(...) the amount of water necessary for its (good) production." (Tamea et al. 2013, p. 1,205). According to Silva et al. (2016), most of studies on virtual water trade are concerned with the pressure on domestic water resources in importing/exporting countries and also on the issue of virtual dependence on water imports and food/ environmental security. Proposed by Allan (1998), the concept of virtual water has been a key feature for the scientific comparison of the water consumption of different goods (Tamea et al. 2013).

The most "direct" positive effect of international water trade, as discussed by Chapagain et al. (2006), is the national saving of the resource in question resulting from the importation of water-intensive goods. Water trade, however, also generates water losses for exporting countries, since water cannot be used for other purposes in the countries that export the products.

Also as analyzed by Chapagain et al. (2006), at the beginning of the 21st century, the total volume of water used in agricultural production was 6.4 billion m^3/year. Without international trade, i.e. assuming that all countries produce their own commodities, the use of water for agricultural production would be 6.75 billion m^3/year. International trade, consequently, reduces the overall use of water in agriculture by 5%.

The efficiency of water use can be increased if nations use their theoretical advantage or comparative disadvantage in relation to the availability of water in the country to stimulate or discourage consumption or "acquisition" of water resources in their exports or imports. According to Chapagain et al. (2006), little effort was made to analyze the use of water efficiency at the global level. Hoekstra (2010) extensively analyzes the effects of the relationship between international trade and water consumption. Based on the author's system, three points can be highlighted: first, imports of water-intensive commodities reduce national demand for water. Second, exports of water-intensive commodities increase national demand for water. Lastly, there is evidence that the trade balance of countries with very low per capita water availability is partially determined by the fact that these countries have a comparative disadvantage in the production of water-intensive goods.

Some studies, however, disagree with these arguments. Yang et al. (2003) quantitatively demonstrated that cereal imports played an important role in compensating for the scarcity of water. The authors demonstrate that below a certain limit on water availability, an inverse relationship can be identified between the importation of cereal from a country and its water resources per capita. In the early 1980s, according to the study, the limit was about 2,000 m^3 per capita per year. By the end of the 1990s, it had decreased to about 1,500 m^3 per capita per year.

According to Debaere (2014), water systematically affects countries' trade patterns in a manner consistent with trade theories. The international distribution of water resources is quite uneven and the differences in the sectoral intensities of water are important enough to affect the international division of production and global labor trade.

Few studies deal with international trade relations and water availability in Brazil, even though Brazil is one of the countries with the largest availability of water in the world and one of the largest exporters of virtual water on the planet. However, the study by Silva et al. (2016) give an overview of exports and imports of virtual water in Brazilian agricultural products from 1997 to 2012. The strong participation of the agricultural sector in water consumption can be explained mainly by the use of water for irrigation (Carmo et al. 2008). According to Silva et al. (2016), in the period 1997-2012, a gross export of virtual (agricultural) water of 67.1 billion m³/year and a net virtual export of water of 54.8 billion m³/year. Europe is the largest importer of virtual (agricultural) water from Brazil, with a gross export of 27.7 billion m³/year (41% of the total). The Asian continent is the second, importing a total of 21.6 billion m³/year, (32% of the total). The Americas represent the third largest destination for Brazilian products, with a virtual water volume of 9.3 billion m³/year. Africa has imported 8.2 billion cubic meters per year of virtual water from Brazil. According to Carmo et al. (2008), the export of Brazilian general commodities has increased significantly in recent years, which is reflected in the volume of virtual water exported by the country. In less than ten years, this volume has more than tripled (Carmo et al. 2008).

Regarding the Brazilian imports (1997-2012), also according to Silva et al. (2016), that its values are quite reduced when compared to exports, confirming that Brazil is still a major exporter of water-intensive products. According to the authors, the average volume of water resources transferred to Brazil from other countries was 12.3 billion m³/year, 91% of South America. Finally, in relation to the Brazilian regions, the authors show that the Northeast region, the one with the most limited availability of water in the country, is the main importer of virtual water. The region with the highest availability of water in the country, the Northern (Amazon) region, however, does not present a high rate of export of water embedded in agricultural products. The other regions, the Mid-West, which contains two large ecological biomes of Brazil, the Pantanal and the Cerrado, the South-Eastern region and its sugar production, and the South region, a large soybean and corn area, one of the most humid in the country, present large volumes of virtual water exports in agricultural products.

By comparing the data available in the Environmental Economic Accounts of Water in Brazil to the literature analyzed here, a study on water availability in Brazil is made possible and justified. A Brazilian sectoral analysis, together with the innovation of the computable general equilibrium models generated the methodology and results described below.

Methodology

Computable General Equilibrium Models are extremely rigorous mathematical models for economic valuation of different subjects, including those of an environmental nature. In recent years, the number of studies that analyze water issues through CGE models has increased. The range of research includes water pricing policies, water resource allocations, water markets, etc. (Wang 2016). Water experts and economists have a long history of knowledge exchange in their models even if there is a certain tension between the two parties, given the "stylization" of water in economic models and the economic simplicity employed in many of the models of water experts. (Robinson and Gueneau 2013). Since the 1990s, however, CGE models have been widely used and evolved to better analyze water issues of different natures (Luckmann et al. 2013). This study, therefore, used the input matrix of 2015 and the data of water consumption by economic sector available in the Environmental Economic Accounts of Water in Brazil to analyze the consumption of this important natural resource in Brazil due to changes in international trade.

Our purpose is analyzing the total consumption of water by the Brazilian economic sector due to the increase of the global demand for domestic products. Thus, shocks to Brazilian exports have been made. These shocks are all positive, reflecting, for the sake of simulation, the constant global economic growth observed in the last decades, since only in 2009 the overall real GDP growth was negative (IMF 2018). Such growth, as mentioned earlier, puts pressure on the water input. Shock values were determined using data from the World Trade Statistic Review of 2018 (WTO 2018). Positive values were found that could represent a soft increase (F) in world exports and a strong increase (G) in world exports. In the historical series 1981-2017, the values of the years 2016 and 2017 were chosen, since they are recent, sequential, positive and with a significant difference between the two. In 2016, there was an increase of 1.8% in the volume of world exports, while in 2017 there was an increase of 4.7% (WTO 2018). In addition, two export standards of the Brazilian economy were established. The first is the current Brazilian standard, and the second is a Brazilian standard with a strong preference for the services sector. In the first pattern, shocks (increase) in exports are uniform (U), that is, the same shock is assigned to all economic sectors, which shows the same behavior as the exporting pattern. In the second pattern, shocks are non-uniform (NU), i.e. stronger shocks are assigned to service sectors (favoring them) and weaker shocks are assigned to the remaining sectors. In the second pattern, shocks of 0.9%, 1.8% and 3.6% (soft) and 2.3%, 4.7% and 9.4% (strong) were used. Table 3 illustrates shocks in exports.

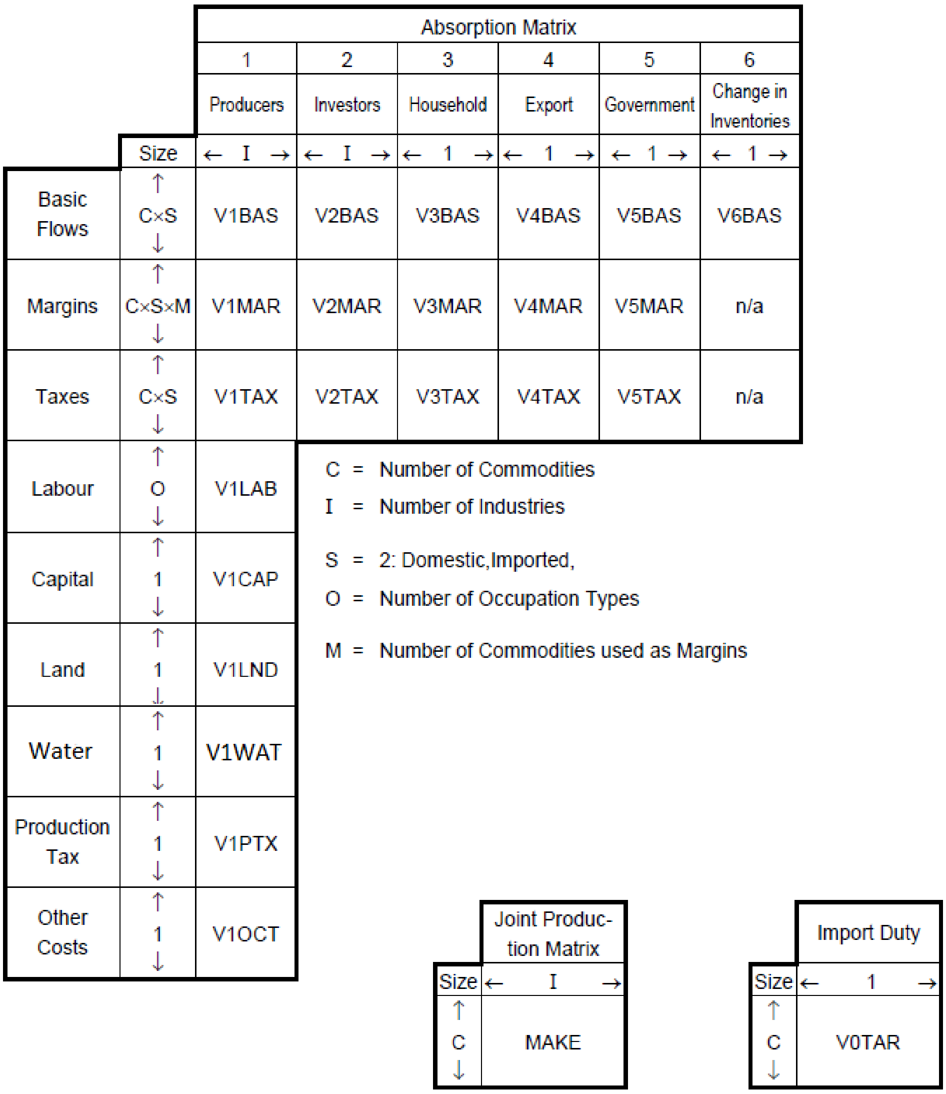
Table 3. *Simulation Values for Changes in Brazilian Exports*

Sector/Simulation (in % change)	**UF**	**NUF**	**UG**	**NUG**
Agriculture	1.8	0.9	4.7	2.3
Extractive	1.8	0.9	4.7	2.3
Industry and Construction	1.8	1.8	4.7	4.7
Eletricity, gas and water	1.8	3.6	4.7	9.4
Retail sector	1.8	3.6	4.7	9.4
Transportation	1.8	3.6	4.7	9.4
Information and Communication	1.8	3.6	4.7	9.4
Finance	1.8	3.6	4.7	9.4
Real Estate	1.8	3.6	4.7	9.4
Other Services	1.8	3.6	4.7	9.4
Public Adm, Health and Education	1.8	3.6	4.7	9.4

Source: Research from IMF and WTO.

The CGE model chosen for the simulations was ORANI-G. This model, however, underwent modifications for the effective inclusion of the water input in its structure. In the modified model, water is treated as one of the four primary factors alongside capital, labor, and land. This allows an efficient qualitative analysis of changes in its consumption, as also observed in the original model, in the primary factors of capital, land and labor. Thus, a “price x quantity” vector was created for the primary water factor. The established quantity is the total consumption present in Table 2, while the established price, according to Souza and Santos (2016), is 2.62 reais (Brazilian currency), since an Input Output table is published in reais, per cubic meter.

Figure 1. *Modified Flows of ORANI-G*



Source: Horridge (2005), modified.

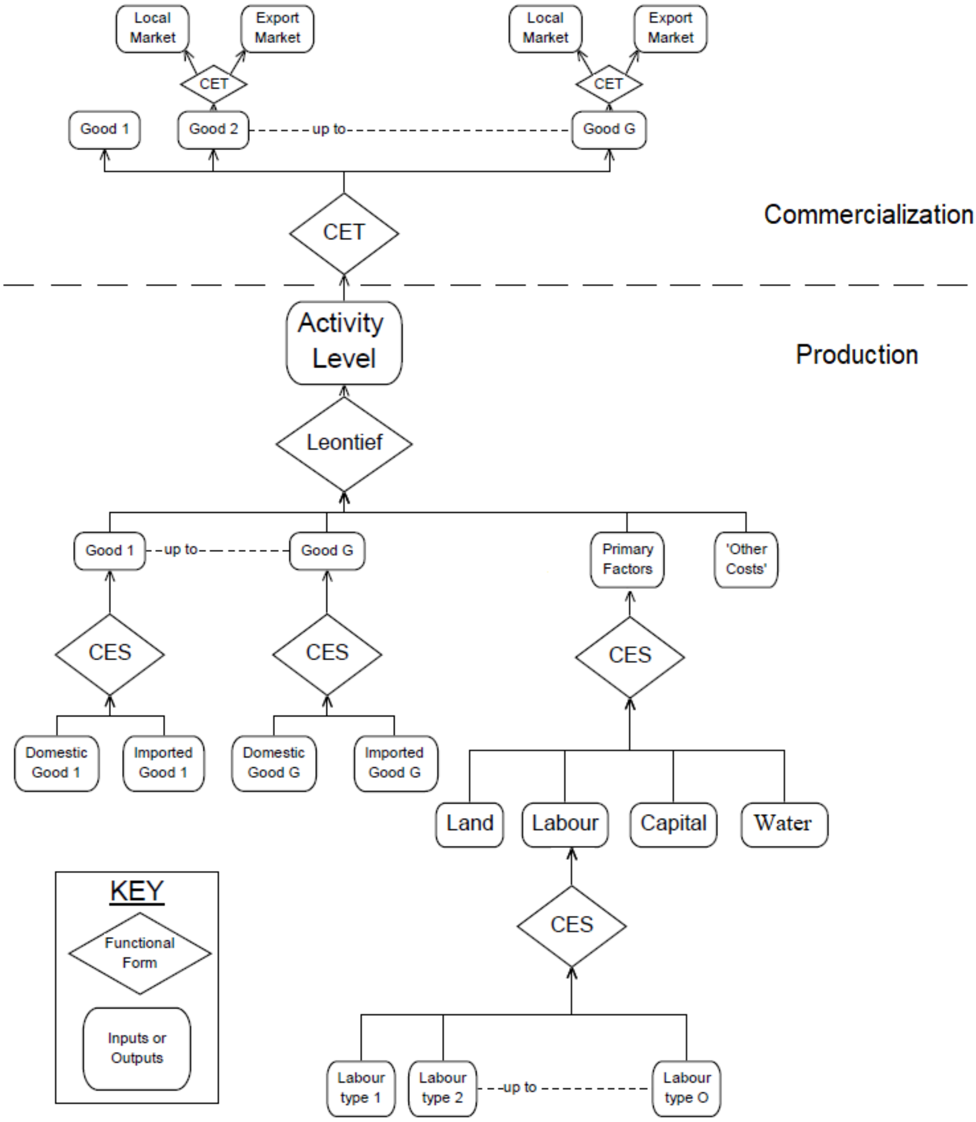
ORANI-G is a static model composed of several equations that explain flows. Each stream originates from a price x quantity multiplication. Supply and demand equations for private sector agents are derived from the solutions of optimization problems (minimization of costs, utility maximization and others) of a traditional new-classical agent. Agents in the model are price takers, with producers operating in competitive markets that prevent them from obtaining "pure profits." Figure 1, based on the work of Horridge (2005), shows the structuring of the modified ORANI-G model for water. The explanations that follow regarding ORANI-G in the remainder of this section are all based on those developed in Horridge (2005).

The model allows each industry to produce various commodities, using as input national and imported goods, labor of various types, land, capital, and water. Commodities destined for export are different from those used locally. The production specifications are illustrated by the nesting (Figure 2). This nesting can be divided into two parts. The lower part concerns production and is divided into a sequence of "nests". From bottom to top: the "work" compound is an aggregate of job types by occupation (O) combined by a CES function (constant substitution elasticity), representing in general the demand for different types of work; the compound "primary factor" is an aggregate CES of land, capital, water and the compound "work", generally representing the demand for primary factors; the commodity is a CES function of a domestic good and the imported equivalent, generally representing the demand for commodities from one source or another (as a "choice" of the source of the intermediate input). The "primary factor" and "well" compounds, combined with "other costs" are combined through a Leontief function, all of which are therefore demanded in direct proportion to the industrial activity index (X1TOT) (Horridge 2005).

The model allows each industry to produce a mixture of every commodity. For each industry, the mix varies according to relative prices. The upper part of Figure 2 determines the composition of the commodities of industrial production. This top part also deals with marketing. The nested CET functions (constant elasticity of transformation) determine whether the good is going to be sold overseas or to the domestic market (Horridge 2005).

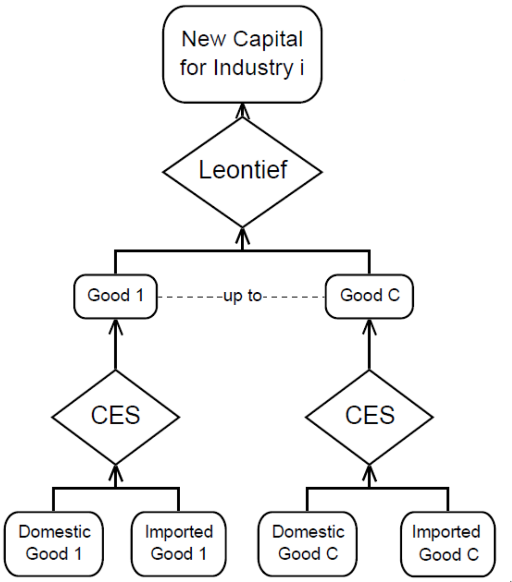
Figure 3 shows the structure of the demand for investment. Its structure is similar to that of intermediate goods. The figure shows, in other words, the nesting structure for the production of new units of fixed capital. Capital is produced with inputs from domestic and imported commodities. Commodity compounds are aggregated via a Leontief function. No primary factor is used directly as input for capital formation (Horridge 2005).

Figure 2. *Production Structure - Modified ORANI-G*



Source: Adapted from Horridge (2005).

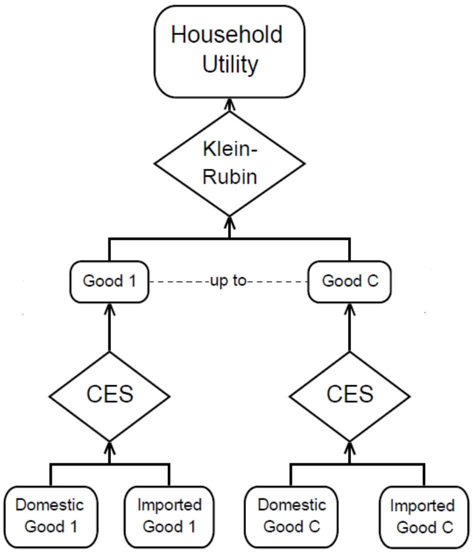
Figure 3. *Demand Structure in Investment*



Source: Horridge (2005), modified.

Finally, Figure 4 shows that the structure of consumer demand (households) is very similar to that of investment, different only by the Klein-Rubin aggregation function, which leads to a linear Horridge (2005) expenditure system.

Figure 4. *Consumer Demand Structure*



Source: Horridge (2005).

Results

The values presented in Table 4 clarify the percentage variation of the water consumption of the economic sectors in the four scenarios, in relations to exports growth.

Table 4. *Percent Change in Water Consumption – By Sector and Simulation*

Sector/Simulation	UF	NUF	UG	NUG
Agriculture	0.11	0.07	0.28	0.18
Extractive	0.93	0.57	2.43	1.48
Industry and Construction	0.41	0.41	1.07	1.08
Eletricity, gas and water	0.15	0.15	0.39	0.39
Retail sector	0.15	0.16	0.40	0.41
Transportation	0.33	0.42	0.87	1.09
Information and Communication	0.13	0.19	0.35	0.51
Finance	0.14	0.20	0.37	0.51
Real Estate	0.04	0.06	0.10	0.14
Other Services	0.17	0.25	0.44	0.66
Public Adm, Health and Education	0.03	0.02	0.08	0.06

Source: Results of the model/simulations.

The agricultural sector, the one that consumes the most water, was not the sector that presented the largest variations of total consumption, regardless of the shock under analysis. The extractive sector was the most affected in all scenarios, even in those with a higher demand for services, with values considerably higher than others, especially when compared to the agriculture and livestock sector. Other sectors that presented changes considerably superior to the agricultural sector were industry and construction and, in the same way, transportation.

The total water consumption in relation to the exporting profile was, in general, as expected. Uniform soft shocks generated greater variations in total water consumption in the primary sectors when compared to the non-uniform soft shocks and generated lower variations in the service sectors when compared to the non-uniform soft shocks. The same pattern was observed in the uniform and non-uniform shocks. Non-uniform soft shocks do not generate greater variations than strong uniform shocks in service sectors, even with the closest approximation of shocks. The exceptions for all these results were the electricity, water and gas and administration, public health and education sectors. The first showed no change in total water consumption with the change in the export pattern, maintaining 0.15% in soft shocks and 0.39% in strong shocks. The second, even with higher shock levels in non-uniform shocks, presented higher water consumption in uniform shocks (0.03% and 0.08% compared to 0.02% and 0.06%), contrary to the idea of improve of service sectors.

In the soft shocks, it was observed that the agricultural sector did not show great variations in the total water consumption in a possible change of pattern of the Brazilian exports. The extractive sector, however, presented considerable variation. On the other hand, the sectors of transport and other services have significantly changed their consumption with a change in the export profile.

Finally, the variations of the real estate and the retail sector, with a change in the export agenda, are little more than water consumption.

In strong shocks, there are generally stronger consumption variations among sectors, considering a change in the export profile. This is evidenced in the variation observed in the industry and construction sector. The shocks established for this sector were the same in the strong scenarios (4.7%) and even so, an increase of 1.07% to 1.08% in total water consumption was observed. The agricultural sector, contrary to its pattern in the mild shocks, shows considerable consumption variations considering a change in the export agenda and the extractive sector continues with high variations. The transportation, other services, information and communication and financial sectors show considerable variations, unlike real estate and retail.

The relationships between the shocks can be better observed in Table 5. Uniform shocks increase water consumption more than non-uniform shocks. Even though shock levels are considerably high in the service sectors in UN shocks, the intensive use of water in the primary sectors still causes their variations to be dominant.

Table 5. *Aggregate Shocks – Water Consumption*

Consumption/Simulation	**UF**	**NUF**	**UG**	**NUG**
Change in Total (%)	0.16	0.12	0.40	0.32
Change in Total Consumption (liters)	476 billion	371 billion	1,223 billion	963 billion

Source: Results of the model/simulations.

Table 6 shows the values in cubic hectometers of the percentage variations previously presented. Even though its percentage variations have been smaller, the agricultural sector remains the largest total consumer of water in Brazil by large differences.

Table 6. *Water Consumption – By Sector – Cubic Hectometer*

Sector/Simulation	**UF**	**NUF**	**UG**	**NUG**
Agriculture	23730	23720	23770	23746
Extractive	284	283	289	286
Industry and Construction	3464	3464	3487	3487
Eletricity, gas and water	2374	2374	2380	2380
Retail sector	689	689	690	690
Transportation	0.07	0.07	0.07	0.07
Information and Communication	0.07	0.07	0.07	0.07
Finance	0.07	0.07	0.07	0.07
Real Estate	0.07	0.07	0.07	0.07
Other Services	0.07	0.07	0.07	0.07
Public Adm, Health and Education	59	59	59	59

Source: Results of the model/simulations.

Finally, we can compare the water supply to two other factors, capital and labor, and the level of national activity. The variations of the Current Capital Stock and the Effective Labor Input show fairly similar values and are then presented together. All variations of the water resource, as observed in Table 7, were superior to both capital and labor variations. As a result of the shock level of exports and the character of exports, the demand for water increases more than the demand for capital and labor. Resources in the economy, therefore, are more focused on water than on the other two primary factors.

Table 7. *Percent Changes in Current Capital Stock and Effective Labor Input*

Sector/Simulation	**UF**	**NUF**	**UG**	**NUG**
Agriculture	0.10	0.06	0.25	0.16
Extractive	0.92	0.56	2.41	1.47
Industry and Construction	0.36	0.38	0.94	0.99
Eletricity, gas and water	0.10	0.11	0.25	0.30
Retail sector	0.10	0.12	0.27	0.32
Transportation	0.27	0.38	0.70	0.98
Information and Communication	0.09	0.16	0.22	0.42
Finance	0.10	0.16	0.25	0.43
Real Estate	_0.02	0.02	_0.05	0.05
Other Services	0.12	0.22	0.31	0.57
Public Adm, Health and Education	_0.02	_0.01	_0.06	_0.04

Source: Results of the model/simulations.

Regarding the level of activity, Table 8 shows how much more was produced by the economic sectors given the proposed shocks. The variation in the level of activity did not overcome the greater demand for water in any of the economic sectors and in none of the proposed shocks. The extractive sector, however, presents variations of level of activity very close to the variations of total water consumption. This result is validated by the high variations of the Current Capital Stock and the Effective Labor Input of the sector. With simulated export increases (with or without profile change), the extractive sector increased its demand for water, capital and labor, which was reflected in the high variations in its level of activity and, consequently, importance to the national economy. The greatest alterations are observed in the agricultural sector, in which the level of activity presented considerably lower variations than those of the demand for water. Sectors such as public administration, health and education and real estate were affected by the increase in exports, given the negative variations in capital, labor and production level (resources flowing to other sectors), which contrasts with the positive variations in total water consumption.

Table 8. *Percent Changes on Activity Level*

Sector/Simulation	UF	NUF	UG	NUG
Agricultural	0.04	0.03	0.11	0.07
Extractive	0.92	0.56	2.41	1.47
Industry and Construction	0.36	0.38	0.93	0.99
Eletricity, gas and water	0.10	0.11	0.25	0.30
Retail sector	0.10	0.12	0.26	0.32
Transportation	0.26	0.37	0.69	0.97
Information and Communication	0.08	0.16	0.22	0.42
Finance	0.09	0.16	0.24	0.42
Real Estate	_0.02	0.02	_0.05	0.05
Other Services	0.12	0.22	0.30	0.57
Public Adm, Health and Education	_0.02	_0.02	_0.06	_0.04

Source: Results of the model/simulations.

Conclusions

This study analyses the impact of international trade in Brazilian economic sectors and it correspondent impact over water consumption across economic sectors. The Brazilian economy is characterized for its presence in international trade by use of natural resources and exports of goods with great natural properties, such as water, energy, and land.

The growth of international trade is one of the most important factors to increase the pressure on this water demand, both in industrial and primary sectors. Different Brazilian export growth scenarios proposed showed that the deviations in total water consumption exceeded the variations in demand for capital and labor in all sectors. In addition, the difference of the total water consumption exceeded the variation of the level of activity of each sector, presenting an elastic pattern for water consumption. The primary extractive activity, vegetable and mineral, observed the greatest increase in water consumption, and its variations in the demand for capital and labor and activity level were also significant in response to export growth. The pattern of the agricultural sector, however, was reversed. The largest water consumer in the world presented low variations in water consumption due to export shocks, with lower values than sectors such as commerce and transport, even in scenarios of preservation of the current exporting figures. The total consumption of the sector, however, is still vastly superior to any other activity developed in the country.

Given the Brazilian national data to 2015, through an input-output table, a typical computable general equilibrium model, given the sectoral distribution, made it possible to bring to the discussion concrete figures regarding the relationship between availability of water resources and exports. Stricter and better enforced charging/control policies are the main alternatives for a more rational use of water. However, it is necessary to recognize the need to unite two aspects: water as an indispensable resource for production and life, threatened by scarcity, and the continuity of this production, threatened by excessive and inefficient use of the national water resource.

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