Spring 2019

Market-base solutions to manage the Guarani Aquifer: Pigouvian Fee and Cap-and-Trade

Julia Hayes Vieira
University of New Hampshire, Durham, jhv1001@wildcats.unh.edu

UNIVERSITY of NEW HAMPSHIRE

UNIVERSITY OF NEW HAMPSHIRE

Carsey School of Public Policy
Master in Public Policy
Capstone Project

Market-base solutions to manage the Guarani Aquifer
Pigouvian Fee and Cap-and-Trade

Julia Hayes Vieira

Advisors: **Professor Carolyn Arcand, Ph.D.**
Professor Robert Mohr, Ph.D.
Professor Thomas Safford, Ph.D.

Durham, May 10th, 2019

ABSTRACT

The objective of this case-study is to analyze the effects and the perception of different groups in possibly implementing market-based approaches of Pigouvian tax and Cap-and-Trade to manage the Guarani Aquifer, Brazil. The Pigouvian Tax is a corrective taxation that assigns a price for the negative impacts water consumption creates to aquifers, as a way to influence a more sustainable level of water consumption. Cap-and-Trade sets a maximum quantity of water allowed to be used from aquifers, and allow economic agents to trade quantities of water they have the right to use, as a way to adapt to the cap. As methods of analysis, the case study combines quantitative data, economic theory, as well as political and sociological analysis. The case-study emphasizes that the current regulatory system of Guarani's management is not guided towards the efficient level of water consumption, which may negatively impact the environment and economic resources. As a way to improve efficiency of water allocation from the Guarani and mitigate the already apparent environmental impacts, the instruments of Pigouvian Tax and Cap-and-Trade could be possible policy solutions. The case-study also outlines the perceptions of different societal sectors to the creation of market-based approaches to govern Guarani's water resources, in terms of their risk perceptions. Broader discourses that were used in previous attempts to establish other water management instruments were described as an attempt to correlate these to a possible implementation of Pigouvian Tax or Cap-and-Trade to manage water use from the Guarani Aquifer. Overall, the analysis inferred that several groups could perceive a Pigouvian Tax positively because it could foster a more rational use of water and protect the Guarani. However, some groups may be against a Pigouvian Tax for fearing a lack of predictability in the cost of production, as well as the fear it could increase inequality in low-income groups' access to water. In terms of a Cap-and-Trade, most groups may perceive negatively the implementation of such approach. This is mainly related to the fact that it would completely change the regulatory system to access water, which could be interpreted as privatizing water access.

Key-words: Guarani Aquifer; Pigouvian Tax; Cap-and-Trade; Water Charge; Water Market; Risk Perception.

SUMMARY

LIST OF FIGURES

LIST OF TABLES

Market-base solutions to manage the Guarani Aquifer
Pigouvian Fee and Cap-and-Trade

> "Devising ways to sustain the earth's ability to support diverse life, including a reasonable quality of life for humans, involves making tough decisions under uncertainty, complexity, and substantial biophysical constraints as well as conflicting human values and interests." (Dietz, Ostrom and Stern, 2003, p.1907)

Introduction

In Brazil, water quality and availability directly impact economic development, public health and welfare policies. Unplanned development, demographic change and climate change are increasing the pressure and competition over water resources in Brazil, which calls for policies that seek conservation and efficiency gains in water consumption across the country (OECD, 2015, p.30). Unfortunately, recent water crisis (severe droughts and floods) have caused devastating damages across all regions of the country. The problem is that the entire country, including the public, businesses, political authorities, and the environment, suffers with mismanagement of water resources, but the real causes of such crisis are not always understood and addressed (OECD, 2015, p.84).

The logic for the government to regulate the market derives from the occurrence of market failures, which encompasses imperfect competition, imperfect information and externalities (Kolstad, 2000, p.135). The main challenge with environmental regulation is that, in general, the government tries to induce actors that are generating negative externalities to take socially desirable actions, but this effort may not be effective or efficient due to the complexities of environmental problems and the process of regulation (Kolstad, 2000, p.137).

Environmental regulations involve a complex web of governmental agencies, technical capacity to understand and find efficient level of market equilibrium, and multiple actors and interests. Regulations to environmental resources may generate inefficient, ineffective or not cost-effective outcomes to the market if policies are not designed in a way that promote flexibility, innovation and reduction of costs to reach the desired environmental outcomes (Kolstad, 2000, p.151-152).

In Brazil, water resources are regulated by a complex and decentralized system that involves federal, state and local spheres, as well as representations from business groups, civil society, and environmental groups. Presently, water management combines a bureaucratic system that encompasses an array of legislations, economic instruments that attempts to induce more

rational water use, and a participatory system that integrates direct inputs from different groups in policy decision making (Campos and Fracalanza, 2010, p. 367).

Groundwater regulations are even more complex to understand as there are many unclear legal aspects in terms of its allocation and incomplete implementation of the instrument of water charge for its use. There are also international examples of the use of water markets as an instrument for water allocation that could be beneficial to the Brazilian reality in cases of water scarcity (OECD, 2015, p. 202-204). Using the example of the Guarani Aquifer, this case-study will try to clarify the regulation for groundwater use and study the perception of different groups in possibly implementing market-based approaches of Pigouvian Tax and Cap-and-Trade as additional instruments for groundwater management in Brazil.

Groundwater is a common pool resource and is likely to be overused in the absence of mechanisms to restrict usage (Sayre and Taraz, 2019, p. 85). As it will be presented in this case-study, evidence point to localized overuse of the Guarani Aquifer, which can become a widespread problem in the future, if it is not already happening today.

Sayre and Taraz (2019, p. 85) explain that there is a compelling economic theory on groundwater, known as the Gisser-Sanchez effect, that finds that the size of the common pool externality is relatively small if the groundwater body is relatively large, as the externality mainly involves the impact on other water users. The Gisser-Sanchez effect theorizes that, as groundwater level decreases, the costs for water extraction will increase because market agents will need deeper wells, more energy to extract water, higher investments in new technology and maintenance (Sayre and Taraz, 2019, p. 87). As the cost of water extraction increases, water use will decrease, along with the rate of water level decline. Water extraction will eventually reach an equilibrium without any necessary control to the free market (Gisser and Sanchez, 1980, p. 639-641).

Even though the Guarani Aquifer fulfills the Gisser-Sanchez effect's assumption of being a very large groundwater reservoir with relatively small recharge capacity, the Gisser-Sanchez effect also assumes that the groundwater will be only used for farming, water use rights are attached to landownership, and only land overlying the groundwater body could be irrigated (Gisser and Sanchez, 1980, p. 641). As it will be explained subsequently, the Guarani Aquifer's resources have multiple uses besides agriculture production, and the domain over the Guarani does not follow individual property ownership.

Moreover, we will argue that the externalities generated by the Guarani's overuse exceeds the simple impact on other water users, generating impacts on surface water levels and flows, soil downgrade, risk for saltwater contamination, and population welfare. For all of those reasons, this case-study will analyze the externalities effects on the Guarani to a possible introduction of market-based control from a Pigouvian tax and Cap-and-Trade system.

The Pigouvian Tax is a corrective taxation that assigns a price for the negative impacts water consumption creates to aquifers, as a way to influence a more sustainable level of water consumption. Cap-and-Trade sets a maximum quantity of water allowed to be used from aquifers, and allow economic agents to trade quantities of water they have the right to use, as a way to adapt to the cap.

The Guarani Aquifer

The Guarani Aquifer System is one of the largest aquifers in South America and is shared by four countries: Argentina, Brazil, Paraguay and Uruguay. Approximately 60% of the aquifer is located in Brazil but the country represents more than 90% of the current exploitation level (Foster *et al.*, 2009). In Brazil, Guarani's resources are mainly used for population consumption, followed by agricultural production, industrial use, and recreation (Borghetti *et al.*, 2011, p. 191). There is an international agreement between the four parties that was signed in August 2010, guaranteeing equitable and reasonable use of its waters and improving cooperation in managing the water resource.

The Guarani Aquifer present areas of recharge, areas of discharge and confined areas. Areas of recharge are specific locations where water is capable of penetrating the aquifer to refill its level, whereas areas of discharge are locations where groundwater intercepts surface water bodies or is artificially extracted through wells (Guimaraes, 2007, p. 37; (Projeto para a Proteção Ambiental e Desenvolvimento Sustentável do Sistema Aquífero Guarani, 2007, p. 80-81). Such areas are the most economically viable to take water from. Groundwater recharge capacity is key to define land-use planning and sustainable groundwater use (Manzione, 2015, p. 185). Estimates point that 40 trillion liters of water per year can be potentially exploited without posing risk to the aquifer (Guimarães, 2007, p. 46). In confined areas, the level of recharge is practically nonexistent, meaning that using that resource would exhaust the water available from the aquifer (Foster et al, 2009, p. 10-12).

In Brazil, the Guarani Aquifer System straddles eight states (Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Mato Grosso, Mato Grosso do Sul, Goiás and Minas Gerais) in urban and rural areas, which have different necessities and deficiencies. Based on data from the 2010 Brazilian Water Supply Atlas[1] (ANA, 2010), it was estimated that by 2015, about 12 million people would have been living in areas of recharge of the Aquifer. According to a requested information by the author to the National Water Agency (ANA), recharge and discharge areas encompass 368 municipalities, as shown in Figure 1.

[1] The Brazilian Water Supply Atlas is a diagnosis research conducted by the Brazilian National Water Agency (ANA) to evaluate water supply in municipalities.

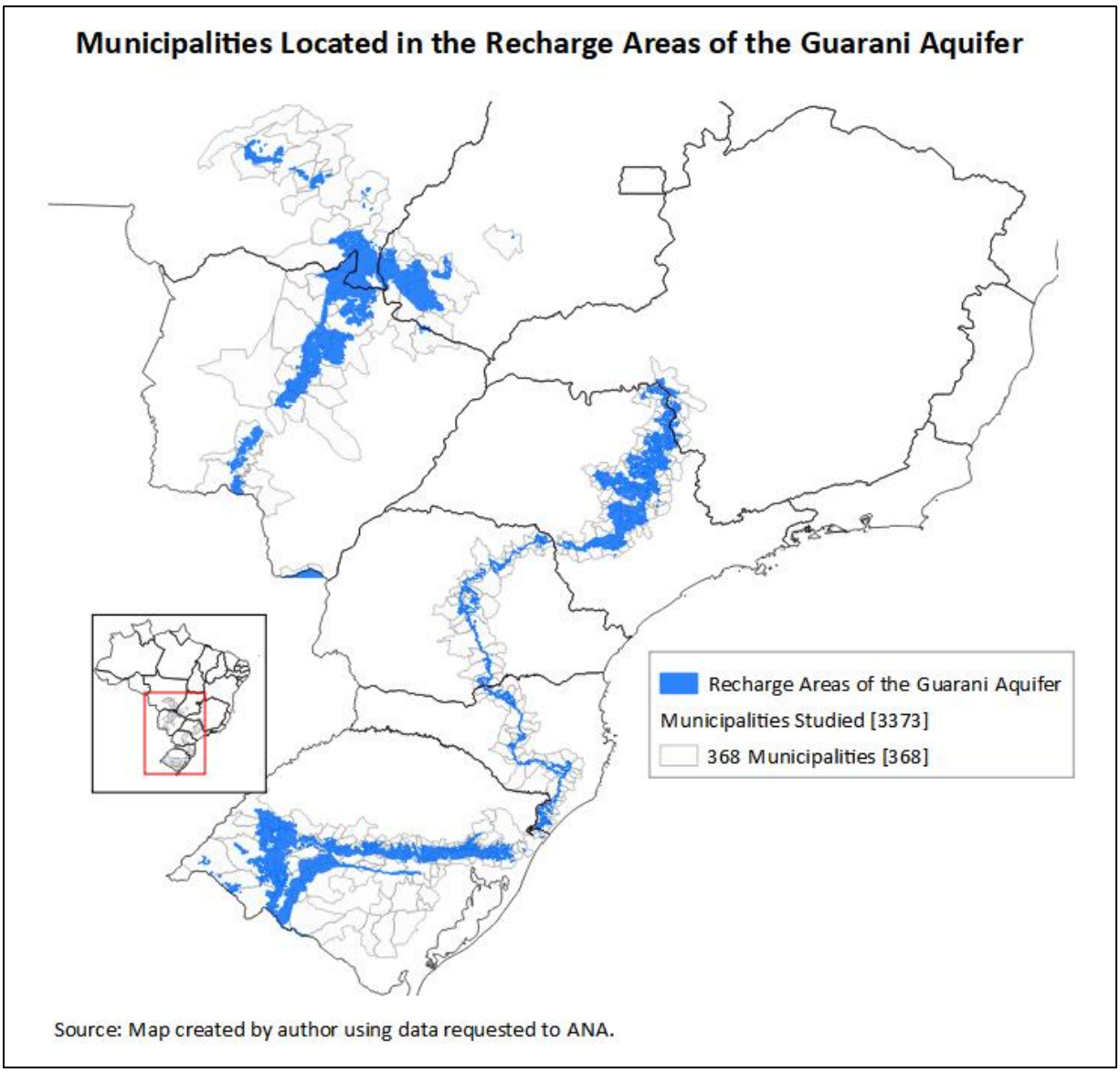


Figure 1. The map shows the recharge areas of the Guarani aquifer and the municipalities

The importance of the Guarani Aquifer for the region can be shown by Figure 2, where most municipalities rely partially or completely in groundwater for water supply. Across Guarani's recharge areas, almost 42% of the municipalities are supplied solely by ground water, 38% solely by surface water, and 20% by both sources[2], which clearly evidences the importance of the aquifer to the region and welfare of the population.

[22] Data from Brazilian Water Supply Atlas of 2010(Agência Nacional de Águas (ANA), 2010), analysis from the author.

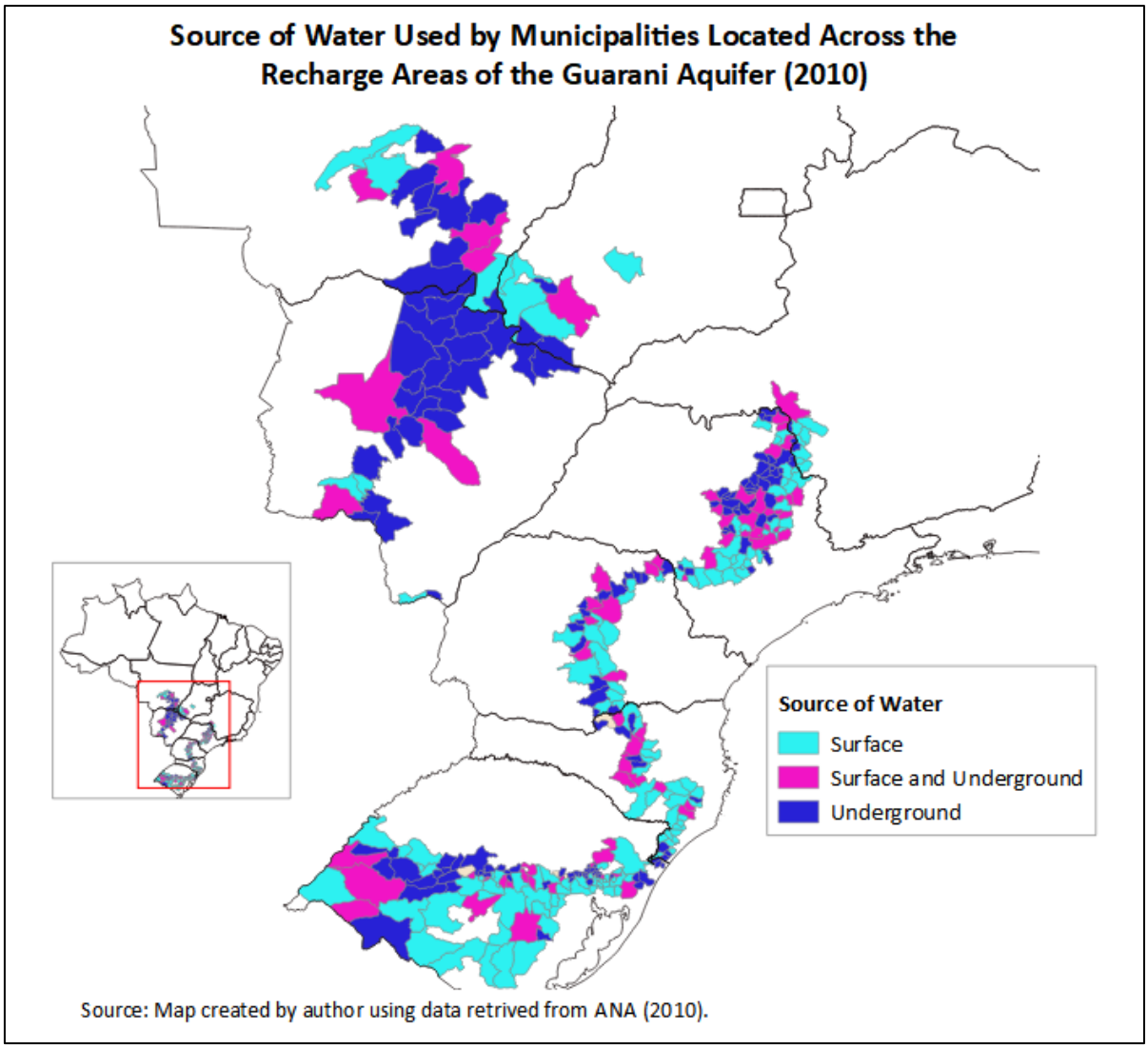


Figure 2. The map shows the source of water used by municipalities located in recharge areas of the Guarani Aquifer

The Problems in the Guarani Aquifer

Before defining which policy could be more effective to manage the Guarani Aquifer, the regulatory body needs to first determine that regulating groundwater brings an actual net benefit to the market because implementing any regulatory policy will generate regulatory costs (Jandoc *et al.*, 2014, p.10). Regulating a resource only brings net benefit if the costs of the exploitation or externality exceeds the governance cost (Jandoc et al, 2014, p.10).

Environmental governance depends on information about stocks, flows, the effects of exploitation, that may be subjected to scientific uncertainty and disagreement (Dietz et al, 2003,

p.1908). Defining such characteristics to regulate and monitor an aquifer is not an easy task, especially in the case of the Guarani. Comparing to surface water, it is harder to define important aquifer characteristics, such as groundwater movement, recharge capacity, and accurately measure individual pumping extraction (Jandoc et al, 2014, p.19).

There are two main categories of problems that can impact groundwater resources: overexploitation and contamination. Experts that work with the Guarani Aquifer point out a substantial risk for localized areas of pollution and depletion across its recharge areas (Sugg *et al.*, 2015, p. 386); Foster et al, 2009, p. 10-12).

The main risk related to the quantity of water available in aquifers is depletion that occurs with overexploitation. Aquifer overexploitation occurs when water exploitation exceeds the annual estimate of recharge from rainwater, which is subjected to seasonal variations from monthly precipitation (Lucca, 2009, p. 33); Manzione, 2015, p. 250). Overexploitation decreases groundwater levels, which can impact surface water levels in cases where the groundwater discharges into surface water streams. Another effect of groundwater level decrease is the possibility of saltwater contamination in coastal areas due to the decrease in the pressure from the volume of groundwater (Bartolino and Cunningham, 2003, p. 2). However, the main effect that municipalities across the Guarani may have been experiencing is soil downgrade.

Perroni and Wendland (2008) found unsustainable levels of exploitation from the Guarani Aquifer in the city of São Carlos (São Paulo), which is causing soil downgrade and generating a high risk of water contamination. Studies from Villar and Ribeiro (2009, p. 55) and Foster et al (2009, p. 17) also point to exploitation levels from the Guarani Aquifer in the city of Ribeirão Preto (São Paulo) that are three times higher than recharge levels, causing groundwater levels to fall by an estimated 30-40m since 1970. Between the border cities of Rivera (Uruguay)-Santana do Livramento (Rio Grande do Sul, Brazil), estimates indicate that the Guarani level has lowered by 5-10m over the last decade, and over 30m since the 1970s (Foster et al, 2009, p. 19; (Companhia de Pesquisa de Recursos Minerais (CPRM), 2012), p. 23). A more recent diagnosis of groundwater extraction from Paraguai River basin (in the states of Mato Grosso and Mato Grossos do Sul) points that estimates indicate sustainable water exploration levels, but clearly indicates that actual extractions are likely to be higher than the estimates (Oliveira, 2016), p.27). Those findings indicate that depletion can be a widespread problem, especially across bigger cities located in recharge areas of the Guarani Aquifer.

Another important contributor to overexploitation is the occurrence of non-compliant or clandestine wells. Regularized and compliant wells need to be registered, have allowance from state water agencies, have periodic monitoring tests, and are subject to water charge in certain situations. Estimates for 2015 pointed to the existence of about 1.2 million wells across Brazil, but only 305,415 were registered, and just 36,308 wells actually had valid allowances for water use (ANA, 2016 In Hirata et al, 2019, p. 11). A study from Hirata et al (2019, p.11) estimate an even more disturbing situation where Brazil might have about 2.5 million wells. Even though

those are national estimates, it is reasonable to say that the recharge areas of the Guarani might have an elevated number of unregulated wells which may be pressuring its resources. The occurrence of an elevated number of unregulated wells compromise the estimations of water use and availability studies, and increase the risk of overexploitation from the lack of appropriate monitoring.

The 368 municipalities located in the recharge areas of the Aquifer differ greatly in terms of size of the population, water supply capacity and – even more – in sewage treatment capacity. There are municipalities that have more than 500,000 residents, such as Ribeirão Preto and Campo Grande, but there are also very low populated municipalities with fewer than 500 residents, such as Lagoa Bonita do Sul and Linha Nova. In terms of water supply, roughly 57% of the municipalities were evaluated as having an adequate system, which means that roughly 43% of the municipalities need to expand their water supply to provide adequate water supply to their entire population[3]. Due to Guarani's good water quality, expanding its water use may be seen as a solution in municipalities that face a lack of adequate water supply. However, expanding Guarani's water use can also add pressure over its sustainable extraction capacity in the short and long-run.

Quality related risks of water bodies involves clandestine wells, as well as pollution that come from the lack of sanitation and industrial and urban waste. Mining, industrial effluent, diffuse inflows from urban and agricultural soil drainage, and solid waste are also other sources of quality risk to water bodies (OECD, 2015, p.30). Moreover, compared to surface water bodies, groundwater contamination can take more time to be identified due to the slower groundwater recharge flow, which can incur in large impacts in terms of water volume and costs for reparation (Oleaga et al, 2009, p. 17-18).

In terms of wastewater treatment, Figure 3 shows that the situation across the Guarani Aquifer is extremely disturbing. With the exception of the state of São Paulo, there is a widespread lack of sewage treatment across the municipalities located in the recharge areas of the Aquifer. According to the 2017 Brazilian Sewage Atlas[4] (Agência Nacional de Águas (ANA), 2017a), in the year 2013, on average, 29% of the wastewater generated was not even collected to be treated, and only 31% of the wastewater generated was actually treated before being discharged into the basins across the area the Aquifer is located[5]. This situation is related to the historical lack of urban planning, and lack of investment in needed infrastructure. In this sense, it is extremely important that urban and rural areas have comprehensive sanitation systems that prevent

[3] Data from Brazilian Water Supply Atlas of 2010 (ANA, 2010), analysis from the author.
[4] Brazilian Sewage Atlas[4] is a diagnosis research conducted by the Brazilian National Water Agency (ANA) to evaluate wastewater treatment across Brazilian municipalities and the impacts of wastewater discharge in water bodies.
[5] Data from Brazilian Sewage Atlas of 2017 (ANA, 2017), analysis from the author.

untreated wastewater from being discharged into the surface water bodies of the Aquifer (Foster et al, 2009).

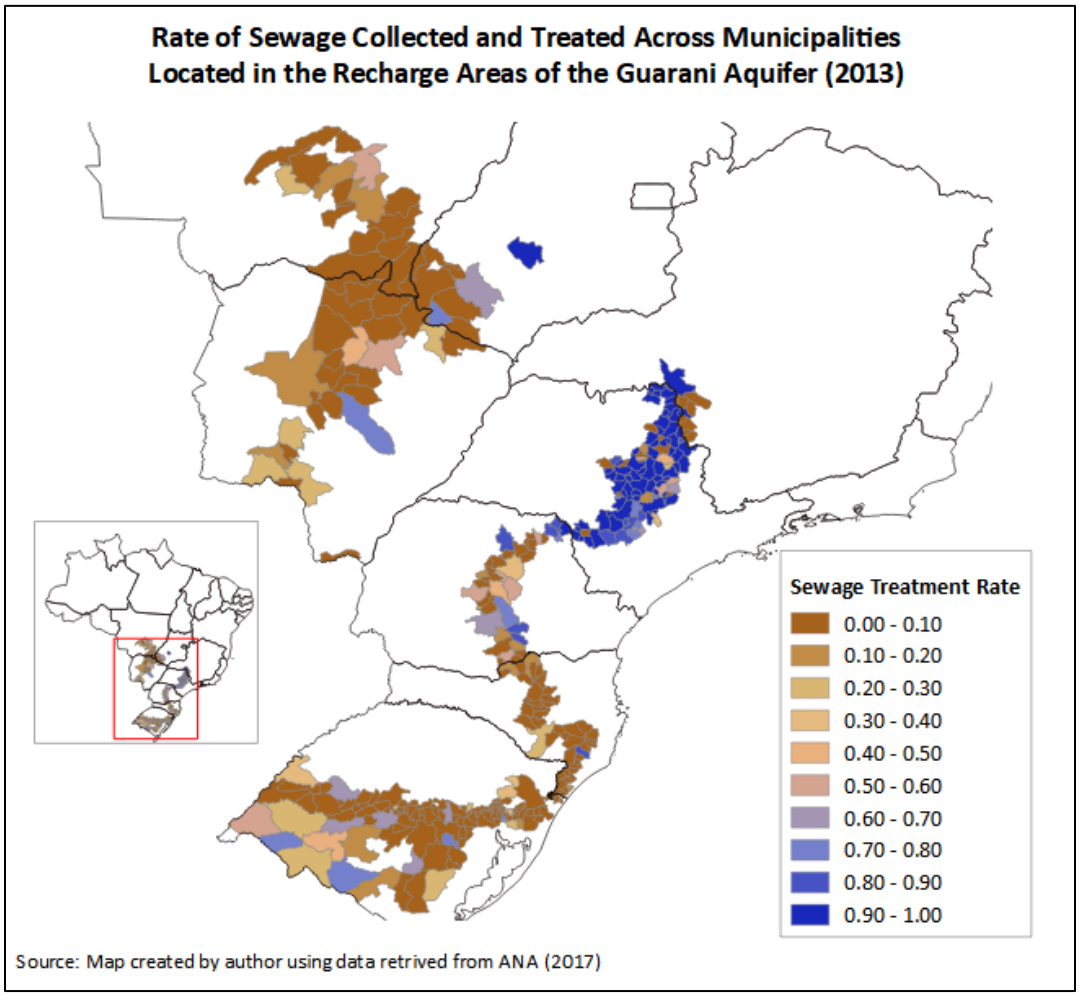


Figure 3. The map shows the rate of wastewater treatment across the municipalities located in recharge areas of the Guarani Aquifer

Due to availability of other surface water resources across most of the Guarani region, pumping water from the confined areas of the aquifer tends to be considered less economically effective but this perception may change as available quality water (Cassuto and Sampaio, 2011, p. 662). Failure to address the current risks is likely to result in collapses of quality water supplied, and create conflicts over water access that can both impact economic development of the region. Moreover, the implications of climate change are likely to increase Guarani's risk by increasing uncertainty in water cycles, as historic flow data may not be applicable in the future, affecting water availability throughout the seasons (OECD, 2015, p.185). In order to protect its resources to future generations, it is extremely necessary that the regulation is effective and promotes Guarani's exploration under the limits of its recharge (Guimarães, 2007, p. 31).

This case-study will specifically focus on the problem of overexploitation, which causes the depletion and exhaustion of the water resources available from the Guarani Aquifer. The research will focus on municipalities that are located in the recharge areas of the Aquifer. The choice for focusing in depletion derives from the fact that the quantity consumed can possibly be managed by price incentives and correction of its level, whereas the pollution problems that threaten the Guarani mostly depend on the expansion of wastewater treatment, which is already a policy in place from the government through the National Plan of Basic Sanitation with a set of goals by region and state until 2033.

Objective and Methodology

The objective of this case-study is to analyze the perception of different groups in possibly implementing market-based approaches to manage water (or other natural resources) in Brazil. The choice for a case study involves the fact that the phenomenon that we want to study is not distinguishable from its context (Yin, 1993, p. 3). In this sense, the system of water regulation cannot be distinguished from the general legislation that governs water, as well as the state apparatus and the status quo in place in Brazil.

The unit of analysis are the different groups that are affected by regulations to the Guarani Aquifer. The conclusions on the impacts and feasibility will define the generalizable theoretical propositions of the case-study for alternatives in managing water resources in Brazil. The example of the Guarani Aquifer could serve as a basis for management ideas of other 26 aquifers that exist in Brazil or other types of natural resources.

As methods of analysis, the case study will combine quantitative data, economic theory, political and sociological analysis and, as a matter of making the two approaches more illustrative, exemplary models.

The first part of the case study will review the current legislation that governs groundwater exploration in light of the Guarani Aquifer case, pointing to a number of elements that could be improved to make the regulation more efficient.

The second part of the study debates the theory of Pigouvian Taxation and Cap-and-Trade and define possibilities for designs to the case of municipalities located in the areas of recharge of the Guarani Aquifer. Exemplary models were created to specific municipalities as a way to make each policy approach more illustrative.

The second part of the study is key to provide the theoretical background of each water management option, discuss possible designs and create some illustrative examples. Ultimately, the research question the case study will try to answer for this part is: **Can market-based approaches be more efficient and cost-effective options to manage the water resources from the Guarani Aquifer, compared to the actual regulatory model in place?**

Reducing depletion from the water bodies of the Aquifer will incur in costs for different water users. Therefore, society needs to face a trade-off between higher costs for water and environmental benefits in the least-cost possible as to maximize the social net benefit (Berck and Helfand, 2011, p. 276). Regulators will have to design a policy that makes each market agent reduce water consumption in a cost-effective manner (Berck and Helfand, 2011, p. 277).

When defining environmental policy, the best economic indication of a cost-effective outcome is through the equimarginal principle (Berck and Helfand, 2011, p. 280). The equimarginal principle is satisfied when all sources of water consumption have equal marginal costs of consumption, making the reduction of water consumption the minimum cost possible (Berck and Helfand, 2011, p. 280). On the other hand, when evaluating a policy efficiency, it is necessary to define the marginal benefit of water conservation. In this sense, efficiency will be met when the marginal benefit of water conservation equals the marginal cost for reducing water consumption (Berck and Helfand, 2011, p. 280).

Based on the previous economic definitions of efficiency and cost-effectiveness, **the first hypothesis of the case-study is that policies of Pigouvian Tax and Cap-and-Trade could be more efficient and cost-effective than the actual regulation to manage the Guarani Aquifer.**

Subsequently, the case-study will focus on the political feasibility of implementing each possible approach by discussing the impacts and benefits those policy options would create to the different sectors (residents/municipalities, industry, agriculture and the environment). The study will assess which sectors would be winners or losers in terms of financial burden and access to water if any of those approaches were implemented and try to suggest possible policy designs to minimize the burden on the losers.

A short discussion on the political positions across sectors' coalitions and social movements will try to expose the public perception to such policy options. The research question this case study will try to answer for this third part is: **How will the different sectors perceive a possible policy change to Pigouvian Tax or Cap-and-Trade?**

One important aspect of market-based approaches in terms of political characteristics is that the implementation of those policies will significantly change the status quo system (Kolstad, 2000, p. 146). When there is a change in the system of regulation, actors that were usually the most benefited and the ones that usually faced the cost could be shifted and that shift can possibly create counter intuitive consequences and resistance (Kolstad, 2000, p. 150). Therefore, **the second hypothesis of the case-study is that each sector will perceive differently how they are impacted by each approach which will define their acceptance or resistance to the policy options.**

Finally, the case-study will review the lessons learnt on the possible effects on the Guarani Aquifer, how users would perceive a change in the regulatory policy of using Guarani's water, and the policy recommendations on how to improve water use from the Guarani and the

aquifer's conservation. This part of the case-study will draw the conclusions on the generalizable propositions for managing water through market-based approaches in Brazil.

Present Legislation and Governance Applied to Groundwater

> "Water governance is often a reflection of a country's culture, legal regime, political system and territorial organization. In every society, water is a complex issue, of importance to all sectors and cutting across all economic actors, combining social values and private interests, with policy formulation and decision making intrinsically linked to overarching debates." (OECD, 2015, p. 38)

Domains and Legislative Competencies

In Brazil, the Federal Government and the states have the domain over water resources, depending on its characteristics. The 1988 Federal Constitution Article 20 determines that the Federal Government has the domain over surface watersheds that are defined as of federal domain, that straddles multiple state boundaries or to other countries, and that serve as border to other countries. Article 20 also determines that the Federal Government have the exclusive domain over mineral resources, which includes mineral water.[6] Article 26 determines that states have the domain over surface water and groundwater located inside their borders.(Brasil, 2018)

The 1988 Federal Constitution Article 21 determines that the Federal Government has the competency of instituting the National Water System management and define the criteria for water allocation and allowances of use (Barroso, 2002), p.258). However, it is the entity that has the domain of the specific water body that has the responsibility to manage the allowance. In this sense, the Federal Government define guidelines of how water will be managed but it is the entity that actually has the domain of the resource (Federal Government, State, or Basin Committees) that will effectively manage it.

Despite the different water domain definitions, the 1988 Federal Constitution Article 22 (Indent IV) determines that the Federal Government has the exclusive competency to legislate over water, unless a Complementary Law authorizes states to legislate over specific topics that Article 22 enumerates. Therefore, the Federal Government has the competency to legislate over groundwater, even though the domain over such resources are under the states, unless Complementary Law authorizes states to legislate over it (Hagger and D'almeida, 2008, p.5).

Articles 20, 22, and 26 created an ambiguous situation over the governmental levels that had the domain and were responsible for regulating surface and groundwater bodies. This ambiguity had the effect of the Federal government abstaining to legislate over groundwater for long time (Hager and D'Almeida, 2008, p.7). Despite such ambiguity, and previous unsuccessful attempts to create the same legal understanding of surface water to groundwater by Constitutional

[6] Mineral water is out of the scope of this study, even though the Guarani Aquifer present some mineral resources in its composition. Mineral water is regulated as a mineral resource, under the jurisdiction of the National Mine Agency through the Mineral Water Code (Decree 7841/1945).

Amendment, the consensus is that the Federal government has the prerogative to legislate over groundwater and the states have the responsibility to manage groundwater in a decentralized manner (Hager and D'Almeida, 2008, p.10).

The 1988 Federal Constitution Art 23 defines the role of municipalities as the protection of the environment and pollution combating, as well as registering and enforcing the concessions of rights to water resources research and exploration in their territories. They are also responsible to manage solid waste, land use and spatial planning (Art 30), which directly and indirectly impact water resources quality and availability, making them key actors of the National Water Management System. More explicitly, municipalities are considered water users as they are responsible for providing the services of urban water supply, sewage collection and wastewater treatment, under the National Directory of Basic Sanitation (LDNSB; Federal Law 11445/2007).

The National Directory of Basic Sanitation (LDNSB) defines the Ministry of National Integration as the coordinator to the implementation of the Federal Basic Sanitation Policy (Art. 52). Under the LDNSB, the Ministry of National Integration is also responsible for promoting water supply and sanitation services for urban centers with more than 50,000 residents, metropolitan areas, and integrated developmental regions (Ride). Water supply and sanitation services for municipalities under 50,000 residents, rural areas, *quilombola* communities[7], and regions under endemic diseases are the responsibility of the National Health Foundation (FUNASA).

Water Resources: a public good with decentralized management

The National Water Resources Plan (Brasil, 1997) is the legislation that guides water management in Brazil. Water is a good of public domain, limited, and endowed with economic value (Art 1). Water has multiple uses but in situations of scarcity, human consumption and provision for animals will be the priorities. Water management is decentralized, meaning that governmental entities, groups representing water users and communities participate in the forums responsible for managing water bodies. Finally, the National Water Plan defines that water management is done at the watershed level, not state borders or other administrative or political boundaries. The definition of the watershed as the unit to be managed is justified by the fact that river basin boundaries cut across state and municipal lines, making water users' behavior impact other uses downstream (OECD, 2015, p. 52).

The National Water Resources Plan has three objectives (Art 2). The first objective is to guarantee to the actual and future generations the availability of water in adequate quality for its multiple uses. The second objective is to foster water use in a rational and integrated manner. Lastly, is the prevention and protection against critical natural events or inadequate use of natural resources.

[7] *Quilombola* communities are settlements of slave descendants that ancestors fled slavory prior to its abolition in 1888.

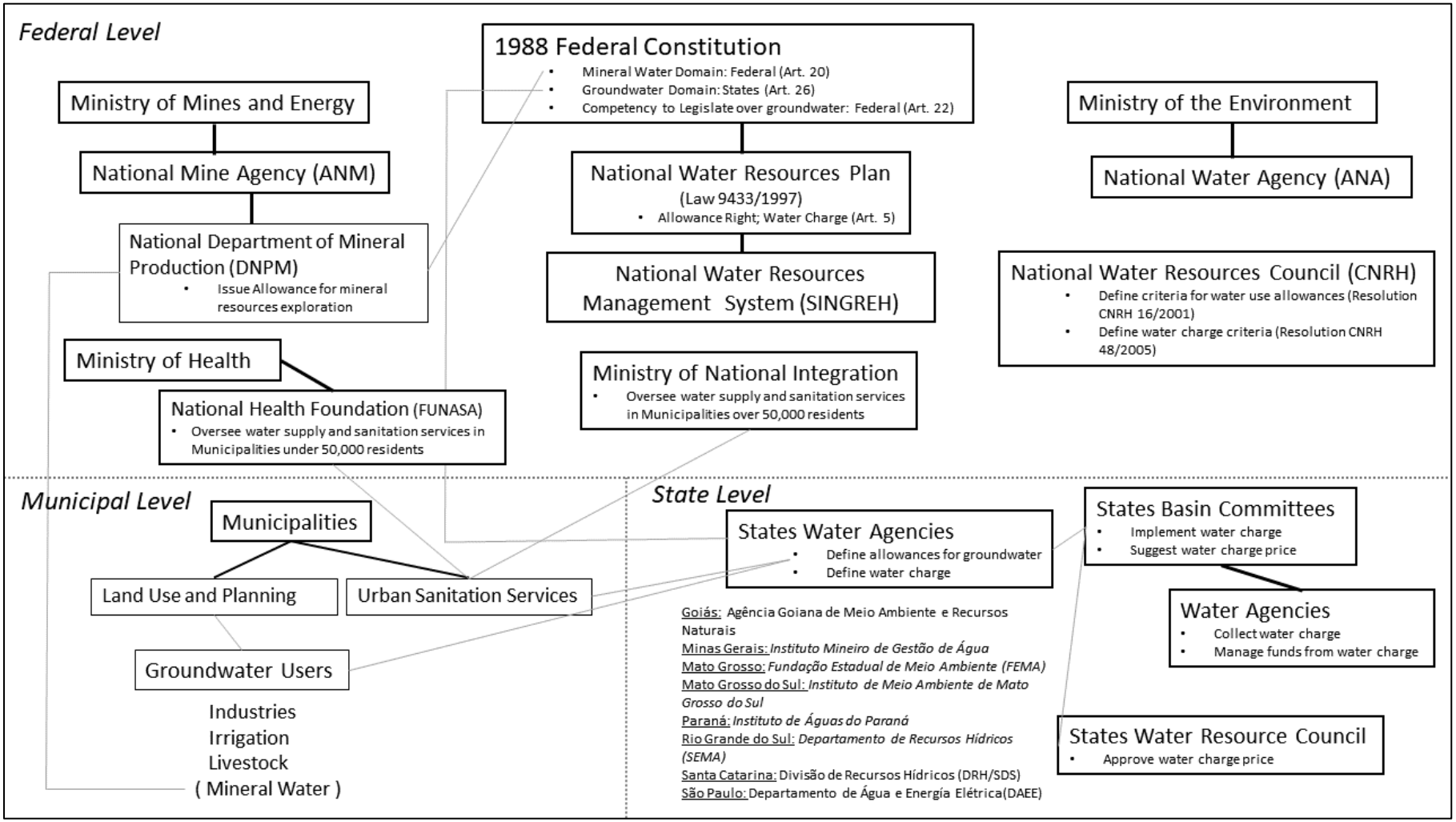


Figure 4. Legislation and Institutions that govern the use of water and water charge from the Guarani Aquifer

Instruments for water management

The National Water Resources Plan has six management instruments (Art 5):

i) specific water plans, that are long-term Master Plans, created by Basin Committees and the states to manage surface water bodies, to guide the implementation of the National Water Resources Plan on specific water bodies;
ii) classifications of different water bodies;
iii) allowance rights to water use;
iv) water use charge;
v) compensations to municipalities; and
vi) the Water Information System.

The National Water Resources Management System (SINGREH) was created by the National Water Plan to coordinate the integrated management of water resources across Brazil. It is responsible to implement the National Plan; regulate, control and preserve water resources; promote the charge for water use; and arbitrate administratively conflicts related to water. The structure of the National System is formed by the National Water Resources Council (CNRH), the National Water Agency (ANA), States' Water Resources Councils (CERH), Basin Committees, municipal, state and federal public institutions responsible for water management, and Water Agencies.

The National Water Resources Council (CNRH) is composed of Ministries and Federal Secretariats responsible for water management, as well as representation from state councils, water users, and civil organizations. It represents the superior entity of the National System, being responsible to define the general criteria for water allowances and water charge. The National Water Agency (ANA) is responsible to implement the National Plan, to control and inspect compliance of water use according to the Federal legislation, provide allowance, define water charge, and inspect water use in Federal domains. State Water Resources Councils (CERH) are states' normative and deliberative bodies of state water laws, with similar attributions as the CNRH. The Basin Committees are advisory bodies that formulate suggestions on water use management in their respective basins, such as allowances, and water charge, as well as being the first instance of administrative arbitration in cases of conflict related to water resources. Each Basin Committee is supposed to have a specific Water Agency which would be responsible to charge water users, and manage the funds gathered from water charges.

Due to the decentralized nature of water management in Brazil, there was a need to create an institution responsible for coordinating actions taken across the country. The Brazilian National Water Agency (ANA) was created in 2000 to coordinate water management (Brasil, 2000). The Agency is responsible for enforcing the implementation, control, and evaluation of the instruments created by the National Water Resources Plan. Other responsibilities include promoting and helping the creation of states' own water agencies and Basin Committees, and

implementing management policy in water bodies of the Federal Government's domain (OECD, 2015; Santos de Souza and Moraes, 2016). Finally, the Agency promotes educational programs to stimulate conservation and rational use of water (Santos de Souza and Moraes, 2016, p. 916).

Allowance for water use

Water allocation regimes are key to promote economic development, equitable use of water, and protect the environment (OECD, 2015, p. 172). In Brazil, water allocation is defined at the Federal, State, and Basin Committee levels. The National Water Agency (ANA) regulates water uses in federal water bodies. State Water Agencies define rules and issue entitlements for state water bodies. The National and States' Water Resources Councils (CNRH and CERH acronyms, respectively) define general rules and deliberate on water conflicts. River Basin Committees define priority water uses and approve river basin plans (OECD, 2015, p. 172). Because states have the domain over groundwater, States' Water Agencies and Water Resources Councils have the jurisdiction in terms of criteria and issuance of allowances for water use.

Allowances for water use are regulated by the National Water Resources Councils (Conselho Nacional De Recursos Hídricos (CNRH), 2001). Allowances of water use are issued for determined period, according to the nature, size and objective of the project. It guarantees the access and control of water use to a specific actor, being it surface or groundwater. Allowances are provided for withdrawal to public supply, agricultural and industrial use, extraction from aquifers, waterborne, hydroelectrical potential, and other uses that alter quantity or quality of water bodies.

Finkler et al. (2015) explain that there are basically eight types of users: urban and rural residents that are supplied by public or private providers, industry, agriculture, mining, livestock, fish farming, or shrimp farming businesses, and companies that extract mineral water. For the case of the Guarani Aquifer, water users would probably be urban water providers, industry, agriculture, livestock businesses, and companies that extract mineral water. Allowances for the Guarani Aquifer's water use will be granted by State Water Agencies. The Federal Government would be responsible for granting allowances in case of mineral water.

Allowances provide a right of use to certain quantities of water - not a right for owning the water resource. It was created to prevent and resolve conflict between different actors. In this sense, an allowance can be suspended in the case of noncompliance with the allowance terms; absence of water use for three consecutive years; necessity in case of extreme situations; necessity to avoid or reverse environmental degradation; to maintain water flow for navigability; or to fulfill priority use when there is no alternative option. It is important to mention that the National Water Resources Plan defines that water use considered negligible or with the objective of supplying small populational cores in rural areas do not need allowances (Art 12).

Finally, the National Water Plan defines as violations the use of water without allowance - being it a surface or groundwater, the drilling of wells to extract groundwater without authorization,

fraudulous water consumption measurement, and actions that hinder inspection of authorities (Art 49).

Water charge

The charge for water use follows the user-pays principle that water resources are recognized as economic goods and the charge indicates its economic value. The objective is to foster rational use, creating revenue to finance programs designed in the Master Plans. The charge applies in cases where allowances are necessary and does not bear upon the use considered negligible.

The water charge is not considered a tax, a fee, or a tariff, but rather a public price in recognition of the economic value of water (POMPEU, 2000, In ANA, 2014, p. 28). The mechanisms of water charge and suggestion of its monetary value are discussed within the Basin Committees between the representatives of different groups of water users, civil organizations and public institutions (ANA, 2014, p. 39). The National and States' Water Resources Councils (CNRH and CERH) approve the values suggested by Basin Committees. Once approved by the CNRH and CERH, water charges will be managed by the Basin Committees' Water Agencies. The revenues are primarily applied in the basins that the resource was generated.

The water charge should not be confused with the water tariff residences and many businesses pay for receiving the service of public water supply. The water charge denotes the public price of impacting water bodies by extracting water or discharging effluents. Water tariffs are paid to public and private companies that provide water supply services and wastewater collection and treatment (Agência Nacional de Águas (ANA), 2014), p. 23).

For the case of water bodies that are under state domains, the states need to create a law to regulate water charge. Subsequently, State Basin Committees need to implement water charges. Most of the states already have such laws created but water charges have only been actually implemented in 53 of the 226 State Basin Committees. For water bodies under Federal domain, the situation is not very different as water charge is implemented in 6 of the 10 Interstate Basin Committees.

For the case of the Guarani Aquifer, those state laws are already created in all states that encompass the Guarani. However, as shown in Figure 4, only a relatively small part of the recharge areas of the aquifer are potentially having this instrument in effect.

In March 2005, the National Water Council approved Resolution 48th that define general criteria to charge the use of water. That resolution guides all norms at national, state and Basin Committee levels to charge the use of water.

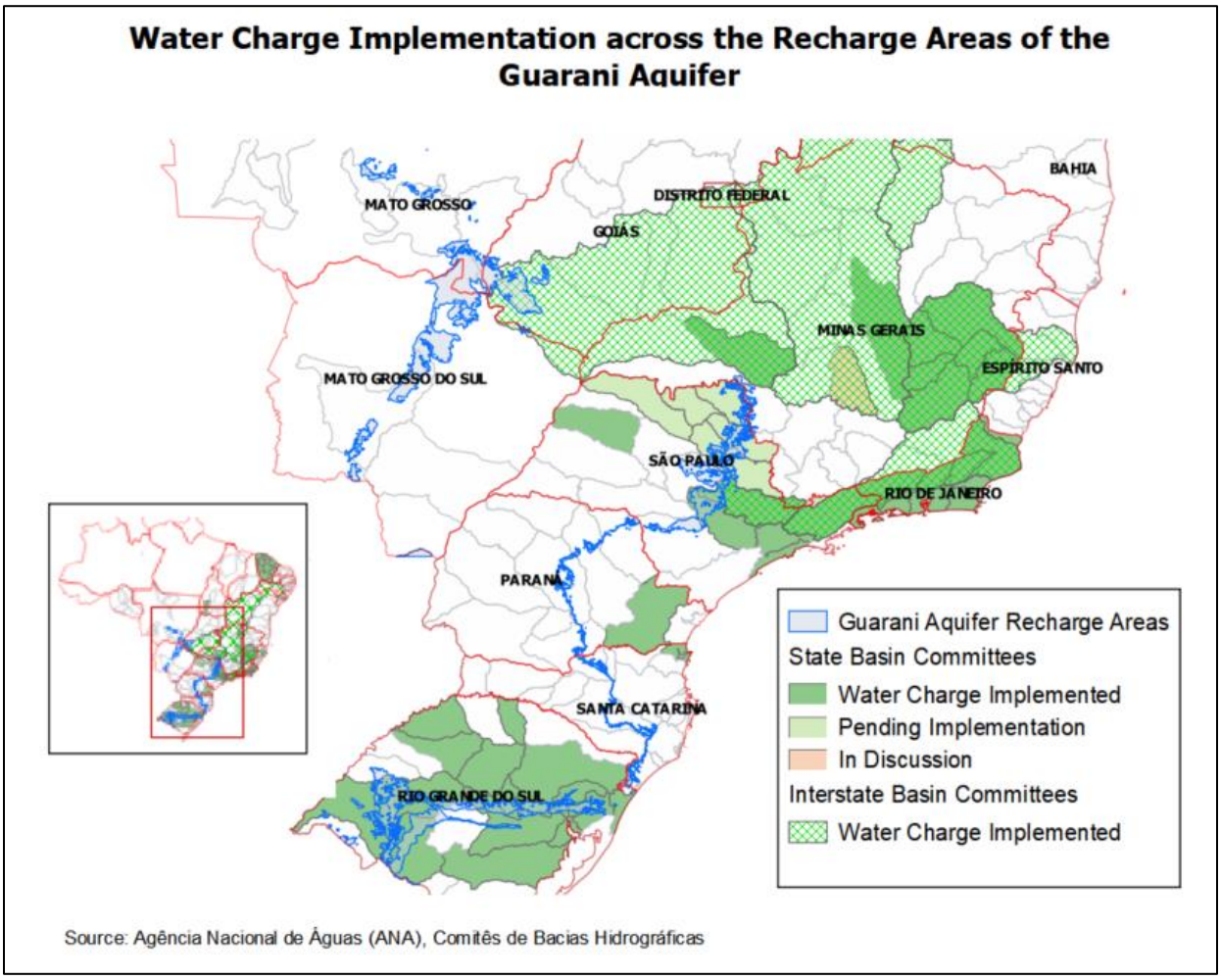


Figure 5. Map of the recharge areas of the Guarani Aquifer and the State and Interstate Basin Committees that implemented water charge. Areas that are not delineated do not have a Basin Committee created.

Chapter IV, Article 7 of Resolution 48^{h}/2005 (Conselho Nacional De Recursos Hídricos (CNRH), 2005) establishes the criteria to define the value of charge, which include among other:

- type of water resource;
- classification of use;
- water availability;
- different definitions of flows and their finality;
- seasonality;
- groundwater characteristics and vulnerability;
- physical, chemical and biological characteristics;
- location of user in the basin;
- soil and water use practices in place that rationalize, conserve, recuperate natural resources;
- existent technical, economic, social, and environmental conditions;
- economic capacity of water users;
- and practices of reutilization.

Basin Committees or institutions responsible for water management may propose different charge according to criteria or parameters that characterize specific cases. They may also define other charges according to voluntary investments or actions that improve the quality or quantity of the water body.

Brief Review of the Allowance and Water Charge Instruments

The present system of allowances for water use and water charge face some criticism in terms of achieving efficiency. The lack of efficiency may contribute to the decrease in water availability from the Guarani, if water demand increases and the effects of climate change become more evident.

Key Criticism to Allowances for Water Use

OECD's analysis of water governance in Brazil argue that, under the present regulation, water allowances are often granted following the order of request, not being guided by clear objectives and priorities of water plans. As pressure increases over water availability, such approach could become problematic in terms of its efficient allocation (OECD, 2015, p. 174-175).

Furthermore, OECD's analysis describe that the present regulation of allowances fails to adequately consider minimum volume flows needed by the environment to maintain stability (OECD, 2015, p. 186-187). Failure to provide adequate water flows to the environment can lead to a wide range of negative, and often unexpected, impacts such as ecosystem instability, floods and change in water cycles. It is also necessary to consider that there are cases where surface and groundwater are highly connected, so allowances for water use need to consider the impacts on the other source when defining the quantity of water available (OECD, 2015, p. 210; Foster et al, 2009, p. 11).

There should also be a periodic assessment of allowances, as several allowances granted in the past may be inaccurate today (OECD, 2015, p. 197). For example, OECD study on Brazil's water governance found that, in the state of Goiás, 7% of pivots with allowances in effect are not active anymore. There are already provisions in the law that allows permits to be revised, or even suspended under certain circumstances. However, it is argued that, most of the times, the allowance system is seen more as the completion of the formal legal requirements than an instrument of continuous water management (OECD, 2015, p. 197).

OECD study on Brazil's water governance suggests a number of criteria that should be included in the allowance system (OECD, 2015, p. 179). For the specific case of the Guarani Aquifer, OECD's suggestions of defining water allocation based on broad policy objectives, creating instruments that minimize transaction costs, and improving the enforcement and compliance are very suited to improve its management. Following international experiences, allowances

criteria could consider efficiency levels based on existing industry guidelines of best-practices, and cost-benefit analysis of achieving certain standards (OECD, 2015, p. 193).

Finally, we cannot underestimate the risks climate change pose to water resources. Recharge capacity is directly related to rainfall and evaporation rates, so groundwater levels are affected when those climate variables change (Manzione, 2015, p. 192). Projections indicate a decrease of 20% in rainfall across Brazilian Southeast and Central Regions by 2040, coupled by temperature rise (Sousa Júnior *et al.*, 2016, p. 2). Specific analysis of the Guarani Aquifer points to an overall decrease in water availability in the north and west areas of the aquifer, with a substantial decrease during Spring and Summer seasons (Projeto para a Proteção Ambiental e Desenvolvimento Sustentável do Sistema Aquífero Guarani, 2007, p. 37-39). In this sense, the allowance system should be prepared to adapt to changes in water flows, at the same time that demand for water may increase (OECD, 2015, p.185).

Key Criticism to Water Charge

OECD's assessment point to two main problems with the current system of water charge. The first is the complex legislation of dealing with public funds. Water charges are considered public funds and have to be spent according to the public finance procedure. Often times there is no way of easily spending the funds collected in the basin so they may accumulate with no visible use. This becomes discouraging for users charged and committees that defined water charges to improve the overall outcomes of the basin (OECD, 2015, p. 43, 66-67).

The second problem relates to how the water charges are defined. Water charges are not grounded on assessments of water users' ability to pay, which is resulting in a low price of charge without knowing the real economic capacity of users (OECD, 2015, p. 65).

A study from Abers and Keck (2013, p.86) about the creation of Basin Committees explain that the first attempt to create a system of water charge took place in the early 2000s in the Paraiba do Sul Basin Committee. Water charge in Paraiba do Sul Basin Committee followed two rationales: raising revenue to finance infrastructure for water management in the basin and to internalize negative impacts of water use (Abers and Keck, 2013, p.94). However, as Abers and Keck (2013, p.94) describe, the debates for implementing water charge reflected production function, user's willingness to pay, or realities of different economic sectors that ultimately wanted to guarantee water charge political viability. As the Committees are composed by the actors that use the water of the Basin, the rates were set at a much lower value than the resources needed to finance water management (Abers and Keck, 2013, p.86). This situation has not had substantial progress as water charge in Brazil is considered low to the market demand, making it still a weak incentive for rational use of water (Da Silveira and Sartori, 2017, p. 45); Ostrensky and Garcia, 2017, p. 17; ANA, 2014, p. 41; OECD, 2015, p. 65). Table 1 shows water charge in different countries, indicating that charges practice in Brazil are relatively lower compared to other countries.

Table 1: Water Charge in Different Countries

Country	**Charge (BRL/m^3)**
Brazil	0.0008 – 0.16
England	0.04 – 0.12
Czech Republic	0.15 – 0.52
Peru	0.0001 – 0.05
Netherlands	0.0748 – 0.45
Germany	0.03 – 0.15

Source: ANA, 2014, p. 41

OECD's study concludes that water tariffs and charges are hardly based on economic analysis (OECD, 2015, p. 204). A further study from Garrido (2018, p.37) also argues that water charges are not being defined by the market equilibrium between the supply and demand of water, but by median operational costs and investment amortization parcels, which diminishes the efficiency in the use of water resources.

Garrido (2018, p.17) observes that charging for water incurs in an opportunity cost of reducing available financial resources for other economic activities to water service providers and consumers, so the price should be set at the most efficient level possible. Economic theory defines that market efficiency can only be met when the equilibrium between the market demand intersects the social marginal cost, which is the sum of the private and external marginal costs of production (Berck and Helfand, 2011, p. 226). The private marginal cost is the incremental cost of producing one more unit of a good, whereas the external marginal cost is the incremental value of health effects and damage to the ecosystem in producing one more unit of a good (Berck and Helfand, 2011, p. 223).

Hence, the water charged practiced in Brazil is not following the marginal cost principle, nor it appears to really internalize the damage that the consumption of water resources causes to the environment. The lack of both elements in the water charge definition may indicate that the regulation is not guided towards the efficient level of water consumption, which may negatively impact the environment and economic resources.

In this sense, other instruments that fully accounts for economic effects could be considered. Pigouvian Tax and Cap-and-Trade are two market-based approaches that attempts to curb environmental impacts by considering the full cost of environmental damage, at the same time as fostering innovation and technology improvements (Kolstad, 2000, p. 153; Berck and Helfand, 2011, p. 298).

Price sensitivity study

Both Pigouvian taxation and Cap-and-Trade use a price to depletion to achieve a sustainable environmental outcome, by signaling water scarcity and encouraging a more sustainable use of water. If defined that market agents are price sensitive to water cost, policies that use economic signals could be considered (Berck and Helfand, 2011, p. 288). However, the effectiveness of those policies depends on the price elasticity of water consumption, in the sense that, the larger the price elasticity, the more effective water use reduction will be achieved (Reynaud, 2015, p. 21).

To define if market agents are price sensitive to water costs, a regression analysis is the usual method used to understand the relationship between the demand of a good and the price to acquire that good (Berck and Helfand, 2011, p. 113). Performing a regression analysis enables the estimation of quantity demanded of water in terms of different parameters, such as the price of water, income, possible substitutes, among others.

A multiple regression analysis can indicate if consumers located in the municipalities situated in the recharge areas of the Guarani Aquifer are sensitive to the price charged for water. For the specific situation of this case-study, the regression analysis will study water consumption price sensitivity on a sample of 192 municipalities *(Municipality)* situated in the recharge areas of the Guarani Aquifer. Data on *Volume of water consumed per capita (L/capita)*, *Average water tariff (BRL/m^3), Population*, and *GDP per Capita (BRL/capita)* between 1995 and 2016 *(Year)* were retrieved from the National System of Sanitation Information (SNIS) (Ministério do Desenvolvimento Regional, 2017), and the Brazilian Institute of Geography and Statistics (IBGE). The characterization of the municipalities in our sample, and the description of each variable is presented in Table 2.

Table 2: Characterization of the municipalities

Municipality municipality **(n= 192)**	**Years of Observation:** 1-5: 11.2% 6-10: 43.1% 11-15: 15.9% 16-20:21.5% 21-22: 8.3%
State State **(n= 8)**	**Goiás** (GO: 0.9%) **Minas Gerais** (MG: 4%) **Mato Grosso do Sul** (MS: 7.7%) **Mato Grosso** (MT: 10.9%) **Paraná** (PR: 2.6%) **Rio Grande do Sul** (RS:27.11%) **Santa Catarina** (SC: 8.2%) **São Paulo** (SP: 38.5%)

Municipality Classification munclass **(n= 1,575)** Source: IBGE	**Urban** (1: 48.3%) **Intermediate** (2: 11.3%) **Rural** (3: 33.1%) **Not Classified** (4: 7.2%)

Variables Description

Volume of water consumed per capita – *watconpcap* Liters of water per capita in a year (L / capita) This data was created by the author dividing the *Volume of water consumed* per year in the municipality (1,000 m³ = 1,000,000L) by the *estimated population* in the municipality Source: SNIS and IBGE	**n= 861** $\bar{x}$ = 60,765.07 σ = 35,152.28 **min** = 0 L / capita **max** = 257,136.4 L / capita
Year **-** year Year of reference that data is available between 1995 and 2016 Source: SNIS	**n= 1,575** $\bar{x}$ = 2010 σ = 4.722 **min** = 1995 **max** = 2016
Average water tariff – tariffm3 Average water tariff in BRL per m³ of water consumed (BRL / 1,000L) Source: SNIS	**n= 1,353** $\bar{x}$ = 1.522 σ = 1.143 **min** = BRL -4.21 per m³ **max** = BRL 16.66 per m³
Population **-** pop Estimated population in the municipality per year of reference Source: IBGE	**n= 986** $\bar{x}$ = 50,548.61 σ = 116,565.1 **min** = 1,544 **max** = 863,982
GDP per Capita **-** gdppcap Gross Domestic Product of the municipality (BRL) by the estimated population in the municipality per year of reference (BRL / capita) Source: IBGE	**n= 986** $\bar{x}$ = 27,019.62 σ = 17,900.75 **min** = BRL 6,550.23 **max** = BRL 182,468

The SNIS database is the most comprehensive database on sanitation services available in Brazil. The database is created from voluntary survey information provided by sanitation providers and municipalities. The information is managed at the federal level by the Ministry of Regional Development. Because the SNIS database counts on voluntary participation, there are large differences on the amount of data available from one municipality to another, and not all municipalities participate in the survey. For example, out of the 368 municipalities located in the recharge areas of the Guarani Aquifer, we could only retrieve information from 192 municipalities.

Moreover, there may be some errors in the dataset. For example, the minimum and maximum values of *Average water tariff* do not seem accurate. The minimum value is BRL-4.21 per m³ consumed, which is highly unlikely as a negative charge is illogical. The maximum value of BRL 16.66 per m³ consumed also appears to be inconsistent with the trend of the distribution, in

which tariff varies consistently between BRL 0.00 and BRL 6.87. Moreover, comparing water tariff in other years for the corresponding municipality, Boa Ventura de São Roque (PR), tariffs vary between BRL 1.60 and 2.81, which are much less for a sudden spike to BRL 16.66 per m^3 consumed.

Despite those possible errors and lack of full information for all municipalities located in the recharge areas of the Guarani Aquifer, the SNIS has the best data available for the information we need to perform our price sensitivity analysis.

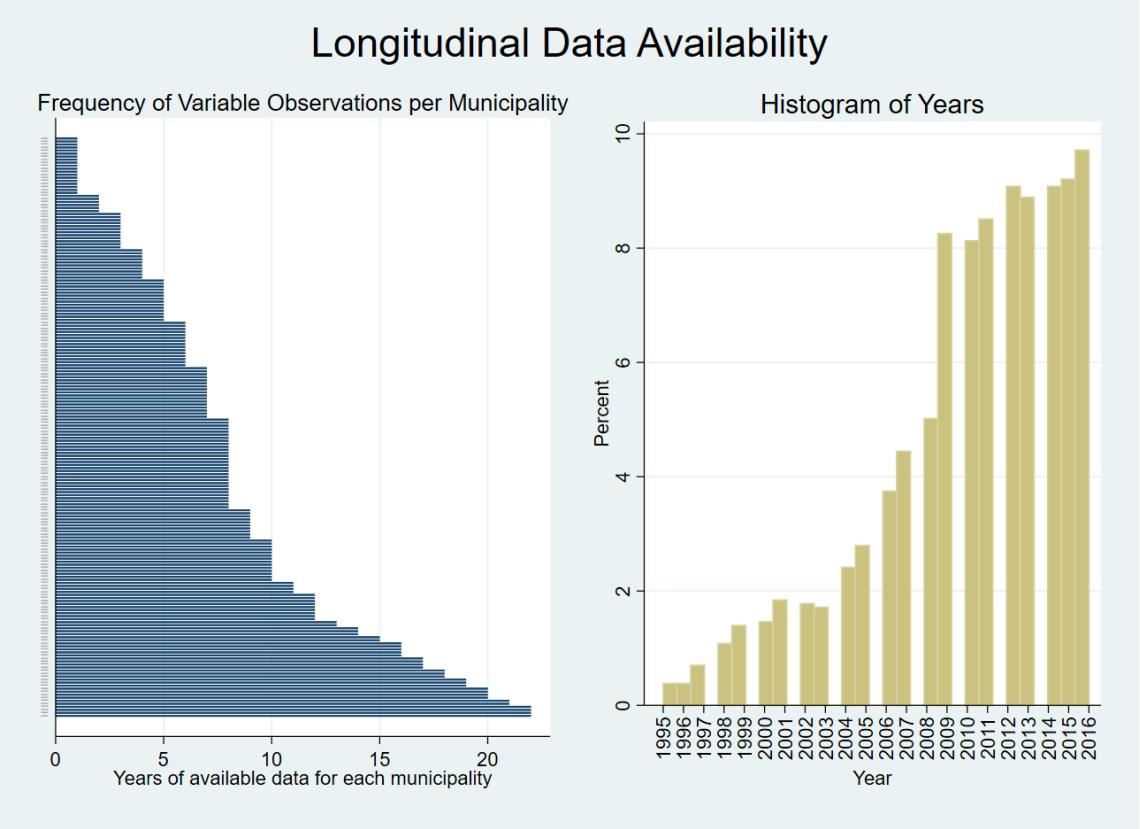


Figure 6. Frequency of years of available data across sampled municipalities.

Figure 6 shows the frequency of observations available for each municipality situated in the recharge areas of the Guarani Aquifer. Data available in our sample vary between 1 and 22 years, with most municipalities presenting between 7 and 15 years available of observations. Moreover, from the histogram of the years which data is available, we can see that there is more data available in more recent years, from 2009 to 2016.

Figure 7 shows water consumption per capita and population size across municipalities situated in the recharge areas of the Guarani Aquifer. *Volume of water consumed per capita* present a positive skewed distribution, as most municipalities in the sample present water consumption per capita between 20,000L and 80,000L, with a few outliers that have a much higher consumption. The distribution of municipal *Population* shows a much more evident positive

skewed distribution, as most municipalities present population size of less than 100,000, but there are a few outliers with very large size population. Comparing *Volume of water consumed per capita* with the distribution of *Population*, it is possible to see a positive effect, which indicates that water consumption varies with the size of the population in the municipality.

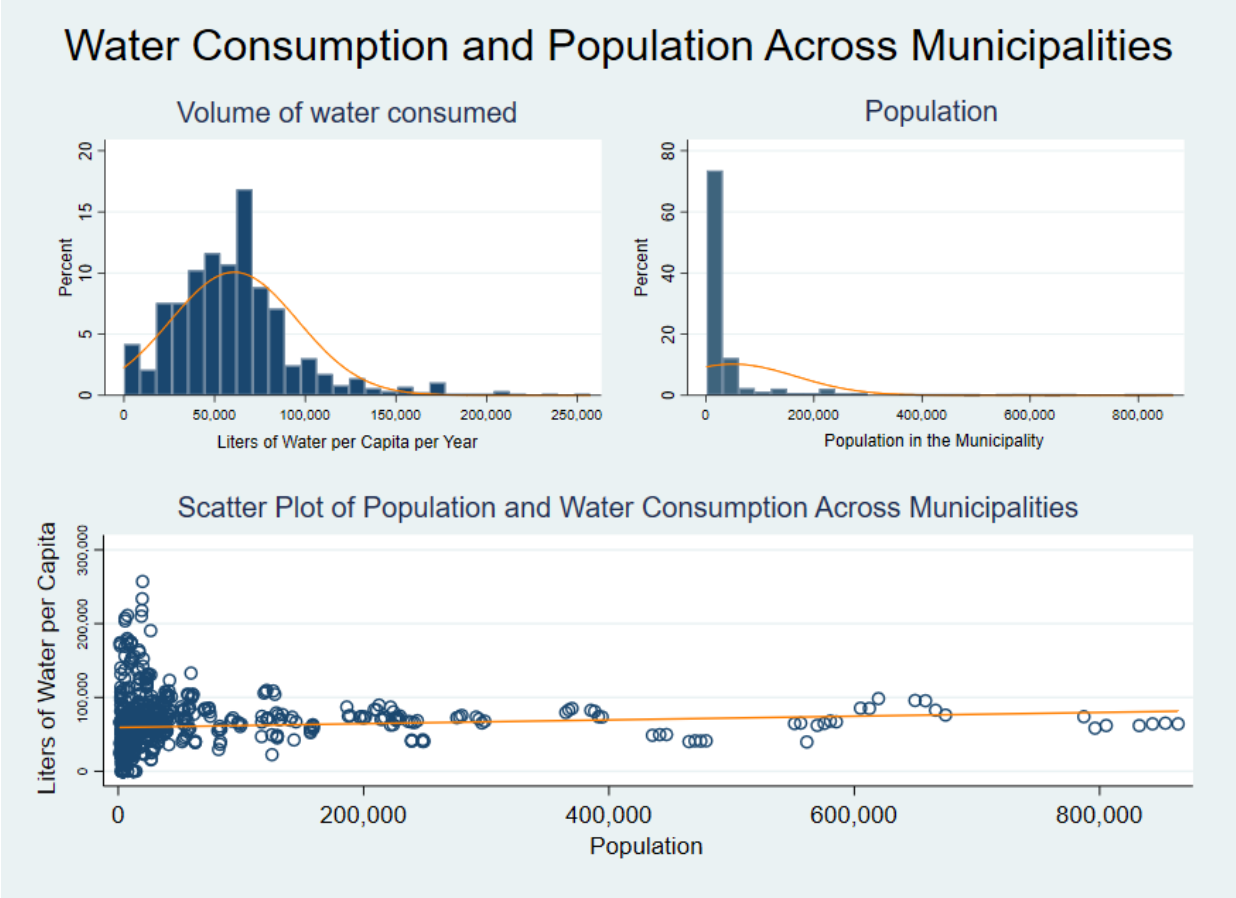


Figure 7 Distribution and scatterplot of *Volume of water consumed per capita* and *Population*

It is important to notice that 2.5% of sample data present *Volume of water consumed* equals to 0 L/capita. Appendix I list such municipalities, that account for 14 municipalities in different years of sampled data. Most municipalities are classified as rural and population size is relatively small - maximum population size is less than 14,500. Those municipalities may not have a centralized system of water supply, and residents may rely on individual wells. Another possibility is that the municipal government did not have the capacity to provide accurate information to the SNIS database. Moreover, another 10% of our sampled data does not have any information on *Volume of water consumed per capita*.

Analyzing *Average water tariff*, most of tariff practiced range between BRL 0.00 and BRL 3.00 per 1,000L of water consumed, with only a few municipalities having a charge over BRL 5.00 per 1,000L consumed. Figure 8 shows the *Average Water Tariff* and *Volume of water consumed* across different types of municipalities (urban, intermediate, rural) located in the recharge areas

of the Guarani Aquifer. *Average Water Tariff* does not vary substantially across different types of municipalities, as most of *Average Water Tariff* are concentrated between BRL 0.00 and BRL 2.00, independently from the type of municipality. This may indicate that the quantity of water consumed is not a very important determinant in the definition of *Water Tariff*, but factors such as cost of water production and distribution to properties. Another possible indication is that *Water Tariff* is not substantially used to rationalize water consumption, as *Water Tariff* would have to be larger with the increase of water consumption for the data to indicate such use. Figure 8 also shows the *Average Water Tariff* over the years across municipalities situated in the recharge areas of the Guarani Aquifer. The positive trend line shows an increase in *Water Tariff* over the years, but there is still a large concentration of *Water Tariff* bellow BRL 2.00 / 1,000L.

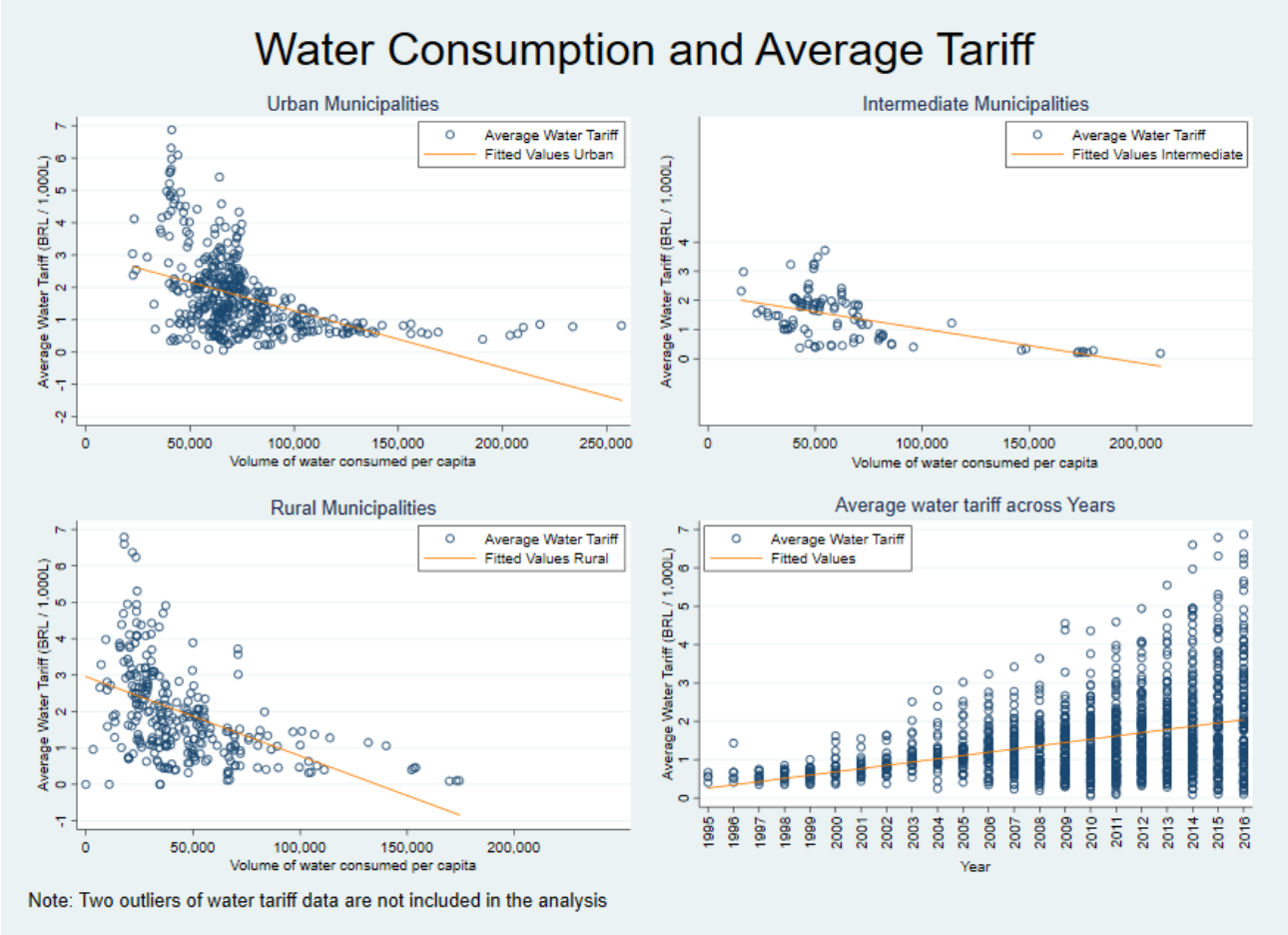


Figure 8. Scatterplot of *Average Water Tariff* and *Volume of water consumed per capita* across different types of municipalities (urban, intermediate, rural), the scatterplot of *Average Water Tariff* and *Year*

In terms of how *Water Tariff* is implemented in different types of municipalities and in different states, Figure 9 shows that rural municipalities tend to have higher water tariffs as almost 75% of those municipalities have water tariff above BRL 1.23/m^3, compared to 50% of municipalities

classified as urban or intermediate. It is also interesting to see that rural municipalities also tend to have the lowest water consumption per capita, compared to the other groups. Figure 9 also shows that most municipalities situated in the recharge areas of the Guarani Aquifer in the states of Santa Catarina (SC), Paraná (PR), Rio Grande do Sul (RS), and Mato Grosso do Sul (MS) present larger charges, as over 50% of the municipalities in those states present *Average Water Tariff* over BRL 1.50 / 1,000L. It is also worth mentioning that municipalities in the states of Paraná (PR), and Goiás (GO) have the highest minimum tariffs in the sample.

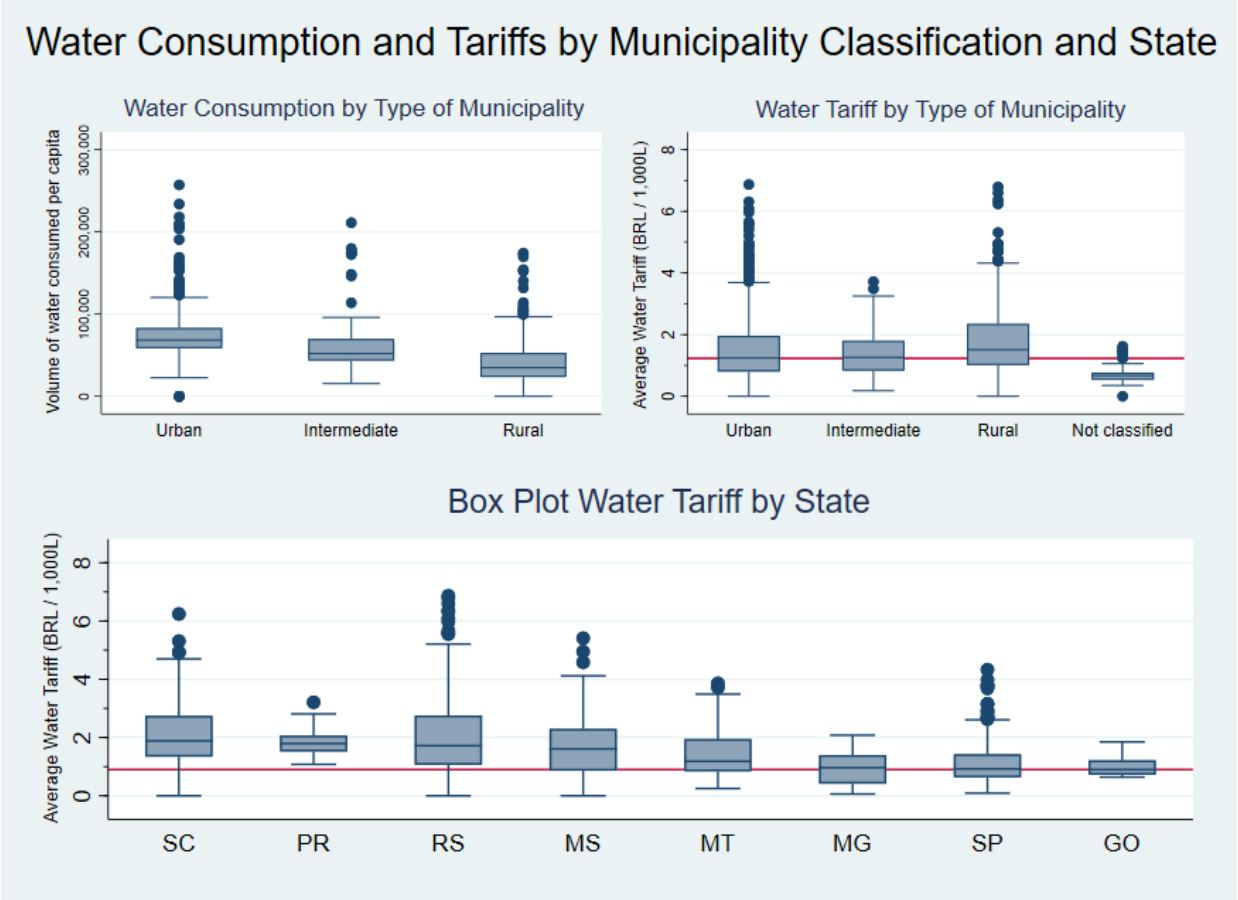


Figure 9. Boxplot of *Average Water Tariff* across different types of municipality and states.

Regression Analysis

A multiple regression analysis is the best method to analyze water price sensitivity across municipalities situated in the recharge areas of the Guarani Aquifer. Multiple regression analyzes how the dependent variable relates to a number of independent variables. For the analysis, the case-study seeks to understand how water consumption per capita (*Volume of water consumed per capita)* is related to the water tariff practiced in the municipality (*Average*

water tariff), controlling for other variables that may drive water consumption in the municipality, such as:

- how water consumption has changed over the years (*Year*);
- how it varies with the change in population size *(Population*); and
- if it is influenced by the economic output of the municipality (*GDP per Capita).*

One of the preconditions of regression analysis is that the dependent variable presents a normal distribution. However, the dependent variable *Volume of water consumed per capita* does not have a normal distribution, being positively skewed. One possibility for making the sample become normally distributed is to perform a log transformation. However, this attempt was unsuccessful as the distribution was still skewed (see Appendix I for more details).

In order to overcome such issue, Bootstrap Regression analysis was used. Bootstrap Regression does not assume that the dependent variable is normally distributed. Through Bootstrap, the data is resampled 1000 times to provide data-based estimates for standard errors and tests. The results of the regression model are presented in Table 3. Appendix I present more details on the results of the regression analysis.

Table 3: Regression Model 1 of *Volume of water consumed per capita* on *Average water tariff*, *Population*, *Year*, and GDP per Capita, with bootstrapped standard errors and tests. Regression Model 2 of *Volume of water consumed per capita* on *Average water tariff*, with bootstrapped standard errors and tests.

Predictor	Bootstrap Model 1	Bootstrap Model 2
Year	2511.129***	
Average water tariff (per year)	-13691.51***	-10,875.65***
Population	.056***	
GDP per Capita	.207*	
Constant	-4976448	82,580.32
R-squared	0.255	0.176

***p < 0.05; **p < 0.01; ***p < 0.001**

All the independent variables in the models are statistically significant. In Model 1, the positive coefficients of *Year*, *Population*, and *GDP per Capita* indicate that water consumption tend to increase over the years, as well as when population and economic output from the municipality increases. However, controlling for the other variables in Model 1, there is a negative association with *Average water tariff (Tariffm3)* (β^{hat}=-13,691.51; p<.001), meaning that water consumption tends to decrease as water tariff increases. Finally, the model is evaluated as explaining 25.5% (r-squared = 0.255) of the variability in *Volume of water consumed per capita.* In Model 2, the association of water consumption with tariff is verified without any other factor. The result of Model 2 points to similar negative association between both variables, where *Average water tariff (Tariffm3)* alone is capable of influencing 17% (r-squared = 0.176) of water consumption.

Two important conclusions can be stressed from such results. The first conclusion is that water consumers across the municipalities situated in the recharge areas of the Guarani Aquifer may be price sensitive to water, so policies that use price signals may be effective. The second important conclusion is that, because the model does not explain much of the variability in water consumption, other factors may be driving water consumption.

Estimating an accurate price elasticity for water demand is a complex task due to the significant number of factors that may explain the demand for water (Espey, Espey and Shaw, 1997, p. 1370). Therefore, this price sensitivity analysis had the intention to indicate that the demand for water across municipalities in the areas of recharge and discharge of the Guarani Aquifer are sensitive to price, not to accurately define the price elasticity of water demand to the Aquifer.

Now that the indication of water demand is confirmed to be sensitive to price, the case-study will turn to the literature that accurately found price elasticity for water. The accurate price elasticities will be used to create an example of the Pigouvian Taxation to the case study, and speculate over the implications of a Cap-and-Trade system in the following sections.

Water Price Elasticity

Since the 1960s, there has been efforts to estimate demand for water but, due to its multiple uses, estimates of its price elasticity vary significantly (Espey et al, 1997, p.1369; Reynaud, 2015, p. 3). Water demand may be affected by region of the world, season, climate conditions, demographic characteristics (income, population size, household size, consumers' ages), size of properties, energy price, whether water use is metered, prices charged and the structure of water pricing, to name a few factors (Espey et al, 1997, p. 1370; (Dalhuisen *et al.*, 2003, p. 292); Reynaud, 2015, p. 3). The result is the definition of different demand elasticities depending on the water use, such as residential, agriculture, and industry, for example (Espey et al, 1997, p. 1370).

The price elasticity estimates for residential water demand in the United States range from -3.33 to -0.02, with about 90% of the estimates ranging between -0.75 and 0 (Espey et al, 1997, p. 1370). Similar results are found across the European Union, where price elasticity of household water demand estimates range from -1.20 to 0.00, and most of elasticities typically varying between -0.5 and -0.1 (Reynaud, 2015, p. 21).

Analyzes of household water demand in developing countries are more difficult to assess because conditions of water access often vary across households in terms of sources, characteristics and level of services (Nauges and Whittington, 2010, p. 264). Research conducted by Nauges and Whittington (2010, p. 283) on 14 countries across Central America, Africa and Asia point that price elasticity estimates of residential water demand range from -2.1 to -0.06, with most estimates varying between -0.6 and -0.3. Studying the basins of Paraiba do Sul and Guandu, in Brazil, Garrido (2018, p. 200), calculated the price-elasticities for the different water

uses: urban supply (|0.16|), industrial supply (|1.07|), hydroelectric generation (|0.14|), rural supply (|0.85|), urban water waste dilution (|0.28|), industrial water waste dilution (|0.16|).

There are different types of urban water supply and sanitation operators in Brazil – state, municipal, or private companies - that may or may not be under a tariff regime for the service. Recent research points that services provision that have water tariff tend to promote a more rational use of water, however, in 2013, roughly 15% of all urban supply operators in Brazil did not charge or charged very little tariff for urban supply of water and sanitation (Fonseca and Gabriel, 2015, pp. 220).

Fonseca and Gabriel (2015) conducted a comparative research between urban operators that charged less than BRL 0.5/m^3 and operators that charged over BRL 0.5/m^3, in terms of service rate, consumption per capita, distribution loss, and quality of water, across 5178 municipalities for the year of 2010. The study concluded that water tariffs influenced operational indicator and the quality of services. Operators that charged over BRL 0.5/m^3 tended to induce a reduction in water consumption. Operators that charged less than BRL 0.5/m^3 had median consumption of 192,6 L, whereas operators that charged over BRL 0.5/m^3 tend had median consumption of 116,5 L (Fonseca and Gabriel, 2015, pp. 223).

OECD's study also points that the introduction of water charges has pushed a few water users to decrease water allowances request as a way to reduce costs. However, in most cases, water charges are not driving water demand because the charge is relatively low and it faces resistance to increase their values (Ostrensky and Garcia, 2017, p. 14-15; ANA, 2014, p. 41, 70; OECD, 2015, p. 203). A survey on the impact of water charge on federal watersheds concluded that water users see the mechanism as potentially inducing more rational use, but most users also declared that water charge introduction had not pushed them to make substantial changes yet (Ostrensky and Garcia, 2017, p. 17; ANA, 2014, p. 70).

A different approach to demonstrate the effect of water charge across economic agents was presented by Ostrensky and Garcia (2017) in studying the impact of water charge implementation in the Alto Iguaçu Basin across the industrial sector. The authors studied the importance of water availability and its financial impact by calculating the equivalent monetary output per cubic meter of water used. Based on their results, chemical industries produced BRL 49.00 per m^3 of water, whereas heavy vehicles industries were able to generate an equivalent of BRL 19,833.00 per m^3 of water (Ostrensky and Garcia, 2017, p. 16). The authors concluded that industries that are more water-intensive tend to be more impacted by water charge, than industries that are not as dependent on water.

Ultimately, despite the regional, economic, and demographic differences, it is possible to conclude that demand for water tends to be inelastic, generally ranging between -0.5 and -0.1. This implies that a hypothetical 10% increase in the price charged for water will affect consumption by 1% to 5%.

Pigouvian Taxation

The Pigouvian taxation is one of the main resources that a government can use as a remedy to negative externalities. In our case of the Guarani Aquifer, negative externalities are negative effects on the environment or other groups that are external to the present market equilibrium of water consumption from the Guarani. In other words, the present level of water consumption is creating costs to the environment that are not being accounted in the price of water consumption. Aquifer depletion's impact on water cycle, and the risk to future generations in not accessing water are a few examples of those externalities that may not be currently accounted in the actual regime of water charge.

If all costs of water consumption are accounted, including the negative externalities generated by water consumption, the market will be operating at an efficient level. Thus, the Pigouvian taxation is a corrective taxation that internalizes in the price of a good, the externality created by the production or consumption of that good to the environment or other groups (Gruber, 2013).

To reach the optimal level of consumption and make the policy economically efficient, the rate of the Pigouvian taxation should be set at a price that equates the *marginal damage of depletion* and the *marginal cost for controlling that depletion* (Kolstad, 2000, p. 120). In other words, the Pigouvian tax should be set at a price where every additional unit of depletion will be equal to a corresponding unit of monetary value that accounts for that depletion.

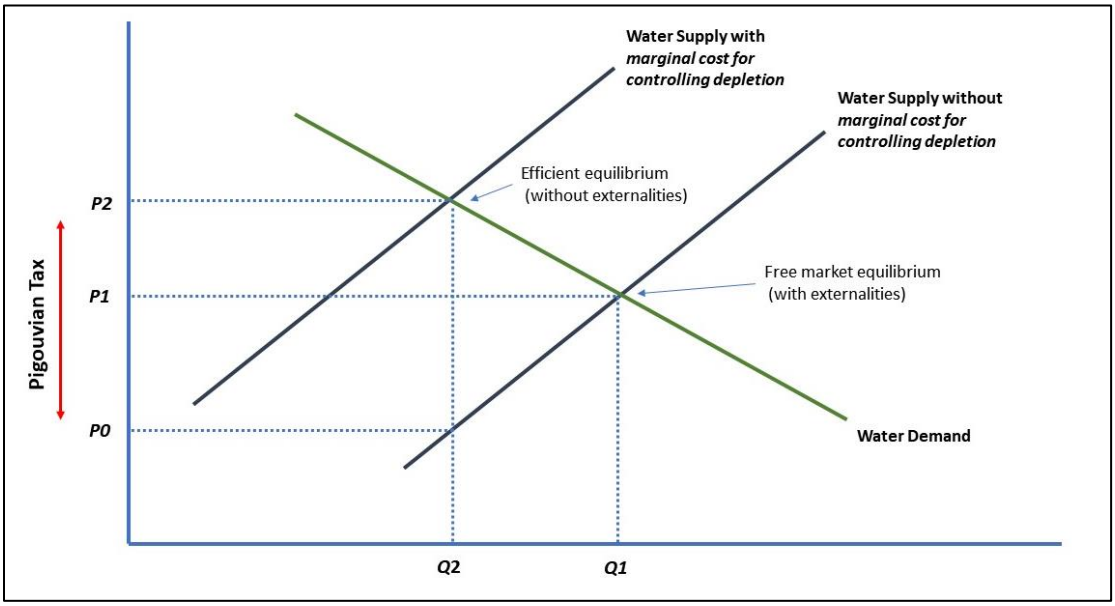


Figure 10. The Graph shows the effect of Pigouvian tax on market equilibrium. $\mathbf{Q_1}$ shows market equilibrium without Pigouvian Tax, where Private Marginal Cost (PMC) equates Private Marginal Benefit (PMB). $\mathbf{Q_2}$ shows market equilibrium with Pigouvian Tax, where Social Marginal Cost (SMC), which can be the *marginal cost for controlling that depletion,* equates Social Marginal Benefit (SMB), which can be the *marginal damage of depletion* in water consumption.

Ultimately, without a Pigouvian taxation to restrict consumption, the price of depletion that the consumer will have to pay is zero (Kolstad, 2000, p. 153). In this situation, the market is not operating at its efficient level, which will become evident by the aquifer depletion, environmental impact, and the lack of access to clean water by future generations. With the Pigouvian tax, a price for the depletion will be implemented at the final price of water that market agents consume, altering the market equilibrium to a more efficient level of water consumption (Kolstad, 2000, p. 119). At a more efficient level of water consumption, the environmental impact and lack of access to quality water will be avoided.

Finally, the tax will be paid by the consumer to the government per unit of depletion equivalent to the aggregate marginal damage caused with the objective of bringing the market to its efficient level (Kolstad, 2000, p. 118).

As described before, an aquifer can be depleted if water consumption supersedes the aquifer's recharge capacity. In the case of the Guarani aquifer, the creation of this taxation would have the aim of accurately internalizing the damage generated by the depletion to the aquifer's resources in the price of water consumption. Therefore, a Pigouvian tax should be set at a price that induces consumption at the aquifer's recharge capacity, so the market operates at its efficient level. Figure 11 exemplifies the Pigouvian Tax effect on water charge in the Guarani.

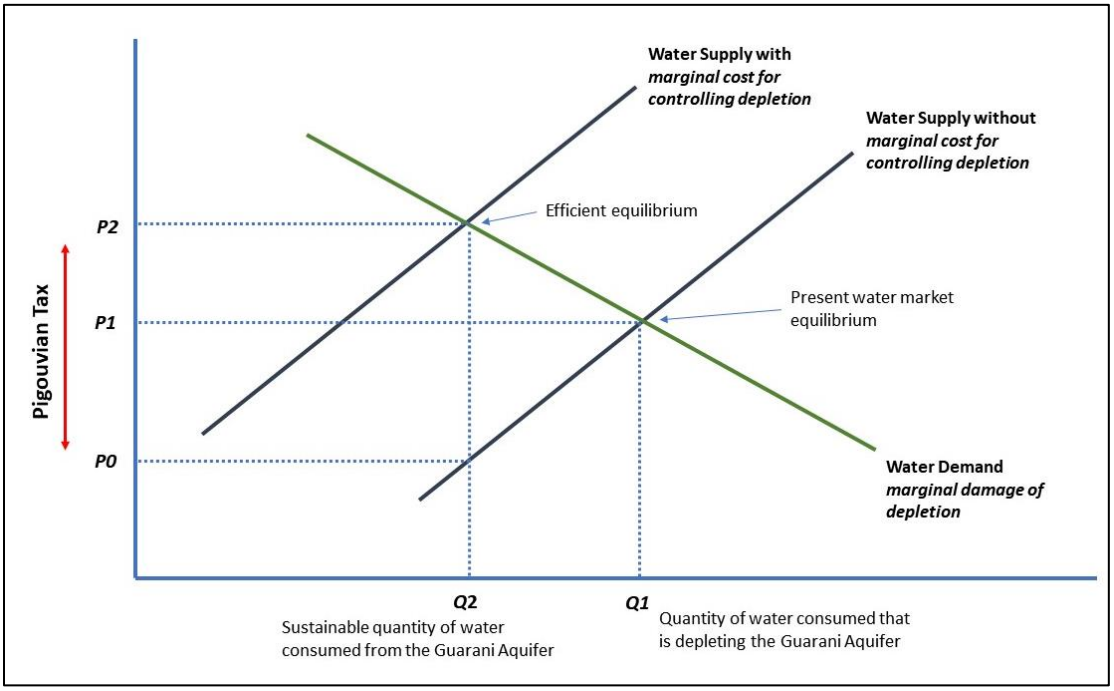


Figure 11. The Graph shows the effect of Pigouvian tax on water charge in the Guarani Aquifer. $\mathbf{Q_1}$ shows market equilibrium without Pigouvian Tax, where consumers are not being charged for the full costs of water consumption and depletion to the aquifer. $\mathbf{Q_2}$ shows market equilibrium with Pigouvian Tax, where the cost for the aquifer depletion is accounted and consumers are pushed to reduce consumption with the increase in price. At $\mathbf{Q_2}$, aquifer depletion and its additional effects are avoided.

Today, most of the recharge areas of the Guarani do not have a water charge implemented (see Figure 5). In the areas where the policy of water charge is implemented, evidence shows that the charge is not set at the sustainable supply of water (the aquifer's recharge capacity). Currently, water charge uses criteria such as the average operational costs of water exploration and distribution, and there are strong indications that such charge is not being effective in curbing the aquifer depletion. Redefining water charge to include a Pigouvian tax will signal consumers the full cost of water consumption from the Guarani aquifer at a level that avoids depletion. Not charging for the proper damage that water consumption causes to the aquifer, results in an inefficient level of water consumption, which may be inducing the Guarani's depletion.

Besides bringing the market to an efficient level of water consumption, the Pigouvian tax has a second important element which is to equate the marginal cost of abatement across all water consumers. Equating every additional unit cost of reducing depletion across all actors is also known as the equimarginal principle. Satisfying the equimarginal principle is essential to achieve cost effectiveness that is the minimum cost of achieving the desired reduction in environmental problem (Kolstad, 2000, p. 146; Berck and Helfand, 2011, p. 298). With the Pigouvian tax, each user has incentives to take any conservation action that cost less than the tax. The most expensive of those actions, which determines the marginal cost, will be equal to the tax. In the end, all users have the same marginal cost because each unit of water will be charged the same, which satisfies the equimarginal principle.

As an example, Figure 12 shows the hypothetical situation of a Pigouvian Tax of $0.5/Liter of Water and the effects on large farms and industrial sector. This example shows the equimarginal principle will hold because both groups will have the same marginal cost of abatement, even though they will have different incentives to take actions to reduce water consumption. Large farms have the incentive to take several actions to avoid the Pigouvian tax such as fixing leaks, change part of the crop, and use different seeds. The marginal cost of taking those actions are less than paying the tax. However, the last action they have the incentive to take to reduce water use and therefore, avoid paying the tax, would be to change the irrigation system. In this example, the marginal cost for large farms to take such action is equal to the tax. Industries, on the other hand, have the incentive to fix leaks in their pipes because the marginal cost of such action is less than paying the tax. However, changing the plant's water system have the same marginal cost as the tax. From this example, the equimarginal principle holds because the last action those two water users could do to avoid paying the tax marginally cost the same, even though those are different initiatives.

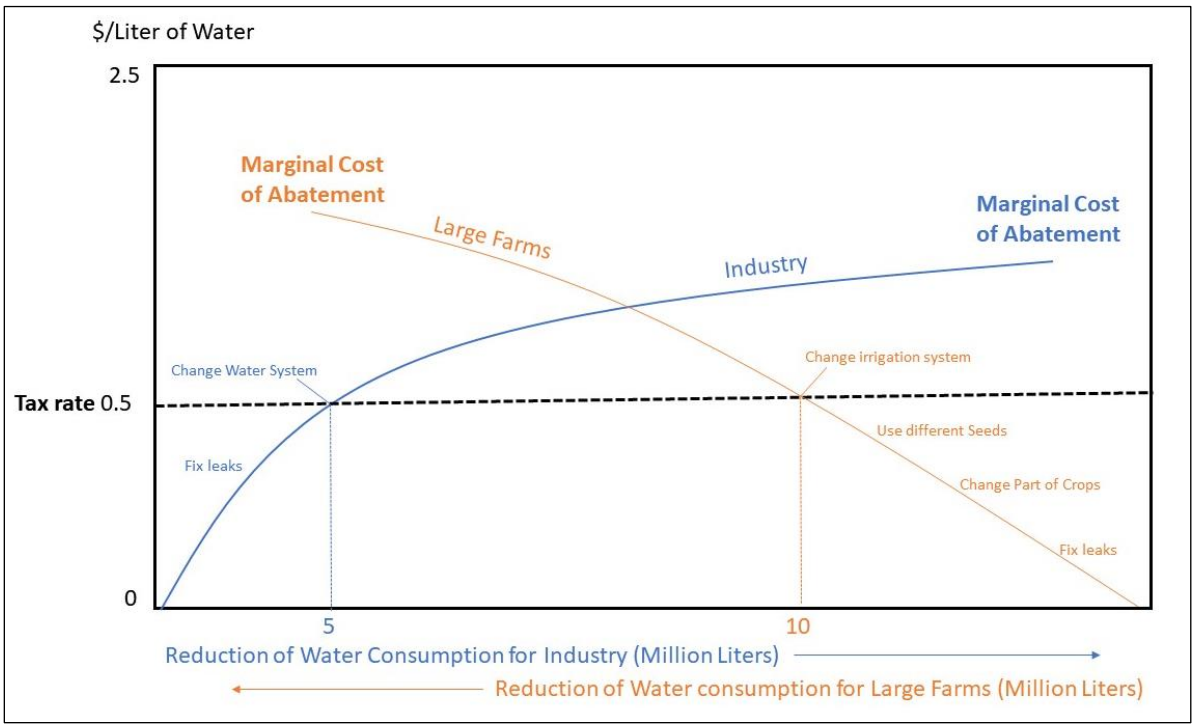


Figure 12. shows the effect of the equimarginal principle. Even though different water users may have to take different steps to adequate to new water charge, the tax rate will be the same for each unit of water consumed.

Besides the indications of positive effects for implementing a Pigouvian tax, there are a few elements that need to be consider to avoid distortions and garner support for implementation. When implementing a Pigouvian tax, it is important to consider any price regime that may affect the good that is being taxed. Regimes of subsidies, price control, or even other taxes can distort the price signal the Pigouvian tax is intended to signal (Qayum *et al.*, 2016, p. 7).

With the funds generated by the Pigouvian tax, programs to expand sewage treatment, environmental preservation, or finance new technologies that use less water could be implemented. Moreover, the Pigouvian tax will possibly have a negative effect on economic redistribution as every market agent has to pay the same rate, so low-income agents will use a higher proportion of their income to pay the tax (Oh and Svendsen, 2015, p. 146). As a way to reduce the economic burden on groups that may be more penalized by the policy, the revenue gains from the Pigouvian tax could be used to create a redistribution program to alleviate the negative impacts on those groups, or to reduce the rate of other taxes, such as taxes on labor, capital and savings (Oh and Svendsen, 2015, p. 146).

Despite economic indication that market-based approaches may be effective, political friction may arise. Probably the major resistance to environmental fiscal reforms is the assumption that it would slow down economic growth (Qayum et al, 2016, p. 9). Public officials must be willing to take political risks to defend sustainable economic growth in the agenda and local residents

have to be aware of the environmental problem and how market base approaches can be useful policy options (Oh and Svendsen, 2015, p. 143).

Legislation change needed

Creating a Pigouvian tax for water resources would not need major changes in the legislation already in place in Brazil. The National Water Resources Plan already determines that water is a public good endowed with economic value. Moreover, the instruments of allowance definition and charge for water use allow economic principles to be used for managing such resource. Probably, the main change would be to include the depletion caused by anthropogenic consumption as a parameter of the charge methodology, that would adjust the price charged to a more efficient level.

Finker et al (2015) conducted a comprehensive study of the water charge methodology used in five large Basin Committees across Brazil (Paraiba do Sul, Piracicaba, Capivari e Jundiai, Sao Francisco, and Doce) and the State of Ceara. The study found that all methodologies of charge had the same structure, even though there were changes in the source of quantitative information used – i.e. one Committee only charged users for the exact amount of water consumed and not for the usual practice of group consumption levels -, as well as a few naming differences (Finker et al, 2015, pp. 38). The methodologies of charge included variables and criteria such as the volume withdrawn according to the allowance; volume withdrawn according to the measurement, annual volume withdrawn, sewage discharge, base charge, coefficient according to nature of allowance, coefficient according to good practices of use and conservation, among others.

However, based on the parameters identified for water charge across the Basin Committees (Finker et al, 2015), as well as the ones listed in Resolution 48th/2005, there is no specific mention to depletion or other externality that the anthropogenic use of water resources may create to water bodies and the environment.

It can be argued that the externality is accounted in the definition of the allowance right of use, as it is defined by considering the conservation of water resources. However, Finker et al (2015, p. 46) present strong indications that the financial revenues from water charge were not enough to face the full costs to recuperate depleted areas, representing about 13% of the funds needed for investments. In this sense, it can be argued that there is a need to include in the charge methodology a criterion of externality that would be capable to clearly indicate the need for preservation of the water resource. This new parameter would internalize in the price of the tariff the social cost of water consumption, defined as the signal to sustainable level of consumption of the Guarani Aquifer's water at recharge levels.

This change should probably occur in Resolution 48th/2005, which defines the parameters that guide water charge.

In the National Water Resources Council, a new Resolution proposal is dispatched to Thematical Chambers that are responsible for the subject. Deliberation requires a minimum of 40% presence, and simple majority vote, in which the result will represent the consensual position of the Chamber to deliberation in the Plenary of the Council. In the Plenary of the Council, a Resolution may be deliberated with the absolute majority presence and simple majority vote.

The change of Resolution 48th/2005 would have to be followed by a revision of the water charge parameters across Basin Committees and state Water Agencies that have domains over the recharge areas of the Guarani Aquifer.

The case of Ribeirao Preto

As a way to make this approach more illustrative, an exemplary model was created using the city of Ribeirao Preto (SP). The aim of the model will be to define a hypothetical tax that could be applied to our case to influence market agents to consume at the efficient level. The detailed calculations can be seen at Appendix II.

Ribeirao Preto is one of the largest cities situated in the areas of recharge and discharge of the Guarani Aquifer, with an estimated population of over 670,000 residents. The city solely relies on the Guarani Aquifer for water supply. Unfortunately, Ribeirao Preto's water consumption is estimated to be three times higher than the Aquifer's recharge capacity which is causing the aquifer depletion and soil downgrade (Villar and Ribeiro, 2009).

Historical data indicates that residents from Ribeirao Preto are price sensitive to the tariff applied by the town. In other words, an increase of the tariff have generated decrease in water consumption, despite population growth. Based on the estimates of price sensitivity, the estimated tariff practiced, and achieving the goal of curbing consumption levels to the aquifer's recharge ability, the average water tariff would have to increase from BRL 2.39/m^3 to, at least, BRL 16.71/m^3 in Ribeirao Preto. Following the Pigouvian

theory, the tariff at BRL 16.71/ m^3 internalizes the externality created by depletion and indicates to market agents a more efficient level of consumption in terms of the Aquifer's preservation.

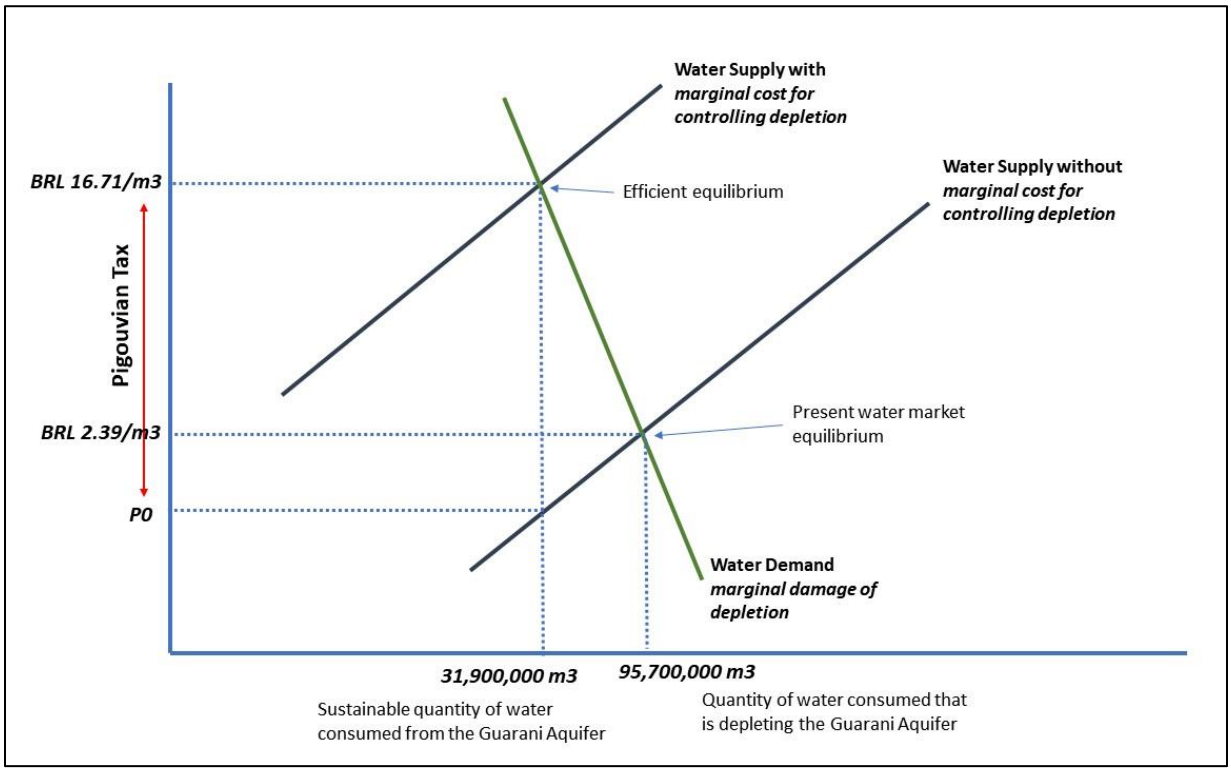


Figure 13. Water consumption with the introduction of a Pigouvian tax. **Q_1,** Actual level of water consumption (95,700,000 m^3); **Q_2**, Ideal level of consumption based on the Aquifer's recharge levels (31,900,000 m^3); **P_1,** Average water tariff practiced (BRL 2.39/ m^3); **P_2,** Water tariff with Pigouvian tax that would incentivize efficient consumption level (BRL 16.71/ m^3).

Cap-and-Trade

Cap-and-Trade is a marketable allowance system in which a set number of permits to water use are distributed to market agents, along with the right to buy and sell these permits (Kolstad, 2000, p. 160; Berck and Helfand, 2011, p. 292). Through this system, market agents can only consume the amount of water designated by their permits.

The idea of a Cap and Trade System derives from Coase's conjecture, which theorizes that the definition of clear property rights and a legal system that functions well, will generate an efficient outcome (Munger, 2000); Goulder, 2013; Gruber, 2013). In a Cap and Trade system, a regulatory authority defines a maximum level of water consumption allowed for all actors covered by the regulatory program, distributes the allowances through auction or free provision, and creates a trading system for allowances (Goulder, 2013). Figure 14 shows the effect of creating a Cap-and-Trade system in the market.

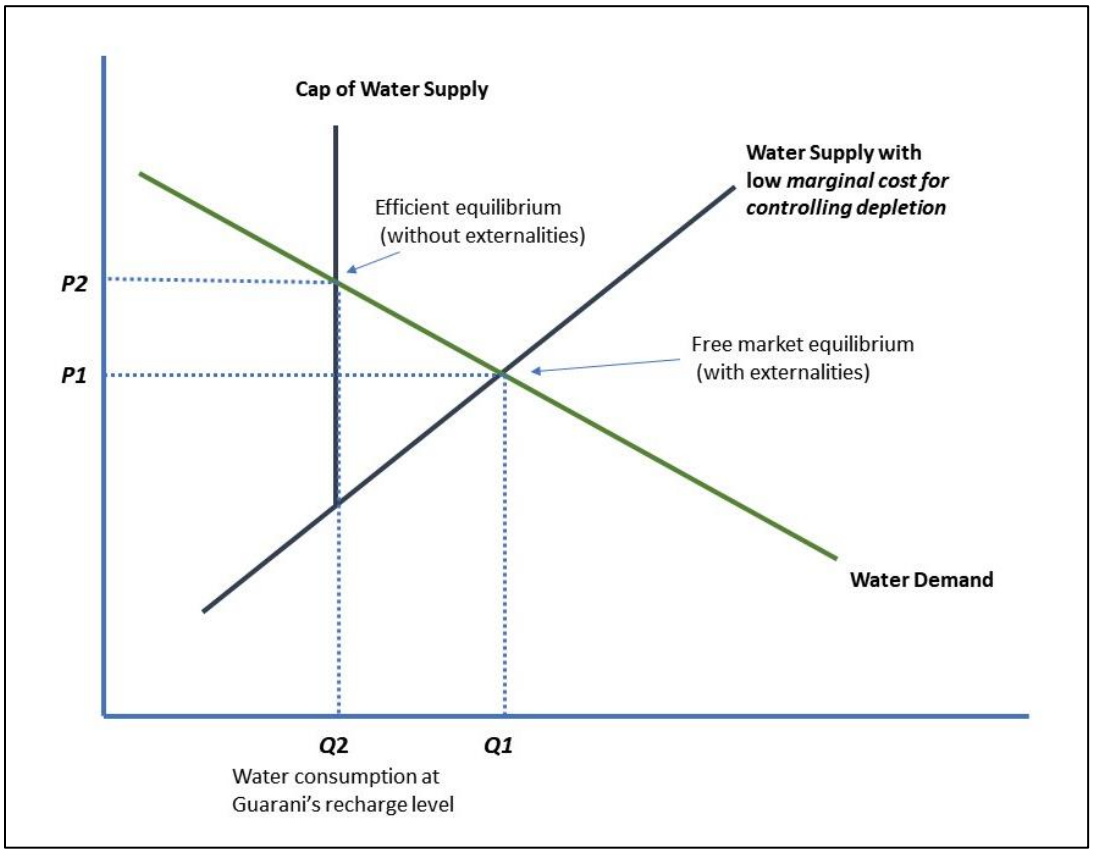


Figure 14. The Graph shows the effect of Cap-and-Trade on water consumption in the Guarani Aquifer. Q_1 shows market equilibrium without Cap-and-Trade, where water consumption is exceeding the aquifer's recharge capacity. Q_2 shows market equilibrium with Cap-and-Trade, where water consumption is caped at the aquifer's recharge capacity, and consumers are pushed to adapt.

The aim of the Cap-and-Trade is to be a more cost-effective policy to decrease depletion and wasteful consumption in which the receptors of permits will negotiate between each other water use permits. Permit receptors that have a high opportunity cost – that find it hard to meet the amount allowed for consumption - can negotiate allowances from those that have a lower opportunity cost for reducing their consumption depletion– or that are consuming water below their allowance levels. The intention is to increase cost-effectiveness of the regulation by encouraging firms and farms to adopt technological and/or managerial innovations to reduce the amount of water consumption, enabling them to sell or lease their allowances to others that cannot meet the targets (Goulder, 2013; Gruber, 2013).

> "The primary goal of trading is to reallocate water from low to high valued uses to promote efficiency gains in the sector" (Brooks and Harris, 2008), p. 393)

In the case of the Guarani Aquifer, the efficient consumption level will be determined by the total annual recharge capacity of the aquifer, following the *Concept of Available Surface and Ground Water Resources* (Governo do Estado de São Paulo, 2015, p.17). The regulatory bodies

in each state would define a fixed amount of allowances to be distributed across market agents, and implement a mechanism for those agents to trade their allowances.

Besides bringing the market to an efficient level of water consumption, the Cap-and-Trade also has the intention to equate the marginal cost of abatement across all water consumers, known as the equimarginal principle. When water users trade their allowances of water use, the price of the allowance determined by the market signals all users of the opportunity cost of using water from the aquifer. The equimarginal principle will hold as all agents will have the same marginal cost to purchase an allowance of water use and the policy will achieve depletion reduction at the lowest possible cost (Kolstad, 2000, p. 146).

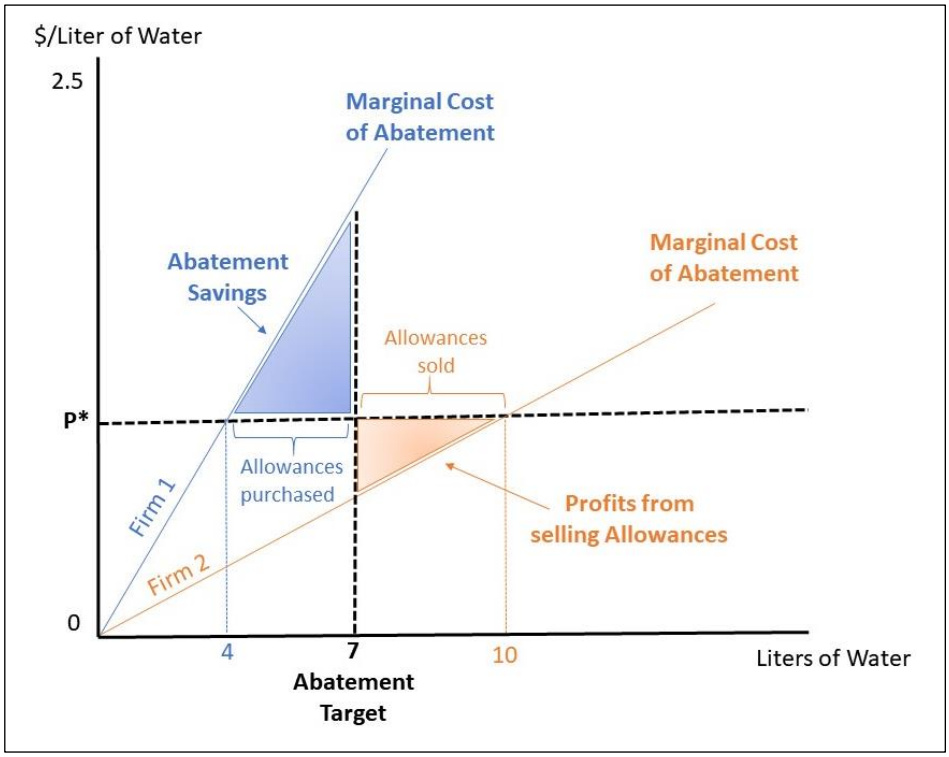


Figure 15. shows the equimarginal principle effect in a Cap-and-Trade system.

As an example, Figure 15 shows the hypothetical situation of an allowances trade for water use between two firms. The abatement target was set by the regulatory body at 7L and therefore grants each firm 7 permits. Firms 1 and 2 have different marginal cost of abatement curves. The abatement cost for Firm 2 is lower than for Firm 1. In this situation, Firm 1 might rather purchase a permit than pay higher costs to abate. If Firm 1 recognizes that its marginal abatement cost is higher than the marginal abatement cost of Firm 2, it could propose a trade. In this situation, the marginal cost of abatement will signal Firm 1 the opportunity to reduce water use to sell exceeding permits to Firm 2; and signal Firm 2 the opportunity to save by purchasing permits from Firm 1. The equimarginal principle will hold because the marginal cost of abatement is the same for both firms.

However, there are key elements in the system that may restrict overall efficiency if not accounted and minimized during the policy design and implementation. These elements include regulatory limitations, information asymmetries, lack of entitlement security, and unclear property rights (Brooks and Harris, 2008, p. 393). In this sense, it could be beneficial that the regulatory system is defined with periodic review plans to monitor, evaluate, and change identified deficiencies. In terms of information, it is key that the system be transparent, with instantaneous information on pricing, market agents, trade, as well as environmental and economic forecasts, so all agents have the ability to evaluate the market and make the most informed decision, avoiding information asymmetries.

As a basic precondition for the system to work, it is important that the distribution of allowances be efficient and the cost associated with trading allowances be the lowest possible, so the policy does not incur in inefficiencies (Kolstad, 2000, p. 113). The main challenge with cap-and-trade is the initial distribution of allowances, which can be auctioned or distributed by the regulator body at no charge to market agents (Kolstad, 2000, p. 167). If auctioned, market agents will incur significant initial cost which can pose strong political opposition to the policy (Kolstad, 2000, p. 167). If distributed at no charge, any rule for distribution may create opposition as some agents may be benefited more than others, as well as the fact that new entrants will face comparatively more costs than older agents (Kolstad, 2000, p. 168).

The distribution of rights to deplete is a matter of equity as that right is valuable (Kolstad, 2000, p. 100). In this sense, vesting an agent with a right to use water will, in the long run, reduce the cost of that agent compared to an agent that did not receive the same right (Kolstad, 2000, p. 105). Therefore, strong political opposition can be seen if the distribution process does not take this factor into consideration and cannot create the least possible contentious structure.

Policymakers also need to be aware of the risk of market thinness and transaction costs. If the market has few actors there is a risk that transactions may be infrequent, unintentionally increasing costs and making the system economically inefficient (Kolstad, 2000, p. 170). Permit trade creates several transaction costs for which policymakers have to find solutions, involving trade information, bargaining and decision-making (Kolstad, 2000, p. 170). Market monitoring and enforcement also incur in costs to the regulatory body that needs to be minimized (Kolstad, 2000, p. 170).

Entitlement security is critical to reach and will probably be based on the confidence of the agents in the system. This is due to the fact that allocations will probably change over time and with seasons, because they will be conditioned by environmental forecast. In this sense, it is imperative that environmental monitoring agencies use sound and transparent methodology, communicating the market in a clear and timely manner. Moreover, as mentioned before, the system of allocation needs to be transparent and fair. There will be a need to create avenues for contestation and dispute, which should be solved with consistency and promptness.

Ultimately, while water trading helps to allocate a scarce resource efficiently by re-allocating water to the highest value users, efficiency might be limited if trading rules and other market interventions lead to inflexibilities and limit trading activities (Burdack, Biewald and Lotze-campen, 2014), p. 325).

Legislation change needed

The Australian water market system is considered one of the most successful cap-and-trade systems in place. Some of its principles can be used as a basis for Brazil, if we were to create such system, because it also considers water as a public good. McKay (2011, pp. 618) described that the Australian Water Act 2007 that created the Australian water market system was guided by the principles of precaution, inter-generational equity, integration of long-term and short-term considerations, ecological integrity, and the promotion of valuation, pricing and incentive mechanisms. All of those guiding principles are present in the Brazilian legislation structure in regard to natural resources. However, creating a Cap-and-Trade for water resources would demand major changes in the legislation in place in Brazil.

First, the National Water Resources Plan would have to be changed through by a Federal Law to include water market as one other instrument of management.

A second change in the National Water Resources Plan would be changing the exception that water use considered negligible do not need an allowance would probably need to change, so as all water users need to have allowance to use water.

A third potential change could take place in the distribution of allowances. In the regulation in place, allowances are acquired through the regulatory body that has the domain over the water body in a “first come first served” base. In a cap-and-trade system, allowances are usually distributed by auction or by free allocation defined at a cap to the efficient level of consumption. For the case of the Guarani Aquifer, the present distribution of allowances for water use could be taken as the distribution arrangement. An equal reduction across all allowance holders could be implemented to the efficient level of water consumption from the Guarani, and the tradable mechanism implemented.

The fourth change relates to the regulatory body that would oversee the monitoring of the water body and manage the trade system of allowances. Multiple possibilities exist for these elements. Maybe the most logical one is that the State Water Agencies that issue allowances for water use would be responsible for managing the trade system, as States detain the domain over groundwater. Another option could be to make this a responsibility of State Basin Committees, where their respective Water Agencies would manage the trade system. Those two arrangements would probably imply that the Cap-and-Trade system would be fragmented across multiple areas, corresponding to the jurisdiction of the responsible forums. However, if

we this system were to be applied through the totality of each watershed, then probably new forums would have to be created with this aim.

There is a bill in the Brazilian Senate that has the aim of creating water market (Projeto de Lei do Senado n° 495, de 2017). The Bill mainly allows Basin Committees and State Water Agencies to create a water market for water bodies under their domain, transmitting to them the discretion and responsibility to regulate the system if implemented. It is a short proposal that simply makes water market one other instrument available in the country.

The dispatch of this bill defines deliberation by the Environmental Commission and the Constitutional Commission, and transmission to the Chamber of Deputies for revision, if approved. Therefore, according to its actual situation, it would not have to be deliberated in the Plenary of the Senate. Moreover, in the form that the Bill is defined – ordinary bill – it would only need a simple majority vote. Considering the large effects of creating the water market instrument in the National Water Resources Plan, it would be likely that one Senator propose a Request for it to be deliberated in the Plenary of the Senate. The requirements of deliberation – simple majority - could also be changed by a Senator Request.

A possible cap-and-trade model for the Guarani Aquifer

Perhaps a possible water market model to manage the Guarani Aquifer could be inspired by the Australian water-right trading market used in the Murray-Darling Basin. In Australia, water is considered a public good which allowed the Australian Government to define water use rights separately from land property rights (Burdack et al, 2014, p. 321). The Murray-Darling Basin water market have two distinct water rights: water access entitlements and water allocations (Burdack et al, 2014, p. 319). Water access entitlement define permanent access to a fraction of water from a specified consumptive pool, whereas water allocations are the seasonal rights to specific volume of water allocated to entitlements relative to the overall volume of water available for that season (Burdack et al, 2014, p. 320). The seasonal volume available are defined by the agency responsible for overseeing the sustainable water resources management in the Basin, the Murray-Darling Basin Authority (Burdack et al, 2014, p. 320).

> "The overall cap, regulating the [water] supply, is combined with water markets. Trading water rights leads to proper price signals and ensures an efficient water allocation." (Burdack et al, 2014, p. 321)

A possible adaptation to the Australian system to the case of the Guarani Aquifer could be the allocation of water access entitlement to each state that is part of the aquifer - following the Constitutional definition that groundwater are property of the states -, allowing them to manage the seasonal water allocations as a water market. The agency responsible for overseeing sustainable water resources management could be the Brazilian National Water Agency (ANA)

(Continue) A possible cap-and-trade model for the Guarani Aquifer

or a Guarani Aquifer Committee could be created, following the already existing system of Basin Committees in Brazil.

Moreover, the Australian system defines general allocations for sectors of the economy and limits inter-sectoral transfer of allowances (Brooks and Harris, 2008, p. 392). Inter-sectoral limitation for the Brazilian case could not be an applicable design as allocations are already defined in a decentralized and participatory system that account for the multiple uses and purposes of hydrological resources.

Adapting the Australian system, seasonal caps would be defined based on the expected recharge levels of the Aquifer by the agency and states could allocate water allowances among market agents that could trade among themselves. It is interesting to mention that the water market in the Murray-Darling Basin has several rules to avoid market failures, inefficiencies through speculation and state inequality (Burdack et al, 2014). A few examples that could be used for the Guarani Aquifer include: (1) The Agency has the highest water-planning powers to which states need to comply, in terms of cap definitions and trade rules; (2) Trade occurs through an internet platform to prevent time delay and uneven information between market agents; (3) Intermediaries such as water exchangers, or water brokers can be hired to facilitate trade, provide transactions and information services; (4) Participation in the water-trading market is

only possible for those who are able to demonstrate use for water, avoiding speculative interests; (5) Cap to inter-state water trade; and (6) Environmental institutions are able to purchase allowances with the aim of increasing water preservation to the environment.

Moreover, it is necessary to create avenues for conflict-resolution in the system. The Australian system offers informal and formal avenues for conflict-resolution in water markets, which are considered key to the success of the system (McKay, 2011). Informal avenues are mainly composed by community consultation and drafting the regional water plans, whereas formal avenues are composed by state courts specialized in environmental law.

Burdack et al (2014, p.323) evaluates that water trade provides incentives to market agents to improve water use efficiency through a production system that responds to the seasonal variability of water, signaled by the allowance price. As an example, high water allowance prices during dry years encourage farmers who cultivate irrigation-intensive annual crops to sell water rights to low-water-need crop farmers or industries, enabling the scarce resource to be allocated more efficiently, and possibly even allowing those farmers to generate more revenue than the profits that could have been gained by cultivating irrigation-intensive crops during a drought. Municipalities could also have a higher incentive to reduce water waste and improve efficiency by improving pipe networks and to improve consumers awareness of effective consumption, enabling them to also increase revenue through the water market.

Takeaways I

Up to this point, the case-study attempted to understand if market-based instruments could be more effective in managing the Guarani Aquifer and mitigate possible cases of overexploitation, compared to the present regulation. The analysis focused on two instruments to manage water use – allowances for water use and water charge - which are managed in a diffuse and, sometimes, confusing way.

As groundwater is defined as state's domain, the State Water Agencies across the Guarani are the entities responsible for the definition of allowances criteria and their issuance. Water charge is defined and applied by Basin Committees, which also apply the funds generated according to Basin's master plans. One important element that adds to the complexity of managing the Guarani is the fact that the geographic boundaries of water basins and the states do not coincide with the boundaries of the Guarani Aquifer. In this sense, there are multiple Basin Committees and State Water Agencies that have jurisdiction across the Guarani. Therefore, there are also multiple water charge and allowance instruments across the Guarani that can differ in implementation status, regulatory criteria, and charge price.

There are important deficiencies in the current regulatory system highlighted by this case-study. The present regulatory system grants water allowances following the order of request, not considering long-term objectives of the Basin's master plan, or criteria that could seek a more efficient allocation of water (OECD, 2015, p. 174-175). A second important criticism to the current allowance system is the current failure to adequately consider minimum volume flows needed by the environment to maintain stability (OECD, 2015, p. 186-187). There is also a need to make the allowance system adaptable to the effects of climate change, which will probably decrease Guarani's overall water availability, at the same time as water demand may increase (Projeto para a Proteção Ambiental e Desenvolvimento Sustentável do Sistema Aquífero Guarani, 2007, p. 37-39; OECD, 2015, p.185).

The main deficiency of the present water charge regulation lies in its price definition from a political agreement between the members of the Basin committees, and not by economic assessment of users' ability to pay and expected effects from price elasticity (Abers and Keck, 2013, p.94; OECD, 2015, p. 65; (Garrido, 2018, p.37). This deficiency in setting water charge prices makes its price a weak incentive for rational use of water, and consequently diminishes efficiency (Da Silveira and Sartori, 2017, p. 45; Ostrensky and Garcia, 2017, p. 17; ANA, 2014, p. 41; OECD, 2015, p. 65; Garrido, 2018, p.17).

Ultimately, the analysis of the present regulation concluded that the current system is not guided towards the efficient level of water consumption, which may negatively impact the environment and economic resources. As a way to improve efficiency of water allocation from the Guarani and mitigate the already apparent environmental impacts, the instruments of Pigouvian Tax and Cap-and-Trade could be possible policy solutions.

In the case of the Guarani Aquifer, the efficient consumption level should be determined by the total annual recharge capacity of the aquifer to avoid negative environmental impacts. The Pigouvian Tax would use price incentives, based on price elasticity, to induce such efficient level of water use. Cap-and-Trade would use a regulatory cap at the optimal level of Guarani's water use, and create a water market to allow water users to adapt to the cap.

This case-study posits that water charge should have the aim of accurately internalizing the damage generated by the depletion to the aquifer's resources in its price, not by simply setting a charge that would be agreed between Guarani's water users. In this case, water charge could be defined as a Pigouvian tax that should be set at a price that induces consumption at the aquifer's recharge capacity, based on the price elasticity of water. Water use at the Guarani's recharge level would not generate negative externalities to the environment, making the market operate at its efficient level.

A Cap-and-Trade could as well be a policy option to induce a more efficient water allocation than the current system. Through this system, water users would only consume the amount of water designated by their permits, caped at the aquifer's recharge capacity. This system would be able to improve water allocation by encouraging Guarani's users to evaluate their opportunity-cost for consuming water or trading their allowances with other users. In this system, there would not be negative impacts to the Guarani because the level of water consumption would be set at its recharge level, and the market would have the flexibility to adapt.

Compared to a Cap-and-Trade, a Pigouvian tax would probably be easier to implement because the enabling legislation is already in place, and this instrument would not make substantial changes from the current one. On the other hand, the Cap-and-Trade system can be more efficient to allocate water in situations of water crisis and guarantee water consumption at the cap level so as to protect the Guarani. With both policy options, it is hard to predict water prices to the final consumer, and how the implementation of those systems would actually affect short-term access to water. Either way, for any of those options to function properly - and even for the current system to function adequately - several elements need to improve, such as monitoring capacity, public understanding of the Guarani's situation, and the bureaucracy to spend the public funds generated, to name a few.

Public Perception

Despite theoretical indications that a given instrument might be effective, the choice for such instruments may be inherently political, which involves different actors and specific institutional systems (Jordan et al, 2011, p. 537). In political terms, actors' preferences can be shaped by multiple elements. Groups' ultimate goals, their level of commitment to a policy, their resources, their perception of what will constitute the practical use of the instrument defined, and their values and ideology are all elements that define preferences of policy designs (Jordan *et al.*, 2011).

An illustration of the political nature of environmental policy can be seen in the discussion of the definition of minimum water flows necessary to fulfill environmental needs, also known as environmental flows, in OECD's report on water governance in Brazil:

> "Critically, environmental flow assessments are ultimately an input to a socio-political process. While the natural sciences can provide information on what the implications will be for different parts of the environment of changing the flow regime, it is a socio-political decision as to what ecosystem services should be protected, and hence what environmental flows should be provided. […] Environmental flow studies are simply a tool to allow for informed decision making." (OECD, 2015, p. 188)

According to Abers and Keck (2013, p.3), new institutions emerge with changes in law and ideas that transform institutions and relationships between actors. Institutional change requires actors to navigate and influence complex systems of organizations and rules, where power is already distributed across multiple institutions. Often times, those institutions can have shared jurisdictions, which can create multiple paths for influence, also known as policy windows (Abers and Keck, 2013, p.3).

A policy window emerged with the idea of creating Basin Committees, when a new decision-making arena for governing Brazil's water resources was created (Abers and Keck, 2013, p.4). Pigouvian Tax and Cap-and-Trade can represent policy windows for certain actors as well. In this study, we attempt to expose the perception to such policy options from the different sectors' coalitions and social movements. This analysis will guide the conclusion to the following research question: **How will the different sectors perceive a possible policy change to Pigouvian Tax or Cap-and-Trade?**

One important aspect of market-based approaches in terms of political characteristics is that the implementation of those policies will significantly change the status quo system (Kolstad, 2000, p. 146). When there is a change in the system of regulation, actors that were usually the most benefited and the ones that usually faced the cost could be shifted and that shift can possibly create counter intuitive consequences and resistance (Kolstad, 2000, p. 150; Demir and Aktan, 2016, p. 228). Therefore, **the hypothesis of the case-study is that each sector will**

perceive differently how they are impacted by each approach which will define their acceptance or resistance to the policy options.

The analysis will use reviews of previous attempts to establish similar instruments, as well as try to assess available positions of important associations of the different economic sectors. The groups analyzed comprise urban supply companies, agriculture production, industrial production, mineral water users, as well as NGOS, environmental organizations, and state agencies. The full list of institutions is available in Appendix III.

Dryzek (2013, p.9) explains that both environmental problems and social systems are complex. Environmental problems are complex because we have limited knowledge on how they are created and the options there are to solve them. Social systems are complex because they relate to different communities' culture, heritage and their interaction with each other and the environment. Therefore, when we are dealing with problems that involve both the environment and social systems, we face twice as much complexity and numerous explanations can be plausible, even the ones that are opposing one another (Dryzek, 2013, p.9).

Understanding the values of each group involved in a given environmental issue can help to identify what matters most for conflicting parties and how to reach a compromise between them to create a policy solution. Conflicts may be more difficult to solve if the groups involved have strong differences in values and priorities (Schulz *et al.*, 2017, p. 248).

In order to understand the perception of different sectors that use resources from the Guarani, sociological interpretation of risk assessment and risk analysis can give some enlightening contributions. Using Dietz et al (2001, p. 1) definitions, risk assessment can be defined as the process of identifying and estimating the likelihood of adverse consequences associated with certain actions, whereas risk analysis "is the process of determining the acceptability of identified risks in order to guide policy decision making" (Dietz, Frey and Rosa, 2001, p. 1).

Tierney (1999, p. 218) and Beck and Kropp (2007, p. 607) describe sociological theories that argue that social representations, defined by cultural views, shape an individual's perceptions of risk. Such social representations define individual's cognitive interpretations of risk and its attributes, based on how risk probabilities are framed. However, sociological risk perception analysis indicates that people's perceived risk may be inaccurate (Tierney, 1999, p. 220; Dietz et al, 2002, p.6). The actual risk certain products or system of production may impose to individual's wellbeing or the environment are sociologically perceived as more/less impactful than they are scientifically assessed to be (Tierney, 1999, p. 220; Dietz et al, 2001, p.6).

Another important perspective that should be recognized is that the choice between different risks is related to different cultural frames (Beck and Kropp, 2007, p. 607) (Hoffman, 2001, p.146). Each frame is the product of particular perceptions of issues, their implications and the

way such groups want to interact with constituents. How groups frame issues define their connections with culture, and practices (Hoffman, 2001, p.146). Discourses define the understanding that is legitimate to a given group, framing their assumptions and evaluations in the debate (Dryzek, 2013, p.9).

Discourse frame is also one of the means through which different groups try to exercise power by influencing the definition of the problem, and, therefore, shaping the direction of policy options that can be considered (Hajer and Versteeg, 2005, p. 177-178). Groups that will be impacted by environmental policies attempt to frame environmental problems in a way that can benefit their position in the decision-making process.

> "Environmental policy making is dominated by particular discourses that provide a bias both in conceptualizing the policy problem at hand as well as the solutions that can be conceived for those problems" (Jensen & Richardson, 2004, In Hajer and Versteeg, 2006, p. 179)

In the case of the Guarani Aquifer, the risk perception can be framed in terms of three aspects: the actual risk the aquifer suffers for depletion; the socio-economic debate over possible policy change; and the risk perception of political implications for changing the management policy.

The actual risk the aquifer suffers for depletion

The first risk is related to what Beck and Kropp (2007, p. 603) define as known and unknown awareness in environmental risks, which is related to the need for information to enable the debate among parties. There is a lack of clear monitoring and analysis of groundwater extraction and its impact on the sustainability of Guarani's resources. There may be no risk to the Guarani in the actual levels of extraction, despite localized indications of soil downgrade. However, the actual risk is that the regulatory agencies just do not know the actual situation and possible depletion threats. Consequently, the public also does not know the actual situation. The possible problem is that the public does not seem to realize that such lack of knowledge on the Guarani actually exists. In this sense, the debate over risk to policy change (incremental or substantial) is centered on socio-economic and political aspects whereas the technical expertise to determine the full extent of depletion threats is not available in the first place.

In any system designed, the policy chosen should focus on achieving environmentally sustainable levels of extraction from the Guarani, avoiding overexploitation. The environment should be accounted first, otherwise the overall development of the region and population welfare may be compromised. However, environmental protection opposes governments' traditional *modus operandi*, including in the case of Brazil's government. Governments seek to foster growth, which most of the time has as consequence an increase in risks to the environment (Tierney, 1999, p. 234).

Through unplanned growth of metropolitan areas since the 1950s, low income migrants and residents only found residency options in low-income areas that had little or no basic infrastructure (Young and Fusco, 2006, In Fracalanza et al, 2013, p.20). Most of the time, such areas coincide with locations that are not fitted for urban development due to their importance for protecting the environment or for being prone to environmental hazards (Hogan et al, 2001, In Fracalanza et al, 2013, p.21). However, governments' traditional development goals of economic growth through the increase of consumption as a way to combat widespread poverty in Brazil has led to negligence and overlooked appropriate environmental regulations (Millenium Ecossystem Assessment, 2003 In Fracalanza et al, 2013, p.21).

Negligence of planning and zoning guidelines negatively impacts the environment, propitiating deforestation, soil sealing, lack of appropriate sanitation systems, and contamination of water bodies. The availability of quality water resources is directly related to appropriate land use, which is a management responsibility of municipalities in Brazil (Oliveira, Lima and Sousa, 2017, p. 49) (Foleto, 2018, p. 42)

In the case of the Guarani Aquifer, with the exception of a few municipalities, all governmental levels have shown negligence in terms of protecting water bodies against contamination from the lack of sewage treatment. As mentioned before, only a very small amount of waste water is treated in the municipalities located in the recharge areas of the aquifer, imposing a great risk of contamination.

There is also a lack of effective implementation of regulation and monitoring (Foster et al, 2009, p. 13). As presented in the Legislation section, only a relatively small number of Basin Committees have effectively implemented the instrument of water charge across the areas of the Guarani aquifer, which may have limited the effects on the rational use of its water resources. Moreover, there are only localized, small-scale assessments of Guarani's conditions[8], despite large-scale projects sponsored by World Bank and other agencies to create a more comprehensive analysis of the Guarani.

Besides the lack of comprehensive monitoring and knowledge of the environmental conditions of the Guarani Aquifer, regulatory bodies have uneven technical capacities and resources to fulfill their responsibilities. Campos and Fracalanza (2010, p.374) describe that, in the State of São Paulo, different institutions that are part of the Integrated System of Water Resources Management (SIGRH) need technical support from the State Water Agency to perform their basic activities due to the lack of resources. Abers and Keck (2013, p.41) also stress that qualified professionals are usually working in agencies located in capital cities or larger urban centers, whereas numerous municipalities lack workers with even higher education. A 2007 survey from the Brazilian Water Agency (ANA) found that every water management institution across the country declared that their technical team had an insufficient number of workers to fulfill all the

[8] (Perroni and Wendland, 2008), Villar & Ribeiro (2009) and Foster et al (2009)

responsibilities of issuing allowances, monitoring water bodies, and enforcing the regulations (Costa and Tybusch, 2015, p. 11). The absence of such capacities can compromise the ability of any sound policy to be implemented and risk the sustainability of environmental resources.

Capacity to monitor and enforce the management policy is one element that needs to be leveled across different states to meet even the present legislation requirements, so the public needs to be fully aware of that need. Monitoring is known to be costly, so strategically choosing a sample of the largest water users and/or concentrating the efforts in the most critical regions has the potential to maximize resources and find an alternative solution to the present problem (OECD, 2015, p. 200).

Finally, it is estimated that most of the wells in the areas of the Aquifer are clandestine[9], which may impose large risks of contamination and depletion, as there is no assessment of their performance. All of those elements do not seem to be aknowledged by the public, which risks that possible problems will only become evident when the Aquifer would already be under stress.

People's perception of risk depends on their functions of social and cultural contexts, as well as on how the media represents such risks and promotes its social recognition (Beck and Kropp, 2007, p. 606). The media is inclined to cover dramatic events and elements that are easy to convey to a mass audience, making undramatic or complex elements less publicized (Dietz et al, 2001, p. 10).

In the Guarani case, both elements can explain the lack of diffused information and media coverage on the risk of depletion to its hydrological resources among the average citizen. It is an issue with elevated technical emphasis, and no critical event has happened (yet). However, several states have lived through critical water crisis in the last decade, such as São Paulo, Ceará, and Distrito Federal, to name just a few, that are still vivid in people's memory and were highly publicized.

In this sense, the implementation of a Pigouvian Tax to extract water from the Guarani Aquifer could be perceived as an instrument that could effectively induce rational water use, decreasing the chances of depletion to that source of water. In terms of the implementation of water markets, the perception could be that people tend to be more rational with goods that are held privately than for what is common (Dryzek, 2013, p. 124). Water markets could create such perception and induce a better use of the Guarani's resources.

Despite the big deficiencies in implementing planning legislation and monitoring capacity from water management institutions, Pigouvian Tax and Cap-and-Trade could be perceived as more flexible management methods even just to cope with situations of water crisis. During the recent

[9] (G1 Bauru e Marília, 2014)
(Matge, 2018)

water crisis, the first step taken from sanitation providers was to increase water tariff to force a decrease in water use in a less restrictive way. However, when low levels in reservoirs got to a tipping point, stringent water rationing was put in place in big cities like São Paulo and Brasília as a way to avoid a complete collapse. Either way, it is known that municipalities with limited resources can stay 20 to 30 days without public water supply, relying solely on tank trucks. Having a Cap-and-Trade mechanism available could, for example, allow municipalities to negotiate with industries and farms to not use water resources that could directly or indirectly impact reservoir levels, and possibly avoid negative impacts on population welfare.

Demir and Aktan (2016, p. 231) posit that policy change can only happen when actors are aware of the need for change. If the different sectors and the public understand the actual lack of basic monitoring and assessment of the Guarani as a risk, at the same time that market-based approaches are presented as possible policies to reduce such risks, there would be a chance that the public perceived such policy options as viable and desirable. Meanwhile, the debate over risk to policy change (incremental or substantial) is centered in socio-economic and political aspects, whereas the basic technical expertise to analyze the actual policy or for any policy change to be implemented is lacking in the first place.

The socio-economic debate over a possible policy change

The second aspect of perceived risk is centered in socio-economic implications of a possible policy of implementing water charge through the Pigouvian Tax or creating a system of water market. Many groups perceive such changes as possibly enhancing social inequality in terms of access to water that would penalize even more low-income groups. On the other hand, not having an effective water management policy could compromise future development and create a critical situation that will probably be mostly borne by low-income groups.

The opposing perceptions to the implementation of a Pigouvian Tax can probably be exemplified by the positions that the National Conference of Brazilian Bishops (CNBB) and the environmentalist group Rede de Águas (Water Network) took during the debates for creating water charge. When the mechanism of water pricing was established, CNBB – a prominent Brazilian civil organization – was emphatically opposed arguing that it would commoditize water, a basic source of life, and exacerbate social exclusion for low-income people (Abers and Keck, 2013, p.95). However, many NGOs and environmentalist groups, such as the Water Network were in favor because the policy was defined as only charging high-volume users, which would counter the perception of water as a common pool resource (Abers and Keck, 2013, p.95).

The creation of the instrument of water charge was based on the principles of “producer-payer” and “user-payer”, which intends to guarantee that the users that benefit from environmental services will be responsible for paying a tariff to curb irrational water use, and direct financial resources to recuperate and protect hydrological resources (Fracalanza, Jacob and Eça, 2013, p.

25). These would be the same principles guiding a Pigouvian Tax for using the Guarani's waters. The economic rational would be that such users will try to find ways of using less water in their production system and consumption, as a way to decrease costs with water. This rational will ultimately reach an equilibrium of improved economic output with less use of water because everyone will understand its value as an input of the production system, and not trasnfer the costs of depleting the aquifer to nature and future generations.

However, there has been a historical lack of water service provision to low-income areas, which made the instrument of water charge be perceived as creating an additional element of social inequality in Brazil. Ioris (2005, p. 132) describe the understanding of a number of intellectuals that perceived the instrument of water charge as a way of distributing the costs to the whole society for recuperating water bodies that were degraded to the advantage and profit of specific groups. Ultimately, it was argued that the instrument of water charge created a myth that everyone was equally responsible for degrading the environment whereas the benefits of hydrological development were unequally distributed (Ioris, 2005, p. 132).

There are elements that can corroborate with the criticism of social components to the water charge policy in Brazil. Tierney (1999, p. 226) argues that the public can be influenced by strategies that frame risks in ways that benefit business and governmental actors. Such actors have at their disposal key determinants of persuasiveness, such as power and resources, that increase the chances of their perspectives to prevail (Heimer, 1988, In Tierney, 1999, p. 226). Sousa Júnior et al (2016, p. 11) describe that, in the context of Basin Committees, companies that hold water entitlements have 40% of the representative seats, making their interests more likely to prevail against civil society and environmentalist representations, as is the case of water charge implementation in most of the basins. As an example of how this can play into the policy design, Abers and Keck (2013, p.96) describe the strong opposition from farmers – a strong economic sector in Brazil and a large water user - that pushed for water charge exemption in the state of Paraná, whereas most of the other sectors still had to comply with the water charge policy established.

Fracalanza et al (2013, p.26) evaluates that the instrument of water charge – and possibly the Pigouvian Tax - creates an irreconcilable issue between its objectives of environmental justice and the social inequalities that Brazil faces. Larger tariffs could induce rational water use and promote a more efficient system. However, this would also increase socioeconomic vulnerability in a country that is already plagued by the exclusion of large shares of the population to basic services related to water provision.

On the other hand, research by Perroni & Wendland (2008) and Villar & Ribeiro (2009) indicates that, at least in specific localities, the actual regulatory policy has not been successful in protecting the water resources in Brazil. If this is actually the case, there could be risks to the economic and socio development of the region. Without water, economic production will decrease, as well as the quality of life of the residents in the areas supplied by the Guarani

Aquifer. Both elements will mostly impact low-income groups that have more limited resources to cope with such situations. Therefore, despite the social impact presented by the critics of water charge that could be similar in the case of a Pigouvian Tax, this policy could be perceived as decreasing the risk of depletion to the Guarani, which would decrease the chance of socioeconomic loss for the region in the long-run.

It is important to stress that water charges are not defined based on affordability studies and economic analysis but are set through political negotiations between different groups in Basin Committees (OECD, 2015, p. 202-203). The lack of economic indicators in the definition of water charge becomes evident in three examples: (i) in states that face water scarcity but do not have water charge, (ii) by the fact that water charges represent just a small portion of resources several basins need in investments; (iii) the analysis that water charges represent a minor expenditure in companies' budgets (OECD, 2015, p. 95; Finker et al, 2015, p. 46; Ostrensky and Garcia, 2017, p. 14-15). The result of not using economic analysis and assessments of the real capacity of water users to pay the charges is a restricted implementation of water charge as a management policy tool (OECD, 2015, p. 202-203). Raising awareness of the cost of inaction in the short and long-term, and of the investments needed in the watersheds could help reshape different groups' levels of acceptability to water charges (OECD, 2015, p. 65).

Those examples can illustrate how a Pigouvian Tax could be perceived as enhancing even more social and political inequalities, and therefore, face strong opposition from groups that prioritize the social component of the policy. On the other hand, other groups might perceive that, without an effective system of water charges, there is a risk that the Guarani's waters will not be used rationally, and can be depleted.

It should also be consider that certain economic sectors would not support policies to protect the aquifer because they could perceive such policies as possibly increasing their production costs or bringing uncertainty to the market (Villar and Ribeiro, 2009, p. 58). Policies that protect the environment and water resources defy traditional forms of economic development, by restricting certain land uses or water abstractions. Increasing the marginal cost of water with a Pigouvian Tax or implementing water markets could potentially increase overall costs of production, at least in the short-term for certain sectors, which could make them resist the implementation of such policies.

A study on the impact of water charge implementation in the Alto Iguaçu Basin across the industrial sector evidences that 40% of industries surveyed were not in favor of the charge, and only a small percentage of industries actually seemed to truly understand what water charges are and where their revenues are spent (Ostrensky and Garcia, 2017, p. 13-14). But as stressed before, increasing awareness of the potential risks in the medium-term, especially for industries that rely on water for their activities, can sensitize users and increase willingness to support policies that use economic incentives (OECD, 2015, p. 95).

When it comes to water markets, the risk debate on socio implication might be slightly different. The socio-economic debate of risk perceptions with the implementation of water markets, might be more centered on the perception that such instruments would create a form of ownership of water resources. The perception of water ownership can be perceived as impairing its Constitutional definition as a public good, transforming water into an economic good, and allowing for the creation of inequalities that are natural in markets. On the other hand, similarly to the Pigouvian Tax, water markets can also be perceived as promoting a more rational use of Guarani's waters at the individual level, as the water users would become economic agents.

During the debates to create the system of Basin Committees in the late 1990s, the World Bank and other international agencies also tried to push for the creation of bulked water markets as a mechanism that would create a more rational use of water than just charging for it (Abers and Keck, 2013, p.51). More recently, Federal Deputy Paulo Magalhães has introduced three Bills to create water markets in the Chamber of Deputies[10], and the latest Bill introduced on this matter was authored by Senator Tasso Jereissati in the Senate[11]. However, both in the 1990s and in more recent debates in Congress, the idea of trading water was understood as opposing the constitutional ownership of water resources of the state (Federal and State). (Abers and Keck, 2013, p.53; (Petterini, 2018, p. 136). The perception was that, in a water market, agents would be able to trade their allowances for water use that were issued by Regulatory Agencies as they owned such allowances.

> "The creation of actual markets in tradable water rights was never seriously contemplated in Brazil, despite the World Bank's efforts to promote them. The idea of state control over natural resources had deep roots in Brazilian national-developmentalist worldview, and the 1988 Constitution clearly established public ownership of water resources (both groundwater and surface water)." (Abers and Keck, 2013, p.93).

Besides the perception that water markets are not compatible with the Brazilian Constitution, there is also opposition that water markets will produce inequalities in access to water for small farmers, business, and low-income groups. Groups that bring up such criticism perceive the risk that large companies, big farms and richer municipalities will be able to purchase water allowances from small farmers and poorer communities, leaving those groups without access to water. This perception would be even more exacerbated when it comes to low-income groups that would have limited means to access water.

At the other end of the spectrum of risk perception, the debate revolves around the benefits that markets could bring to society. The OECD report on water governance in Brazil argues for the reconsideration in creating water markets as an additional instrument for water

[10] Projeto de Lei N. 6979/2002, Projeto de Lei N. 287/2015, and Projeto de Lei N.4452/2016.
[11] Projeto de Lei do Senado N. 495/2017

management in Brazil because it could be a more effective management mechanism in periods of water crisis, as well as enhance resources to improve water infrastructure (OECD, 2015, p. 202-204).

> "Support for the creation and expansion of water markets underpins an intellectual shift in thinking about allocation and pricing of natural resources where markets can offer low cost improvements in allocative efficiency" (Brooks and Harris, 2008, p. 394).

Burdack et al (2014, p.323) evaluate that water trade provides incentives to market agents to improve water use efficiency through a production system that responds to the seasonal variability of water, signaled by the allowance price. As an example, high water allowance prices during dry years encourage farmers who cultivate irrigation-intensive annual crops to sell water rights to low-water-need crop farmers or industries. This trade enables the scarce resource to be allocated more efficiently, and possibly even allowing those farmers to generate more revenue than the profits that could have been gained by cultivating irrigation-intensive crops during a drought. Municipalities could also have a higher incentive to reduce wasteful consumption and increase efficiency by improving pipe networks and consumers awareness of rational consumption. In this sense, water crisis and well-known periods of water rationing could be avoided through a clearer incentive of sustainable use of water across the Guarani.

In sum, water markets can have strong opposition from the perception that it is not compatible with the actual regulations and that it can risk access to water to groups that have more limited means. On the other hand, water markets could also be perceived as a more flexible management instrument to water use, that prevents water crisis from happening, and therefore, protects everyone from the negative consequences of water crisis.

The risk perception of political implications for changing the management policy

Finally, the third perception of risk relates to the disturbing sentiment created by policy change. This sentiment is related to risk perception of uncertainty as a consequence of change and expected increase in burden and costs (Demir and Aktan, 2016, p. 229-332).

On one hand, a policy change can create a risk perception that what may be created can be worse than the present situation. Two main disadvantages of market-based approaches in terms of the current political characteristics are that the implementation of those policies will significantly change the status quo system and those approaches need to be adjusted as new scientific information become available (Kolstad, 2000, p. 146).

When there is a change in the system of regulation, actors that were usually the most benefited and the ones that usually faced the cost will probably be shifted and that shift can possibly create counter intuitive consequences (Kolstad, 2000, p. 150; Demir and Aktan, 2016, p.228). As an

example, depending on how the policy is structured, the cost of water can increase to poorer municipalities or low-income families, which can increase water insecurity. In this sense, a policy that has the aim of guaranteeing water resources could be actually making access to water even harder for low-income families.

On the other hand, the political risk sentiment can be also related to the perceived effectiveness of the policy, based on the transaction costs to set new political arrangements. New political arrangements have a higher probability of success when there are lower transaction costs for bargaining over the benefits/costs of implementation, monitoring and enforcement of the policy option (Jones et al, 1997, In (Lubell *et al.*, 2017, p. 669).

Lubell et al (2016, p. 675) analysis on water policy negotiations concluded that the main elements that reduce transaction cost, and, therefore, increase the probability of political effectiveness are: (i) different actors perceptions that the policy option can bring mutual gains, instead of a sum-zero arrangement; (ii) intensity of actors participation on decision-making forums, which increases familiarity with the issue, and allows for increased trust between actors, (iii) scientific knowledge that enables actors to understand which policy options may work better for given problems, and (iv) political knowledge that may improve negotiation skills, and the understanding of which alternatives are most likely to be accepted by other actors.

The first element is probably the foundation for ideal policy, where it should be designed in a way that promotes the perception of widespread improvements to all groups. In this sense, the political risk perceptions of a Pigouvian Tax and a Cap-and-Trade could be overcome if such instruments are designed in ways that decrease the perception of loss. From previous explanations, strong opposition to any of those policies come from the fear that they could exacerbate even more inequalities in the region of the Guarani.

However, there are examples of policy designs that create mechanisms to reduce the negative impacts to such groups. As an example, low-income groups could have a differentiated water tariff rate, that would exempt the relative Pigouvian Tax. Another example could be that part of the funds from the Tax could be used to create a means-based program to provide financial assistance to such groups. In terms of the Cap-and-Trade, the regulation could define the original distribution of allowances in ways that guarantee access to lower-income groups and that well-off groups would have to necessarily purchase allowances from them. Those were just a few examples of policy design that could decrease the perception of political risk from implementing such policies in the context of the Guarani for groups that are worried about social inequality issues.

Another important source of resistance to a possible Pigouvian Tax or Cap-and-Trade previously described relates to the risk perceptions of economic sectors in terms of economic loss from an increase in operation costs. If those sectors perceive that the actual water management policy in place is not protecting the Guarani's resource which may cause serious consequences in terms

of water access in the short, medium or long-term, they may be more willing to consider other policy options. In this case, if Pigouvian Tax or Cap-and-Trade are presented as viable options to improve water availability, these policies may be framed as bringing mutual gains to different water users.

A recent study of social networks across members of the National Council of Hydrological Resources (CNRH) conducted by Costa and Mertens (2015) bring contributions to the second and forth elements enumerated by Lubell et al (2016). The CNRH is the highest collegiate body that sets the priorities and regulations of the National Plan of Hydrological Resources in Brazil. It is composed by 57 permanent members (and 57 substitute members) representing governmental institutions, state councils, groups of users and civil organizations. Costa and Mertens (2015, p 162) analysis point that average social network by groups of members vary from 8 connections from members of governmental institutions to 14 connections from members of civil organizations. Members representing state councils tend to have the most diverse connections with even distributions across the different groups. Moreover, members participating for fewer than 3 years in the Council tend to have 16 connections, whereas members participating for over 5 years tend to have only 7 connections (Costa and Mertens, 2015, p 163).

Such findings may indicate that different groups approach decision-making forums for water management with different goals. Civil organizations may perceive such forums as a good opportunity to effectively express concerns of civil society and try to connect with a lot more members to spread such concerns, whereas state councils may try to find consensus across a larger number of actors. Moreover, keeping in mind that the whole regulatory system can still be considered in its establishing phase, the fact that members participating for less time in the Council have more connections than members participating for longer periods may indicate the system is promoting a more active participation across different groups and opportunities for consensus building.

Sholtz et al. (2007, In Costa and Mertens, 2015, pp. 155) describe that social networks that are small and bonded generate an increase in credibility and compromise between their members, whereas social networks that are large generate an increase in information exchange. In order to increase the political knowledge and negotiation skills of different actors in debates over the implementation of Pigouvian Tax and Cap-and-Trade, both types of forums for negotiation should be created. The CNRH promotes good opportunities for broader information exchanges between different groups. However, the Basin Committees that are located in the areas of the aquifer could be better fitted spaces for the different groups to build trust and compromise for the possible creation of such policies.

In sum, there are successful examples of forums that promote the exchange of information and increase trust building between different groups that deal with water management in Brazil.

This indicates that there are good chances that the possible instruments of Pigouvian Tax and Cap-and-Trade could find adequate forums for being debated and possibly reaching consensus.

When it comes to the capacity of different groups to understand scientific and technical elements, there are clear indications that Brazil needs to improve on that front. Sousa Júnior et al (2016, p. 12) concluded that another source of inequality that takes place within the decision-making process of Basin Committees is the use of technical and scientific information in the definition of models and environmental impact. The authors describe that the use of technical information creates obstacles for different groups to similarly understand the situation and participate in the debates, leaving the groups with the most capacity and resources in a better place to influence the decision-making process than groups with fewer resources.

Clear and accessible information, as well as public outreach were also found key to a correct public understanding of water policy objectives. When Basin Committees and Water Agencies were discussing regulatory mechanisms for water charge, the National Council of Brazilian Bishops (CNBB), the Movement of People Affected by Dams (MAB) and other organized social groups were condemning the ideas that were being discussed based on inaccurate interpretations of the charge mechanism and water management organizations (Abers and Keck, 2013, p.80).

These examples stressed the need for improvements in communication of technical and scientific information in ways that any group could understand. This is not only key to decrease transaction costs, but also for creating good governance that needs to be put in place in any management design for the Guarani Aquifer. In the case of Pigouvian Tax, the criteria to define the tax need to be transparent and agreed upon by different groups. For a Cap-and-Trade, there will be a need for public outreach to explain the concepts that govern this instrument, a transparent system for water allowance transaction would have to be put in place, and regulations to curb inefficiencies and speculation would have to be implemented.

It is also realistic to point out that several groups benefit from the current lack of environmental legislation enforcement and land use compliance. Ioris (2012, p. 137-138) explains very well that the lack of appropriate sanitation infrastructure in neighborhoods built without the appropriate zoning regulations were politically capitalized by demagogic politicians and other economic agents, to maintain power and economic gains:

> "The systematic announcement of new projects for the same problems and the same locations—without resolving the structural deficiencies and without ever changing the hierarchical, authoritarian relation between state agencies and the local communities—serves the double purpose of containing popular criticism and creating a permanent source of political profit. The perpetuation of a precarious water condition has transformed popular demands into an enduring, and profitable, political machinery that operates intermittently both during the

> electoral campaigns (eg with the promises of new investments) and between elections (eg occasional and paternalistic provision of water lorries by politicians in exchange for votes in the next election, which are either paid with public money or provided by the water utility according to political influence)" (Ioris, 2012, p. 137-138).

In this sense, implementing policies that would put more pressure on governmental authorities to solve such problems could pose a threat to a power system already in place. At the same time, those same politicians are also influenced by economic forces that pressure for accountability and by a rising sense of empowerment from organized social groups. Depending on the risk perceptions regarding the Aquifer by those economic agents and organized groups, the pressure for policy change could prevail.

In conclusion, policy change always creates a sentiment of fear for different groups and interests. This is related to the fact that communities are structured to maintain the status quo and fear drastic changes in the political system. However, there are key elements that can contribute to reduction of such perception of risk that any policy governing the Guarani aquifer and water resources in Brazil should have. The different groups would have to perceive a decrease, created by the policy design, in the risk of economic and social inequality, possibly through forums that promote the exchange of information and consensual political decisions, and by improvement of the communication of technical elements and outreach.

Analysis

This section will convey and analyze the position of different groups of actors and water users that would be impacted by a change in the current system of allowances and water charge to the Guarani Aquifer. As explained before, the analysis will laid out the position such groups had in previous debates regarding correlated topics, and draw possible conclusions to Pigouvian Tax and Cap-and-Trade. Appendix IV systematizes the conclusions drawn from this section. The groups analyzed are governmental agencies, agribusiness and family-based farming sector, environmental groups, urban water suppliers and municipal governments, and the industrial sector.

Governmental agencies support mechanisms that brings short-term benefits in rational water use and funding(Agência Nacional de Águas (ANA), 2017b)(Alves, 2019). As an example, a recent Resolution (No. 192/2017) from the National Water Resources Council (CNRH) to automatically adjust water charges to annual inflation in Federal water bodies was celebrated by the Council and the Brazilian National Water Agency (ANA) as a way to correct water charges and increase funds to be invested by Basin Committees(Salusitado, 2018).

Those agencies may also advocate for more resources and personnel. As previously presented, there is a lack of appropriate resources to allow those agencies to perform their duties well. Because of that situation, those agencies know that there may be a large risk for the Guarani Aquifer - with economic, environmental and social consequences - that they are not able to fully cope with(Aranha, 2010). Under such circumstances, governmental organizations may perceive that a Pigouvian Tax may generate more financial resources and push for changing in water users' behavior that can decrease the risks to the aquifer in the long-run. Therefore, they may be in favor of implementing a Pigouvian Tax.

As described by a former head of the Brazilian National Water Agency, governmental agencies may be skeptical of the creation of a Cap-and-Trade system, even for cases of water crisis. A Cap-and-Trade system could create market and regulation insecurities, and, in practice, violate the principle that water is a public good by allowing the trade of allowances between water users(Nassif, 2018).

During the debates on CNRH's resolution regarding water charge inflation adjustments, the agribusiness sector, represented by the Brazilian Confederation of Agriculture and Cattle Raising (CNA), advocated against arguing it would disproportionately impact irrigators and fish farmers. The sector contends that water charge does not have the aim of raising revenue, so adjustments in its price should be aligned with basin management plans(Assessoria de Comunicação CNA/SENAR, 2017)(Xavier, 2017). In recent debates on raising water charge in São Francisco basin and Rio Doce basin, CNA positions against such increase and additional compliance requirements for issuance of new allowances to irrigators. They argued that the adjustment of water charge would be excessively high for certain farmers and that the policy is not clear on how the new instruments would be used to improve water management in the basin(Confederação da Agricultura e Pecuária do Brasil (CNA), 2018a)(Confederação da Agricultura e Pecuária do Brasil (CNA), 2018b). Based on such positions, the agribusiness sector may not be in favor of a Pigouvian Tax if it would abruptly make water charges more expensive and not clearly delineate how the policy would be beneficial for water management.

Due to the risk of unpredictability in price, and how the system of production may be affected, the sector may also be against a Cap-and-Trade. However, there is also a chance that the agribusiness sector may favor a Cap-and-Trade system in situations of water scarcity because their bargaining power could increase compared to the present regulation. Right now, in cases of water scarcity, allowances of water use from industries and farms could be withheld, without any compensation, because human and animals have the priority for water consumption. However, in a Cap-and-Trade system, water allocation is traded considering users' opportunity-cost. In situations of water scarcity, water users that cannot meet water caps would seek to purchase allowances, whereas users that are able to decrease water use bellow their cap could sell their exciding allowances. In a hypothetical example, during a drought, farmers could sell their allowances to urban water suppliers, that would probably be facing an increase in water

demand. In this example, farmers would be compensated, and the risk for a complete water collapse would be decreased because there would be less competition for water use between different groups during periods of drought.

Ultimately, the agribusiness sector is highly impacted by water crisis and droughts, so they tend to support methods of production that marginally use less water(Idoeta, 2015). The sector promotes efficient irrigation technology, better water and soil management strategies, and resources to implement irrigation expansion as necessary to guarantee a more rational use of natural resources. There are numerous practices and innovative instruments used that decrease water use in agriculture production, such as no-till farming, the use of small dams, seeds that are tolerant to low-water environments, and highly efficient equipment(Alves, 2016). In this sense, the sector may be more receptive to market-based instruments if they are accompanied by policy designs that reward environmental-friendly practices and use the funds generated is an effective and visible way.

In the Brazilian National Congress, different agendas can be mobilized through parliamentary caucus. Maybe one of the strongest groups in the Brazilian Congress is the Agriculture Caucus, coordinated by the Agriculture Parliamentary Caucus (Frente Parlamentar da Agropecuária). The Agriculture Caucus has been advocating for policies that rewards practices that protect the environment, spending accountability from water charge funds, and for policies to mitigate climate change(Junqueira, 2015)(Sperafico, 2017). The Caucus is also vocal in denying that the agriculture sector is the largest water user, arguing that most of farm land in Brazil relies solely on rain(da Silva Junior, 2015).

When it comes to the family-based farming sector, the opposition to market-based mechanisms is evident. This sector perceives the risk of water scarcity as a social problem that needs to be addressed in a more comprehensive way(Confederação Nacional dos Trabalhadores na Agricultura (CONTAG), 2016). Based on positions of the National Confederation of Agriculture Workers (CONTAG), water charge is interpreted as a privatization of water access(Confederação Nacional dos Trabalhadores na Agricultura (CONTAG), 2017b). The family-based farming sector also opposes the allowance system - even when there is no charge for water - because they interpret it as limiting water access(Confederação Nacional dos Trabalhadores na Agricultura (CONTAG), 2017a). Due to their perception of water charge and allowances, this is a group that may oppose any policy that uses economic incentives. Either way, it is interesting to see that this group and the agribusiness group have in common the advocacy for policies that benefit actions to preserve the environment, and that allocate funds for infrastructure and compensation for rational use of environmental resources(Confederação Nacional dos Trabalhadores na Agricultura (CONTAG), 2017b).

When it comes to environmental groups, there are some distinct perceptions. All environmental groups perceive the risk to water depletion as very dangerous, but there are some large distinctions on what policies are perceived as positive. Environmental groups that mainly focus

on an environmental agenda, such as SOS Mata Atlântica, push for the expansion of actions to protect the environment as their main priority, including the implementation of water charge to every water user(Hirota, 2014). Those groups are also willing to partner with the economic sector, including large corporations, and make political alliances to push for sustainable development policies, even if, in practice, they only represent incremental steps[12].

On the other hand, environmental groups that mainly focus on an environmental justice agenda, such as Cáritas Brasileira and Comissão Pastoral da Terra, converge with the family-based agriculture sector. They perceive the current water charge policy as a privatization of water resources, and are suspicious of large economic groups(Ribeiro, 2016). They advocate for small-scale/local economy and low-income groups, fighting against inequality, gender, racial and ethnical oppression, and capitalist methods of production(Rocha, 2018)(Comissão dos Povos Originários e Comunidades Tradicionais (PCTS), 2018). The environmental group Comissão Pastoral da Terra also publishes every year statistics on conflicts caused by water access, such as droughts, pollution, water access restrictions, private appropriation, among others. The number of conflicts has only increased since the beginning of the survey in 2005, reaching a peak in 2017, with 197 conflicts (Comissão Pastoral da Terra (CPT), 2017, p. 131).

The environmental group Comissão Pastoral da Terra had one of the few clear positions regarding Cap-and-Trade that this case-study was able to find. They are very emphatic in opposing the creation of such mechanism, arguing that it opposes the Constitution and the definition of water as a public good. They also argue that, because water consumption to humans and animals are the priority in cases of water scarcity, a Cap-and-Trade system would be unethical as it would condition water access to economic resources, and create speculative practices under a delicate situation(Malvezzi, 2015).

The environmentalist agenda is also mobilized in the National Congress through a parliamentary caucus, the Environmental Caucus (Frente Parlamentar Ambientalista). During 2014's water crisis across many states in Brazil, the caucus pushed for the creation of special committees to create long-term policies to prevent water crisis, to incentivize rational water use and protect water bodies(Oliveira, 2015)(Brasil, 2015). Leaders also criticized the fact that environmental issues are not mobilizing political demands, even after water crisis(Lavoratti, 2015)(Ribeiro, 2015).

One policy that is convergent between environmental groups and the agriculture sector is the support for the creation of policies that reward environmental practices, such as protecting forests and water bodies, also known as "environmental services payments". It is interesting to

[12] (Fundação SOS Mata Atlântica, 2017)
(Fundação SOS Mata Atlântica, 2007)

notice that both the Agriculture and Environmental caucus favor the creation of such policies, as they usually express opposing views regarding natural resources[13].

Urban water suppliers may be in favor of a full application of Pigouvian Tax because they may see it as pushing for a more rational use of water and fostering investments in new technology to obtain efficiency on water consumption. Urban water suppliers argue that there is a need for implementing new technology in water treatment to improve efficiency, decrease water loss in pipeline connections and wasteful consumption. They also argue that water tariffs should be set at a more efficient level that takes into consideration the payment capacity of water users and the necessary funds to cover operational costs(Besse, 2017). Therefore, the sector may see a Pigouvian Tax as pushing for more rational use in the short term and fostering the implementation and use of new technology that promotes water-use savings in the long-term both at the individual level as well as in the production complexes of sanitation providers.

Urban water suppliers also argue for the implementation of direct and indirect subsidies to protect low-income groups from potential lack of access to water due to price. They criticize the present crossed subsidized tariff system in which well-off municipalities are paying for low-income municipalities for hiding operational inefficiencies of the system[14].

As explained before, urban water suppliers have an intrinsic connection to municipal governments, and the main institutions that represent the interests of municipal governments are the National Confederation of Municipalities (CNM) and the National Mayors Front (FNP). CNM has been vocal in condemning the decrease in Federal investments in the expansion of sanitation infrastructure, and that the Federal government is not honoring the original Basic Sanitation Plan (Plansab) where almost 60% of investments would come from Federal money, and 40% from other agents. Right now, overall investments are very low, with 60% of it coming from private investments, increasing the risk of deepening inequality between rich and poor municipalities, and not achieving universal sanitation(Agência CNM de Notícias, 2019)(Portal FNP, 2018). However, municipal government actors fear an increase in water tariff due to political pressure from the electorate, so they may be against the implementation of a Pigouvian Tax that can indirectly increase water tariff in the short-term(Lima, 2018).

Mayors tend to have an agenda that is limited to the duration of the mandate, therefore not necessarily valuing and opting for policies with long-term effects. This causes a big problem in terms of water bodies protection, as effective actions may need large resources and efforts that might not show results during electoral mandates. In cases where the Guarani Aquifer is being depleted, but the negative consequences may not be perceived during the mandate, mayors don't tend to receive enough political pressure to prioritize this issue against so many others the

[13] (Jesus, 2019).
[14] Yves Besse, "Tecnologia e Uso Racional Reduzem o Custo Da Água," *Associação Brasileira Das Concessionárias Privadas de Serviços Públicos de Água e Esgoto (ABCON)*, January 23, 2017, http://abconsindcon.com.br/noticias/tecnologia-e-uso-racional-reduzem-o-custo-da-agua/.

mandate have a higher probability to be held accountable for. However, in municipalities that the negative consequences are already affecting the municipality, Mayors will be pressured to find immediate mitigating solutions that may not represent long-term solutions to the policy problem.

The industrial sector may see both the full application of Pigouvian Tax in water charge, as well as the creation of water markets as positive. The industrial sector as a whole argue that they are trying to optimize the use of water in its production process as a way to decrease production costs(Instituto Aço Brasil, 2018)(Confederação Nacional da Indústria (CNI) and Instituto Aço Brasil, 2012). An important contributor to the implementation of optimization methods and innovation is water charges, as the more users must pay for water, the more they are motivated to seek new production methods[15].

Water availability is strategic to the industrial sector, which can become even more important as the risk to water scarcity increases(Confederação Nacional da Indústria (CNI), 2018). In this sense, associations are pushing for governmental actions in terms of increasing the capacity and resources of regulatory agencies to improve their work(Associação Brasileira da Indústria Têxtil e de Confecção (Abit), 2015)(Rodrigues, 2018). The sector also advocates for policies that benefit industries that implement policies to reduce water and energy consumption in their production process, water charge reimbursement regulations, and policies to regulate water reuse that encompasses reuse of discharge, rainwater and desalination (Associação Brasileira da Indústria Têxtil e de Confecção (Abit), 2015)(Confederação Nacional da Indústria (CNI), 2018)(JusBrasil, 2012).

At the same time, the industrial sector is concerned with the increase in production costs that water charges can generate and advocate for a cap in water charge prices[16]. Because of the sector's concern with predictability of prices and legislation, it may be against Cap-and-Trade and to a Pigouvian Tax that does not provide such predictability.

[15] (Vialli, 2012).
[16] (Federação das Indústrias do Estado de São Paulo (FIESP), no date)

Takeaways II

A second objective of this case-study was to outline the perceptions of different societal sectors to the creation of market-based approaches to govern Guarani's water resources. In terms of risk perceptions, we described broader discourses that were used in previous attempts to establish other water management instruments and tried to correlate these to a possible implementation of Pigouvian Tax or Cap-and-Trade to manage water use from the Guarani Aquifer.

The first risk perception involved the present lack of monitoring and assessment of the Guarani Aquifer. Several elements presented corroborate the conclusion that the different levels of government are being negligent in protecting water resources. The conclusion stressed that, if the different sectors and the public perceived the actual lack of basic monitoring and assessment of the Guarani as a risk, at the same time that market-based approaches are presented as possible policies to reduce such risks, there would be a chance that the public could perceive such policy options as viable and desirable.

The second risk perception involved the socio-economic impacts of market-based approaches. Three possible discourses were outlined. The first one emphasized the perception that the implementation of market-based approaches could enhance social inequality in terms of access to water and restrict even more low-income groups access to quality water. The second discourse could be viewed as more pragmatic, emphasizing that, not having an effective water management policy, could compromise future development and probably create a critical situation that would be mostly borne by low-income groups. The third discourse considered that certain economic sectors could not support policies to protect the aquifer because such policies could potentially increase overall costs of production, at least in the short-term.

The conclusions indicated that groups that perceived socioeconomic elements or short-term economic gains as their main priority could be resistant to a Pigouvian Tax, whereas the groups that perceived the actual instrument of water charge as ineffective in the long-run, could be more inclined to accept such policy options. For the creation of water markets, we concluded that groups that perceive water as a strict public good might be resistant to the idea of creating such instrument, whereas groups that are able to perceive alternative regulations that keep water as a public good but its use as a private consumption, might be more open to accept such instrument.

The third risk perception involves the fear of changing the status quo. A number of elements were suggested that might contribute to decrease the natural sentiment of resistance to change. The analysis also described a few examples of policy designs, decision-making forums, and improvements that could promote larger acceptance to both Pigouvian Tax and Cap-and-Trade. The conclusions indicated possible policy designs that enable a broader support to each policy approach, and that there already exists forums that can promote a transparent decision-making

process if market-based approaches were to be implemented. However, there is a need for more investment in monitoring, assessment and communication of the exploitation levels of water resources in Brazil, an assessment which is not limited to future policy implementations, but to the present situation as well.

The analysis inferred conclusions from available positions of large associations that represent certain economic sectors, political groups in the Brazilian Congress, governmental institutions, and class associations. It was possible to make clearer inferences from current debates to Pigouvian Tax than to a Cap-and-Trade. This is probably related to the fact that the current water charge system follows the basic premises needed for a Pigouvian Tax to be implemented.

Overall, the analysis inferred that governmental agencies, environmental groups, urban water suppliers, and the industrial sector could perceive a Pigouvian Tax positively because it could foster a more rational use of water and protect the Guarani. Those sectors fear the lack of monitoring and clear actions to prevent future water crisis, and support policies that could generate better behavior, resources and innovation to protect water resources. However, the industrial sector could be against such instrument if it does not guarantee a certain predictability in price for water.

At the opposite spectrum, the agribusiness and family-based agriculture sectors, environmental justice groups, and municipal representations may be against a Pigouvian Tax. The agribusiness sector may see a Pigouvian Tax as a policy that does not create price predictability to the cost of production. Municipal representations may fear the increase in water tariffs and the electoral consequences it could generate. Family-based agriculture and environmental justice groups tend to resist any policy that charge for the use of environmental resources because of their fear it could increase inequality in low-income groups' access to such vital resources.

In terms of a Cap-and-Trade, most groups may perceive negatively the implementation of such approach. This is mainly related to the fact that it would completely change the regulatory system to access water, which could be interpreted as privatizing water access. Moreover, different groups fear that a Cap-and-Trade system could generate water price unpredictability and legal insecurity.

The analysis allowed the perception of one interesting element. It was inferred that the policy of "payment for environmental services" seems to bring convergence across the different groups and sectors. This may indicate that a way forward may be to incentivize positive environmental practices by creating tax credit or deductions, or policies that reward best-practices, instead of solely charging water use from the Guarani.

Conclusion

The Guarani Aquifer System is one of the main sources of groundwater in Brazil, used for population consumption, agricultural production, industrial use, and recreation (Borghetti et al, 2011, p. 191). This case-study focused on studying the Guarani's recharge areas in Brazil, which encompass 368 municipalities across eight states.

The analysis evidenced that there are strong indications that the aquifer is being depleted as the amount of water used is exceeding its recharge capacity. Groundwater overexploitation can generate several negative consequences to the environment and access to quality water, such as decrease in necessary environmental flows to surface water bodies, saltwater contamination, and soil downgrade.

A review of the present regulation of water use concluded that the current system is not guided towards the efficient level of water consumption, which may be contributing to the Guarani's overexploitation. The analysis focused on two instruments to manage water use – allowances for water use and water charge - which are managed in a diffuse and, sometimes, confusing way. The present regulatory system grants water allowances following the order of request, not considering long-term objectives of the Basin's master plan, or criteria that could seek a more efficient allocation of water (OECD, 2015, p. 174-175). The main deficiency of the present water charge regulation lies in its price definition from a political agreement between the members of the Basin committees, and not by economic assessment of users' ability to pay and expected effects from price elasticity (Abers and Keck, 2013, p.94; OECD, 2015, p. 65; Garrido, 2018, p.37).

The objective of this case-study was to analyze if market-based approaches could be more efficient than the current regulatory system to manage water use from the Guarani Aquifer, and how water users and governmental institutions would perceive such policy options. The case-study intended to answer the following research questions:

- Can market-based approaches be more efficient and cost-effective options to manage the water resources from the Guarani Aquifer, compared to the actual regulation model in place?
- How will the different sectors perceive a possible policy change to Pigouvian Tax or Cap-and-Trade?

The guiding hypotheses were:

- Pigouvian Tax and Cap-and-Trade could be more efficient and cost-effective than the actual regulation to manage the Guarani Aquifer.
- Each sector will perceive differently how they are impacted by each approach which will define their acceptance or resistance to the policy options.

The method of analysis to answer the first research question used reviewed the present regulation for groundwater use, the literature on its performance, and the theoretical concepts

of Pigouvian Tax and Cap-and-Trade. The analysis concluded that either market-based approach could be more efficient than the current system to regulate water use from the Guarani. However, comparing both methods, the Pigouvian Tax could be more easily implemented than the Cap-and-Trade because most of the enabling legislation is already in place.

The method of analysis to answer the second research question drew upon the sociological theory of risk perception to implement market-based approaches, and reviewed available positions on correlated policies to infer different groups' perception to the implementation of Pigouvian Tax and Cap-and-Trade.

Despite the probability that the Pigouvian Tax and Cap-and-Trade could be more efficient instruments to manage the Guarani Aquifer than the current policy, these policy options do not seem to be perceived by water users and governmental institutions as viable solutions at the moment. There could be support for a Pigouvian Tax, but most members seem to perceive the risk of socioeconomic and cost of production as more pressing than the risk and consequences of water crisis. In terms of Cap-and-Trade, the risk perception of an inflexion with the current Constitutional rights to water, price unpredictability and legal insecurity seemed to generate resistance from the different groups to this policy option.

The analysis evidenced that the risk of Guarani's depletion, and a consequent water crisis, have not been capitalized as a primary political agenda. Despite recent water crisis in major states of Brazil, the public has not demanded a comprehensive solution from policymakers, and long-term consequences of unsustainable water use do not seem to mobilize economic groups to actually demand political solutions. In times of water crisis, the focus has been directed to short-term solutions, and stakeholders do not seem to perceive the recurrent character and long-term nature of such crisis. Therefore, no public demand to prioritize long term sustainable policies to mitigate such problems has emerged. The public and different sectors of the economy do not seem to understand that ineffective water use legislation, non-compliance to land-use policies, outdated water supply and sewage treatment utilities, as well as outdated methods of production, and lack of resources to monitor and to enforce environmental legislation, are also sources and causes of water crisis.

Another element evidenced throughout the analysis was that the current mechanism of water charge is not fully understood. Water charge is not a tax or fee, but a public price that is charged in recognition of water's economic value. However, the difficulty in understanding what a public price represents, and the large costs of production in Brazil, make water charge be perceived as another tax. In the same way, the difficulty in understanding that consumption of water causes negative externalities to the environment, and therefore should be assigned a cost to consumers, is also a difficult concept to understand.

Educating the public about the importance of water issues and on the relationship between the lack of appropriate policy, monitoring and legislation enforcement are key to improve public

understanding of the contributors to water crisis. Another important aspect the public should be educated on is the economic value and the environmental services groundwater provide (Hirata *et al.*, 2019, p.29). A better understanding of the causal relationships of water crisis may improve public engagement to pressure elected officials to build a comprehensive agenda on water issues. Through the increase in education and engagement on water issues, the comprehension of other types of management options, such as a Pigouvian Tax and Cap-and-Trade, could become perceived as possible avenues to decrease the Guarani's depletion.

Climate change and the recent cases of water crisis also evidence that there is a need for a clear debate on water allocation priority in periods of water crisis. Climate change will affect water cycles across Brazil, which, coupled with population and economic growth across the Guarani region, will likely create a situation of increased water demand during periods of decreased availability. The recent water crisis events have not inspired a long-term agenda to cope with such situations in a sustainable way. Large cities had to live through water rationing for many months, affecting population well-being and economic growth. The definition of water allocation priority in periods of water crisis is key to prepare residents and businesses to situations that are likely to be more-and-more frequent as the effects of climate change become more evident.

Besides educating the public, all levels of government need to improve participation and funding contribution to necessary programs across the basins of the Guarani. Necessary investments should be included in municipal, state and federal budgets, and not solely delegated to basin committees to gather the funds. All jurisdictions need to better coordinate policy action to improve Guarani's management and protect its waters.

One policy that seems to bring convergence across different sectors is the payment for environmental services. The aim of this policy is to provide compensation to practices that protect the environment, instead of solely charging for the use of natural resources. All groups analyzed, even the ones that have opposite views on many topics, expressed support for this agenda, which should be further explored in future studies.

As usually happens to most policies in the historical context of Brazil, traces of former policies remain in reformed projects because complex systems of negotiation are necessary to attract large enough coalitions to change a policy. The resulting political compromise rarely allows for a complete change (Abers and Keck, 2013, p.20). Back in the 1990s, the creation of the new system of Basin Committees was just the first step in stablishing a new water management model. However, that reform carried many inherited inconsistencies and gaps that persisted throughout the process of establishing Committees and managing water resources through this system (Abers and Keck, 2013, p.55). The same situation is likely to occur if a Pigouvian Tax or a Cap-and-Trade system were to be implemented. Several feedback loops, adjustments, and reconfigurations would need to occur for the system to be completely established.

There is also a need an assessment of the real source of environmental degradation and, in the case of the Guarani Aquifer, the possibility of depletion of this resource. For Campos e Fracalanza (2010, p. 375), in Brazil, the lack of government leadership in enforcing environmental regulations has been the source of both environmental degradation and unequal access to water resources. However, the government's role of promoting economic growth allows only the conflict over water access to be evidenced. The deterioration of environmental resources is mainly related to the methods of production used by society that require more resources and generates more degradation (Campos and Fracalanza, 2010, p.375).

Before we close this paper, we need to make two last observations in terms of the methods of analysis and recommended improvements for the debate it promotes. This case-study analyzed the public perception to Pigouvian Tax and Cap-and-Trade based on risk perceptions of groups of water users. Other possible approaches could have been used, and maybe the conclusions would have been different. Another element was the use of secondary analysis, instead of surveying water users from the Guarani on their perception to Pigouvian Tax and Cap-and-Trade. Despite the limitations and difficulties of conducting a survey, it could provide a more accurate and direct perception from water users, and it is recommended if future studies have the possibility to do it.

BIBLIOGRAPHY

Abers, R. and Keck, M. E. (2013) *Practical authority : agency and institutional change in Brazilian water politics*. Oxford University Press.

Agência CNM de Notícias (2019) 'CNM participa da audiência pública de revisão do Plano Nacional de Saneamento', *Confederação Nacional de Municípios (CNM)*, 1 April. Available at: https://www.cnm.org.br/comunicacao/noticias/cnm-participa-da-audiencia-publica-de-revisao-do-plano-nacional-de-saneamento (Accessed: 10 May 2019).

Agência Nacional de Águas (ANA) (2010) *Atlas Brasil - Abastecimento Urbano de Água*. Brasilia. Available at: http://biblioteca.ana.gov.br/index.asp?codigo_sophia=3636 (Accessed: 6 May 2019).

Agência Nacional de Águas (ANA) (2014) *Cobranca pelo uso de Recursos Hidricos*, *Cadernos de Capacitação em Recursos Hídricos*. Brasília. Available at: http://biblioteca.ana.gov.br/index.asp?codigo_sophia=60544.

Agência Nacional de Águas (ANA) (2017a) *Atlas Esgotos - Despoluição de bacias hidrográficas*. Brasília. Available at: http://biblioteca.ana.gov.br/index.asp?codigo_sophia=72208.

Agência Nacional de Águas (ANA) (2017b) 'Relatório apresenta pontos para aperfeiçoamento da cobrança de recursos hídricos', *Agência Nacional de Águas (ANA)*, 28 November. Available at: http://www3.ana.gov.br/portal/ANA/noticias/cobrancas-pelo-uso-de-recursos-hidricos-no-brasil-caminhos-a-seguir (Accessed: 10 May 2019).

Alves, E. R. de A. (2016) 'Valor da água', *Portal Embrapa*, 15 February. Available at: https://www.embrapa.br/busca-de-noticias/-/noticia/9861726/artigo---valor-da-agua (Accessed: 9 May 2019).

Alves, R. (2019) 'ANA abre audiência pública sobre procedimentos para cobrança pelo uso da água de domínio da União', *Agência Nacional de Águas (ANA)*, 3 April. Available at: http://www3.ana.gov.br/portal/ANA/noticias/ana-abre-audiencia-publica-sobre-procedimentos-para-cobranca-pelo-uso-da-agua-de-dominio-da-uniao (Accessed: 10 May 2019).

Aranha, M. (2010) 'Duas alternativas ao Aquífero Guarani estão na lista de estudos do Daerp para diminuir a extração da reserva', *Agência Nacional de Águas (ANA)*, 9 November. Available at: http://www3.ana.gov.br/portal/ANA/noticias-antigas/duas-alternativas-ao-aquafero-guarani-estapso-na.2019-03-15.5296205634 (Accessed: 10 May 2019).

Assessoria de Comunicação CNA/SENAR (2017) 'Indexação da cobrança pelo uso da água pode elevar custo de produção para o setor agropecuário', *Confederação da Agricultura e Pecuária do Brasil (CNA)*, 19 December. Available at: https://www.cnabrasil.org.br/noticias/indexação-da-cobrança-pelo-uso-da-água-pode-elevar-custo-de-produção-para-o-setor-agropecuário (Accessed: 10 May 2019).

Associação Brasileira da Indústria Têxtil e de Confecção (Abit) (2015) *Agenda de*

Competitividade da Indústria Têxtil e de Confecção Brasileira 2015 a 2018. Sao Paulo. Available at: www.abit.org.br (Accessed: 10 May 2019).

Barroso, L. R. (2002) 'Saneamento básico: competências constitucionais da União, Estados e Municípios', *Revista de Informação Legislativa*, (153), pp. 255–270.

Bartolino, J. R. and Cunningham, W. L. (2003) *Ground-Water Depletion Across the Nation*, *U.S Geological Survey Fact Sheet 103-03*. Available at: http://pubs.usgs.gov/fs/fs-103-03/#pdf.

Beck, U. and Kropp, C. (2007) 'Environmental Risks and Public Perceptions', in Pretty, J. et al. (eds) *The SAGE Handbook of Environment and Society*. Los Angeles: SAGE, pp. 601–612. Available at: https://www.academia.edu/20897213/Environmental_Risks_and_Public_Perceptions?auto=download (Accessed: 6 May 2019).

Berck, P. and Helfand, G. E. (2011) *The economics of the environment*. Pearson Addison-Wesley. Available at: https://books.google.com/books?id=TPyktgEACAAJ&source=gbs_book_other_versions (Accessed: 6 May 2019).

Besse, Y. (2017) 'Tecnologia e uso racional reduzem o custo da água', *Associação Brasileira das Concessionárias Privadas de Serviços Públicos de Água e Esgoto (ABCON)*, 23 January. Available at: http://abconsindcon.com.br/noticias/tecnologia-e-uso-racional-reduzem-o-custo-da-agua/ (Accessed: 10 May 2019).

Borghetti, B. *et al.* (2011) *A integração das águas: Revelando o verdadeiro aquífero guarani*. Curitiba: Edição da Autora.

Brasil (1997) *Lei 9433 de 8 de janeiro de 1997.* Brasil. doi: 10.1177/1077800407308905.

Brasil (2000) *Lei 9984 de 17 de julho de 2000.* Brasil. Available at: http://www.planalto.gov.br/ccivil_03/Leis/L9984.htm (Accessed: 6 May 2019).

Brasil (2018) *Constituição da República Federativa do Brasil: texto constitucional promulgado em 5 de outubro de 1988*. 53rd edn. Edited by C. dos Deputados. Brasília: Edições Câmara.

Brasil, E. (2015) 'Comissão sobre a crise hídrica visitará locais afetados por escassez de água', *Frente Parlamentar Ambientalista*, 6 April. Available at: http://www.frenteambientalista.com/comissao-sobre-a-crise-hidrica-visitara-locais-afetados-por-escassez-de-agua/ (Accessed: 10 May 2019).

Brooks, R. and Harris, E. (2008) 'Efficiency gains from water markets: Empirical analysis of Watermove in Australia', *Agricultural Water Management*, 95(4), pp. 391–399. doi: 10.1016/j.agwat.2007.10.020.

Burdack, D., Biewald, A. and Lotze-campen, H. (2014) 'Cap-and-trade of Water Rights', *GAIA - Ecological Perspectives for Science and Society*, 23(4), pp. 318–326. doi: https://doi.org/10.14512/gaia.23.4.7.

Campos, V. and Fracalanza, A. P. (2010) 'Governança das Águas no Brasil: Conflitos pela Apropriação da Água e a Busca da Integração como Consenso.', *Ambiente & Sociedade*, 13(2), pp. 365–382. doi: http://dx.doi.org/10.1590/S1414-753X2010000200010.

Cassuto, D. N. and Sampaio, R. S. R. (2011) 'Keeping it legal: Transboundary management challenges facing Brazil and the Guarani', *Water International*, 36(5), pp. 661–670. doi: 10.1080/02508060.2011.599779.

Comissão dos Povos Originários e Comunidades Tradicionais (PCTS) (2018) *Dossiê: Violações aos Territórios Tradicionais e Crimes Contra as Águas*. Available at: https://pt.scribd.com/document/374527485/Dossie-Aguas-Fama-20mar2018-Versao-Final-Sandra (Accessed: 9 May 2019).

Comissão Pastoral da Terra (CPT) (2017) *Conflitos no Campo Brasil 2017*. Edited by A. Canuto, C. R. da S. Luz, and T. V. P. Andrade. Goiânia: CPT Nacional.

Companhia de Pesquisa de Recursos Minerais (CPRM) (2012) *Projeto Rede Integrada de Monitoramento das Águas Subterrâneas: Relatório diagnóstico Aquífero Guarani no Estado do Rio Grande do Sul. Bacia Sedimentar do Paraná*. Belo Horizonte.

Confederação da Agricultura e Pecuária do Brasil (CNA) (2018a) 'Atuação da CNA evita aumento abusivo de cobrança pelo uso da água na Bacia do Rio Doce', 12 September. Available at: https://www.cnabrasil.org.br/noticias/atuação-da-cna-evita-aumento-abusivo-de-cobrança-pelo-uso-da-água-na-bacia-do-rio-doce (Accessed: 9 May 2019).

Confederação da Agricultura e Pecuária do Brasil (CNA) (2018b) 'Comissão de Irrigação da CNA debate aumento da cobrança pelo uso da água na bacia do São Francisco', 15 August. Available at: https://www.cnabrasil.org.br/noticias/comissao-de-irrigacao-da-cna-debate-aumento-da-cobranca-pelo-uso-da-agua-na-bacia-do-sao-francisco (Accessed: 9 May 2019).

Confederação Nacional da Indústria (CNI) (2018) *Mapa estratégico da indústria 2018-2022*. Brasília. Available at: https://bucket-gw-cni-static-cms-si.s3.amazonaws.com/media/filer_public/ee/50/ee50ea49-2d62-42f6-a304-1972c32623d4/mapa_final_ajustado_leve_out_2018.pdf (Accessed: 10 May 2019).

Confederação Nacional da Indústria (CNI) and Instituto Aço Brasil (2012) *A indústria do aço no Brasil*. Brasilia. Available at: www.cni.org.br (Accessed: 10 May 2019).

Confederação Nacional dos Trabalhadores na Agricultura (CONTAG) (2016) 'Agricultura familiar e uso da água: um debate ainda por fazer!', *Comunicação CONTAG*, 22 March. Available at: http://www.contag.org.br/indexdet.php?modulo=portal&acao=interna&codpag=101&id=11290&mt=1&nw=1 (Accessed: 9 May 2019).

Confederação Nacional dos Trabalhadores na Agricultura (CONTAG) (2017a) 'Água é um direito, é vida!', *Comunicação CONTAG*, 22 November. Available at: http://www.contag.org.br/indexdet2.php?modulo=portal&acao=interna2&codpag=101&id=12

660&mt=1&nw=1&ano=&mes= (Accessed: 9 May 2019).

Confederação Nacional dos Trabalhadores na Agricultura (CONTAG) (2017b) 'Região Sudeste discute a questão hídrica e cobranças abusivas pelo uso da água pela agricultura familiar', *Comunicação CONTAG*, 8 November. Available at: http://www.contag.org.br/indexdet2.php?modulo=portal&acao=interna2&codpag=101&id=12631&mt=1&nw=1&ano=&mes= (Accessed: 9 May 2019).

Conselho Nacional De Recursos Hídricos (CNRH) (2001) *Resolução 16 de 8 de Maio de 2001.*

Conselho Nacional De Recursos Hídricos (CNRH) (2005) *Resolução 48 de 21 de Março de 2005.* Brasil.

Costa, A. L. Da and Mertens, F. (2015) 'Governança, Redes E Capital Social No Plenário Do Conselho Nacional De Recursos Hídricos Do Brasil', *Ambiente & Sociedade*, 18(3), pp. 153–170. doi: 10.1590/1809-4422asoc865v1832015.

Costa, J. V. M. and Tybusch, J. S. (2015) 'Uma abordagem crítica sobre a outorga dos direitos de uso dos recursos hídricos no Brasil', *Anais da Semana Acadêmica Fadisma Entrementes*, (12), pp. 1–16.

Dalhuisen, J. *et al.* (2003) 'Price and Income Elasticities of Residential Water Demand : A Meta-Analysis', *Land Economics*, 79(2), pp. 292–308. doi: 10.2307/3146872.

Demir, I. and Aktan, C. C. (2016) 'Resistance to Change in Government: Actors and Factors that Hinder Reform in Government', *International Journal of Social Sciences and Humanity Studies*, 8(2), pp. 226–242.

Dietz, T., Frey, R. S. and Rosa, E. A. (2001) 'Risk , Technology , and Society', in Dunlap, R. E. and Michelson, W. (eds) *Handbook of Environmental Sociology*. 1st edn. Greenwood.

Dietz, T., Ostrom, E. and Stern, P. C. (2003) 'TRAGEDY OF THE COMMONS? The Struggle to Govern the Commons', *Science*, 302(12 december 2003), pp. 1907–1910. Available at: www.sciencemag.org.

Dryzek, J. S. (2013) *The politics of the earth : environmental discourses*. 3rd edn. Oxford University Press. Available at: https://global.oup.com/academic/product/the-politics-of-the-earth-9780199696000?cc=us&lang=en& (Accessed: 7 May 2019).

Espey, M., Espey, J. and Shaw, W. D. (1997) 'Price elasticity of residential demand for water.pdf', *Water Resources Research*, 33(6), pp. 1369–1374. doi: https://doi.org/10.1029/97WR00571.

Federação das Indústrias do Estado de São Paulo (FIESP) (no date) *Cobrança pelo uso da água: ações da Fiesp*, *Portal Fiesp*. Available at: https://www.fiesp.com.br/indices-pesquisas-e-publicacoes/notas-informativas-e-de-esclarecimentos-cobranca-pelo-uso-da-agua-acoes-da-fiesp/ (Accessed: 10 May 2019).

Foleto, E. M. (2018) 'O Contexto dos Instrumentos de Gerenciamento dos Recursos Hídricos no

Brasil', *Geoambiente On-line*, (30), pp. 39–59. doi: 10.5216/REVGEOAMB.V0I30.52823.

Fonseca, A. and Gabriel, C. F. (2015) 'Análise da influência da tarifação em seis indicadores operacionais e de qualidade dos serviços de abastecimento de água no Brasil', *Engenharia Sanitaria e Ambiental*, 20(2), pp. 219–224. doi: 10.1590/s1413-41522015020000129123.

Foster, S. *et al.* (2009) *The Guarani Aquifer Initiative - Towards Realistic Groundwater Management in a Transboundary Context*. Washington, DC. Available at: https://isarm.org/publication/guarani-aquifer-initiative-towards-realistic-groundwater-management-transboundary (Accessed: 7 May 2019).

Fracalanza, A. P., Jacob, A. M. and Eça, R. F. (2013) 'Justiça ambiental e práticas de governança da água: (re) introduzindo questões de igualdade na agenda', *Ambiente & Sociedade*, 16(1), pp. 19–38. doi: 10.1590/s1414-753x2013000100003.

Fundação SOS Mata Atlântica (2007) 'Conheça a Frente Parlamentar Ambientalista', *Fundação SOS Mata Atlântica*, 14 February. Available at: http://homologaportal.sosma.org.br/1888/conheca-a-frente-parlamentar-ambientalista/ (Accessed: 9 May 2019).

Fundação SOS Mata Atlântica (2017) *Relatório Annual de Atividades 2017*. Available at: https://www.sosma.org.br/wp-content/uploads/2018/10/AF_RA_SOSMA_2017_web.pdf (Accessed: 9 May 2019).

G1 Bauru e Marília (2014) 'Fiscalização encontra cerca de 40 poços irregulares por dia em Bauru', *G1*, 5 November. Available at: http://g1.globo.com/sp/bauru-marilia/noticia/2014/11/fiscalizacao-encontra-cerca-de-40-pocos-irregulares-por-dia-em-bauru.html (Accessed: 9 May 2019).

Garrido, R. J. S. (2018) *Contribuições à Cobrança pelo Uso da Água no Brasil - Abordagem Econômica e Avaliação de Preços Ótimos Vis- à-Vis Preços Praticados na Bacia do Rio Paraíba do Sul*. Universidade de Brasília - UnB.

Gisser, M. and Sanchez, D. A. (1980) 'Competition versus Optimal Control in Grounwater Pumping', *Water Resources Research*, 16(4), pp. 638–642. doi: 10.1029/WR016i004p00638.

Goulder, L. H. (2013) 'Markets for Pollution Allowances: What Are the (New) Lessons?', *Journal of Economic Perspectives*, 27(1), pp. 87–102. doi: 10.1257/jep.27.1.87.

Governo do Estado de São Paulo (2015) *Orientações para Utilização de Águas Subterrâneas no Estado de São Paulo*. São Paulo.

Gruber, J. (2013) *Public finance and public policy*. 4th edn. Worth Publishers.

Guimarães, L. R. (2007) *Desafios Jurídicos na Proteção do Sistema Aquífero Guarani*. Pontifícia Universidade Católica de São Paulo.

Hagger, F. P. V. and D'almeida, M. L. (2008) 'Aguas Subterrâneas e o Direito Constitucional', *Anais do XV Congresso Brasileiro de Águas Subterrâneas*, pp. 1–15. Available at:

https://aguassubterraneas.abas.org/asubterraneas/issue/view/1178.

Hajer, M. and Versteeg, W. (2005) 'A decade of discourse analysis of environmental politics: Achievements, challenges, perspectives', *Journal of Environmental Policy and Planning*, 7(3), pp. 175–184. doi: 10.1080/15239080500339646.

Hirata, R. *et al.* (2019) *A revolução silenciosa das águas subterrâneas no Brasil: uma análise da importância do recurso e os riscos pela falta de saneamento*.

Hirota, M. (2014) 'Faltou água no debate eleitoral', *Fundação SOS Mata Atlântica*, 25 September. Available at: http://homologaportal.sosma.org.br/90346/faltou-agua-debate-eleitoral/ (Accessed: 9 May 2019).

Hoffman, A. J. (2001) 'Linking Organizational and Field-Level Analyses', *Organization & Environment*, 14(2), pp. 133–156. doi: 10.1177/1086026601142001.

Idoeta, P. A. (2015) 'A agricultura é vilã ou vítima na crise hídrica?', *BBC News Brasil*, 4 March. Available at: https://www.bbc.com/portuguese/noticias/2015/03/150302_agua_agricultura_pai (Accessed: 9 May 2019).

Instituto Aço Brasil (2018) *Relatório de Sustentabilidade da indústria brasileira do aço*. Available at: http://www.acobrasil.org.br/sustentabilidade/assets/pdfs/Aço Brasil » Completo.pdf (Accessed: 10 May 2019).

Ioris, A. A. R. (2005) 'Água, cobrança e commodity: a geografia dos recursos hídricos no Brasil', *Revista Terra Livre*, 2(25), pp. 121–137.

Ioris, A. A. R. (2012) 'Applying the strategic-relational approach to urban political ecology: The water management problems of the baixada fluminense, Rio de Janeiro, Brazil', *Antipode*, 44(1), pp. 122–150. doi: 10.1111/j.1467-8330.2011.00848.x.

Jandoc, K. *et al.* (2014) *University of Hawai ` i at M ā noa Department of Economics Working Paper Series Working Paper No . 14-16 Towards an Economics of Irrigation Networks By Karl Jandoc Ruben Juarez Towards an Economics of Irrigation Networks*. 14–15. Honolulu.

Jesus, M. (2019) 'Frente Parlamentar Ambientalista deve conter retrocessos e promover uma transição para o desenvolvimento sustentável do país', *Frente Parlamentar Ambientalista*, 8 March. Available at: http://www.frenteambientalista.com/frente-parlamentar-ambientalista-deve-conter-retrocessos-e-promover-uma-transicao-para-o-desenvolvimento-sustentavel-do-pais/ (Accessed: 10 May 2019).

Jordan, A. *et al.* (2011) 'Policy Instruments in Practice', in Dryzek, J. S., Norgaard, R. B., and Schlosberg, D. (eds) *The Oxford Handbook of Climate Change and Society*. New York: Oxford University Press, pp. 536–549. doi: 10.1093/oxfordhb/9780199566600.003.0036.

Junqueira, G. D. (2015) 'Água: para novos desafios, atitudes inéditas', *Agência FPA*, 10 March. Available at: https://agencia.fpagropecuaria.org.br/2015/03/10/agua-para-novos-desafios-

atitudes-ineditas/ (Accessed: 9 May 2019).

JusBrasil (2012) 'Custo da água preocupa a indústria', *Agência Nacional de Águas (ANA)*, 29 February. Available at: http://www3.ana.gov.br/portal/ANA/noticias-antigas/custo-da-a-gua-preocupa-a-indaostria.2019-03-15.9630424963 (Accessed: 10 May 2019).

Kolstad, C. D. (2000) *Environmental economics*. Oxford University Press. Available at: https://ideas.repec.org/a/eee/jrpoli/v27y2001i1p54-55.html (Accessed: 8 May 2019).

Lavoratti, L. (2015) 'Menos imposto para as águas', *Frente Parlamentar Ambientalista*, 26 June. Available at: http://www.frenteambientalista.com/menos-imposto-para-as-aguas/ (Accessed: 10 May 2019).

Lima, B. (2018) 'FNP reafirma rejeição ao novo marco legal do saneamento', *Frente Nacional de Prefeitos (FNP)*, 31 October. Available at: http://www.fnp.org.br/noticias/item/1912-fnp-reafirma-rejeicao-ao-novo-marco-legal-do-saneamento?highlight=WyJhZ3VhIl0= (Accessed: 10 May 2019).

Lubell, M. *et al.* (2017) 'Transaction Costs and the Perceived Effectiveness of Complex Institutional Systems', *Public Administration Review*, 77(5), pp. 668–680. doi: 10.1111/puar.12622.

Lucca, L. M. S. (2009) *A tutela do sistema Aquífero Guarani: um processo de integração regional*. Universidade Regional Integrada do Alto Uruguai e das Missões.

Malvezzi, R. (2015) 'A volta do mercado de outorgas de água', *Comissão Pastoral da Terra*, 9 November. Available at: https://www.cptnacional.org.br/publicacoes/noticias/artigos/2960-a-volta-do-mercado-de-outorgas-de-agua (Accessed: 9 May 2019).

Manzione, R. L. (2015) *Águas subterrâneas : conceitos e aplicações sob uma visão multidisciplinar*. 1a ediçã. Jundiaí: Paco Editorial. Available at: https://www.nhbs.com/aguas-subterraneas-book (Accessed: 8 May 2019).

Matge, P. R. (2018) 'Cidade tem 2,5 mil poços irregulares e só 29 licenciados', *Diario de Santa Maria*, 5 April. Available at: https://diariosm.com.br/notícias/geral/cidade-tem-2-5-mil-poços-irregulares-e-só-29-licenciados-1.2059809 (Accessed: 9 May 2019).

McKay, J. M. (2011) 'Australian water allocation plans and the sustainability objective—conflicts and conflict resolution measures', *Hydrological Sciences Journal*, 56(4), pp. 615–629. doi: 10.1080/02626667.2011.580456.

Ministério do Desenvolvimento Regional (2017) *Sistema Nacional de Informações sobre Saneamento (SNIS) Série Histórica*, *Dados Municipais*. Available at: http://app4.cidades.gov.br/serieHistorica/ (Accessed: 9 May 2019).

Munger, M. C. (2000) *Analyzing policy : choices, conflicts, and practices*. 1st edn. W.W. Norton.

Nassif, L. (2018) 'O PL 495/17 e a privatização da água, por Vicente Andreu', *GGN – O Jornal de Todos os Brasis*, 4 August. Available at: https://jornalggn.com.br/artigos/o-pl-495-17-e-a-

privatizacao-da-agua-por-vicente-andreu/ (Accessed: 10 May 2019).

Nauges, C. and Whittington, D. (2010) 'Estimation of Water Demand in Developing Countries: An Overview', *The World Bank Research Observer*, 25(2), pp. 263–294. doi: 10.1093/wbro/lkp016.

OECD (2015) *Water Resources Governance in Brazil*. Paris. doi: 10.1787/9789264238121-en.

Oh, C. and Svendsen, G. T. (2015) 'Command-And-Control or Taxation? The Cases of Water Regulation in California and Denmark', *Environmental Management and Sustainable Development*, 4(2), p. 141. doi: 10.5296/emsd.v4i2.8358.

Oliveira, F. R. De (2016) 'Avaliação Disponibilidade Hídrica Subterrânea na Bacia do Rio Paraguai'. Cuiabá. Available at: http://www3.ana.gov.br/portal/ANA/gestao-da-agua/planejamento-dos-recursos-hidricos/plano-de-recursos-hidricos-rio-paraguai/grupo-de-acompanhamento/7a-reuniao-do-gap/ana_aguassubterraneas2-anexo3.pdf.

Oliveira, J. C. (2015) 'Deputados e especialistas apontam soluções para enfrentar crise hídrica', *Frente Parlamentar Ambientalista*, 9 February. Available at: http://www.frenteambientalista.com/deputados-e-especialistas-apontam-solucoes-para-enfrentar-crise-hidrica/ (Accessed: 9 May 2019).

Oliveira, R. C. de M., Lima, P. V. P. S. and Sousa, R. P. (2017) 'Gestão ambiental e gestão dos recursos hídricos no contexto do uso e ocupação do solo nos municípios', *Gestão & Regionalidade*, 33(97), pp. 48–64. doi: 10.13037/gr.vol33n97.3101.

Ostrensky, V. P. and Garcia, J. R. (2017) 'A cobrança pelo uso da água na Região Metropolitana de Curitiba: uma análise dos impactos econômicos no setor industrial', *Revista da FAE*, 20(2), pp. 7–20. Available at: https://revistafae.fae.edu/revistafae/article/view/271 (Accessed: 9 May 2019).

Perroni, J. C. A. and Wendland, E. C. (2008) 'Avaliação das Condições de Ocorrência e Explotação do Sistema Aquífero Guarani em São Carlos -- SP', *Águas Subterrâneas*, 22(1), pp. 13–24. doi: 10.14295/ras.v22i1.8571.

Petterini, F. C. (2018) 'Mercado de Água: Como Aconteceu nos EUA e Como Pode Acontecer no Brasil', *Revista Internacional Interdisciplinar INTERthesis*, 15(1), pp. 130–143. doi: 10.5007/1807-1384.2018v15n1p130.

Portal FNP (2018) 'FNP e outras entidades lançam Nota Conjunta contra MP 844/2018', *Frente Nacional de Prefeitos (FNP)*, 26 October. Available at: http://www.fnp.org.br/noticias/item/1908-fnp-e-outras-entidades-lancam-nota-conjunta-contra-mp-844-2018?highlight=WyJhZ3VhIl0= (Accessed: 10 May 2019).

Projeto para a Proteção Ambiental e Desenvolvimento Sustentável do Sistema Aquífero Guarani (2007) *Síntese hidrogeológica do Sistema Aquífero Guarani*. 5. Available at: http://www.terrabrasilis.org.br/ecotecadigital/index.php/estantes/diversos/1138-aquifero-guarani-05-sintese-hidrogeologica-do-sistema-aquifero-guarani (Accessed: 9 May 2019).

Qayum, A. *et al.* (2016) 'Environmental taxation based integrated modeling towards sustainable environmental conservation approach', *Environmental Systems Research*, 5(1), p. 23. doi: 10.1186/s40068-016-0074-1.

Reynaud, A. (2015) *Modelling Household Water Demand in Europe Insights from a Cross-Country*. Report EUR 27310 EN. Ispra. doi: 10.2788/95638.

Ribeiro, M. (2015) 'Água: tragédia anunciada', *Frente Parlamentar Ambientalista*, 30 January. Available at: http://www.frenteambientalista.com/agua-tragedia-anunciada/ (Accessed: 10 May 2019).

Ribeiro, S. (2016) 'As faces da privatização da água', *Associação Nacional dos Serviços Municipais de Saneamento (Assemae)*, 6 June. Available at: http://www.assemae.org.br/artigos/item/1625-as-faces-da-privatizacao-da-agua?highlight=WyJtZXJjYWRvIiwiZGUiLCJcdTAwZTFndWEiLCJcdTAwZTFndWEnLCIsIlx1MDBlMWd1YScuIiwiJ1x1MDBlMWd1YSIsIidcdTAwZTFndWEnIiwibWVyY2FkbyBkZSIsIm1lcmNhZG8gZGUgXHUwMGUxZ3VhIiwiZGUgXHUw (Accessed: 9 May 2019).

Rocha, J. (2018) 'Declaração final do FAMA reafirma a água como direito humano e direito da natureza', *Cáritas Brasileira*, 22 March. Available at: http://caritas.org.br/declaracao-final-do-fama-reafirma-a-agua-como-direito-humano-e-direito-da-natureza/38329 (Accessed: 9 May 2019).

Rodrigues, M. J. (2018) 'Melhorar infraestrutura e sistema de alocação de água reduzirão riscos de escassez', *Agência CNI de Notícias*, 26 November. Available at: https://noticias.portaldaindustria.com.br/noticias/sustentabilidade/melhorar-infraestrutura-e-sistema-de-alocacao-de-agua-reduzirao-riscos-de-escassez-/ (Accessed: 10 May 2019).

Salusitado, V. (2018) 'Cobrança pelo uso da água dos rios PCJ passa a ser atualizada todo ano', *Associação Brasileira Das Concessionárias Privadas de Serviços Públicos de Água e Esgoto (ABCON)*, 17 January. Available at: http://abconsindcon.com.br/noticias/cobranca-pelo-uso-da-agua-dos-rios-pcj-passa-ser-atualizada-todo-ano/ (Accessed: 10 May 2019).

Santos de Souza, J. and Moraes, B. S. (2016) 'Análise das Políticas Públicas Implementadas para a Gestão dos Recursos Hídricos no Brasil', *Ciência e Natura*, 38(2), pp. 913–919. doi: 10.5902/2179-460X21896.

Sayre, S. S. and Taraz, V. (2019) 'Groundwater depletion in India: Social losses from costly well deepening', *Journal of Environmental Economics and Management*, 93, pp. 85–100. doi: 10.1016/j.jeem.2018.11.002.

Schulz, C. *et al.* (2017) 'The Value Base of Water Governance: A Multi-Disciplinary Perspective', *Ecological Economics*, 131, pp. 241–249. doi: 10.1016/j.ecolecon.2016.09.009.

da Silva Junior, J. M. (2015) 'Água e agronegócio', *Agência FPA*, 23 March. Available at: https://agencia.fpagropecuaria.org.br/2015/03/23/agua-e-agronegocio/ (Accessed: 9 May 2019).

Da Silveira, P. A. C. V. and Sartori, P. M. (2017) 'A Extrafiscalidade e a Tributação dos Serviços de Fornecimento de Água Potável: Possibilidades e Alternativas', *Direito e Desenvolvimento*, 8(2), pp. 38–54. doi: 10.25246/direitoedesenvolvimento.v8i2.540.

Sousa Júnior, W. *et al.* (2016) 'Water: Drought, Crisis and Governance in Australia and Brazil', *Water*, 8(11), pp. 493–514. doi: 10.3390/w8110493.

Sperafico, D. (2017) 'Desastres naturais e o agronegócio brasileiro', *Agência FPA*, 24 March. Available at: https://agencia.fpagropecuaria.org.br/2017/03/24/desastres-naturais-e-o-agronegocio-brasileiro/ (Accessed: 9 May 2019).

Sugg, Z. P. *et al.* (2015) 'Transboundary groundwater governance in the Guarani Aquifer System: reflections from a survey of global and regional experts', *Water International*. Routledge, 40(3), pp. 377–400. doi: 10.1080/02508060.2015.1052939.

Tierney, K. J. (1999) 'Toward a critical sociology of risk', *Sociological Forum*. Kluwer Academic Publishers-Plenum Publishers, 14(2), pp. 215–242. doi: 10.1023/A:1021414628203.

Vialli, A. (2012) 'Projeções de escassez de água no futuro e cobrança por seu uso em alguns Estados levam empresas a racionalizar processos e práticas.', *Instituto Aço Brasil*, 24 October. Available at: http://www.acobrasil.org.br/site2015/noticia_interna.asp?id=10392 (Accessed: 10 May 2019).

Villar, P. C. and Ribeiro, W. C. (2009) 'Sociedade e gestão do risco: o aquífero Guarani em Ribeirã o Preto-SP, Brasil', *Revista de geografía Norte Grande*, (43), pp. 51–64. doi: 10.4067/S0718-34022009000200003.

Xavier, C. (2017) 'Pagamento de água gera polêmica entre produtores da região do rio Paranaíba', *Canal Rural*, 11 December. Available at: https://canalrural.uol.com.br/programas/pagamento-agua-gera-polemica-entre-produtores-regiao-rio-paranaiba-70403/ (Accessed: 10 May 2019).

Yin, R. K. (1993) *Applications of case study research*. SAGE Publications.

Appendix I

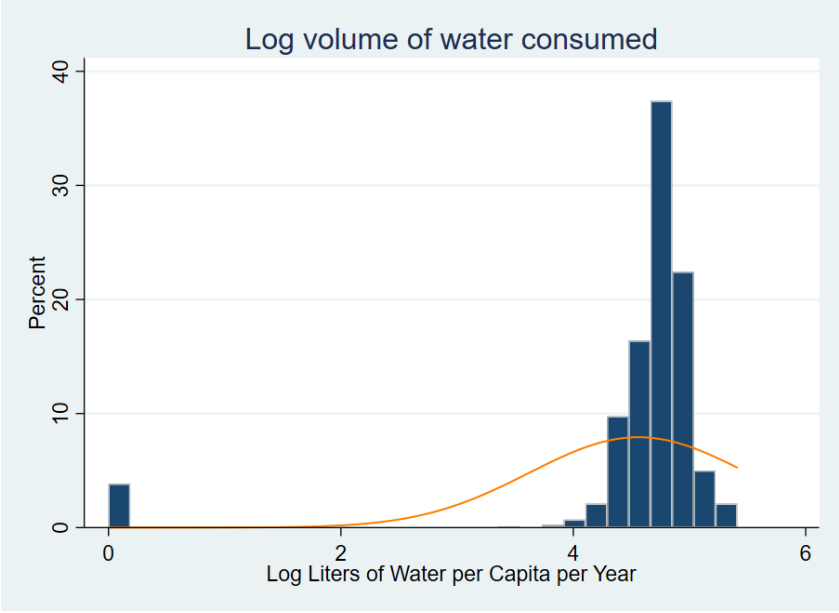
List of Municipalities that *Volume of water consumed* = 0m^3/year

Municipalities that *Volume of water consumed* = 0 m3/year

Municipality	State	Year	Population	Municipality Classification	Municipality	State	Year	Population	Municipality Classification
Itiquira	MT	2015	12472	Rural	Anitápolis	SC	2008	.	Rural
Itiquira	MT	2013	12109	Rural	Anitápolis	SC	2009	.	Rural
Itiquira	MT	2002	.	Rural	Anitápolis	SC	2013	3259	Rural
Itiquira	MT	2016	12620	Rural	Anitápolis	SC	2012	3211	Rural
Itiquira	MT	2014	12293	Rural	Anitápolis	SC	2014	3256	Rural
Dilermando de Aguiar	RS	2013	3144	Rural	Rio Rufino	SC	2011	2438	Rural
Dilermando de Aguiar	RS	2016	3133	Rural	Rio Rufino	SC	2009	.	Rural
Dilermando de Aguiar	RS	2014	3140	Rural	Rio Rufino	SC	2014	2484	Rural
Dilermando de Aguiar	RS	2015	3136	Rural	Treviso	SC	2006	.	Urban
Ibarama	RS	2015	4518	Rural	Gavião Peixoto	SP	2014	4662	Urban
Ibarama	RS	2016	4518	Rural	Luís Antônio	SP	2011	11603	Urban
Ibarama	RS	2012	4368	Rural	Luís Antônio	SP	2012	11910	Urban
Ibarama	RS	2013	4516	Rural	Luís Antônio	SP	2013	12704	Urban
Ibarama	RS	2014	4517	Rural	Saltinho	SP	2014	7714	Urban
Jari	RS	2014	3660	Rural	São Simão	SP	2012	14448	Urban
Jari	RS	2016	3650	Rural	Tejupá	SP	2014	4788	Rural
Jari	RS	2015	3655	Rural	Tejupá	SP	2011	4769	Rural
Jari	RS	2013	3665	Rural	Tejupá	SP	2009	.	Rural
Novo Cabrais	RS	2010	3855	Rural	Tejupá	SP	2010	4809	Rural
São José do Sul	RS	2009	.	Rural	Tejupá	SP	2012	4730	Rural

Log transformation to make dependent variable present a normal distribution

The histogram shows the distribution of the dependent variable transformed in logarithm. Compared to the original distribution, the log one looks more normally distributed, but it still presents skew.



Bootstrap Regression Analysis Result

```
Bootstrap replications (1000)
----+--- 1 ---+--- 2 ---+--- 3 ---+--- 4 ---+--- 5
..................................................    50
..................................................   100
..................................................   150
..................................................   200
..................................................   250
..................................................   300
..................................................   350
..................................................   400
..................................................   450
..................................................   500
..................................................   550
..................................................   600
..................................................   650
..................................................   700
..................................................   750
..................................................   800
..................................................   850
..................................................   900
..................................................   950
..................................................  1000
```

Linear regression

Number of obs	= 819
Replications	= 1,000
Wald chi2(4)	= 74.32
Prob > chi2	= 0.0000
R-squared	= 0.2590
Adj R-squared	= 0.2554
Root MSE	= 29118.0223

watconpcap	Observed Coef.	Bootstrap Std. Err.	z	P>|z|	Normal-based [95% Conf.	Interval]
year	2511.129	571.8204	4.39	0.000	1390.381	3631.876
tariffm3	-13691.51	2062.107	-6.64	0.000	-17733.17	-9649.855
pop	.0569886	.0079188	7.20	0.000	.041468	.0725091
gdppcap	.2070321	.0885489	2.34	0.019	.0334795	.3805848
_cons	-4976448	1149023	-4.33	0.000	-7228491	-2724405

```
. regress watconpcap tariffm3, vce(bootstrap, rep(1000))
(running regress on estimation sample)

Bootstrap replications (1000)
----+--- 1 ---+--- 2 ---+--- 3 ---+--- 4 ---+--- 5
..................................................    50
..................................................   100
..................................................   150
..................................................   200
..................................................   250
..................................................   300
..................................................   350
..................................................   400
..................................................   450
..................................................   500
..................................................   550
..................................................   600
..................................................   650
..................................................   700
..................................................   750
..................................................   800
..................................................   850
..................................................   900
..................................................   950
..................................................  1000

Linear regression                               Number of obs     =         81
> 9
                                                Replications      =      1,00
> 0
                                                Wald chi2(1)      =      53.5
> 2
                                                Prob > chi2       =     0.000
> 0
                                                R-squared         =     0.177
> 2
                                                Adj R-squared     =     0.176
> 2
                                                Root MSE          = 30627.029
> 4

------------------------------------------------------------------------------
> -
             |   Observed   Bootstrap                         Normal-based
  watconpcap |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval
> ]
-------------+----------------------------------------------------------------
> -
    tariffm3 |  -10875.65   1486.633    -7.32   0.000     -13789.4   -7961.90
> 8
       _cons |   82580.32   3041.863    27.15   0.000     76618.38    88542.2
> 6
------------------------------------------------------------------------------
```

Appendix II

The Case of Ribeirao Preto - Methodology

To calculate the market impact by the introduction of a Pigouvian tax to water tariff in Ribeirao Preto, the following steps were carried out:

I. Calculation of Price Elasticity of water demand
II. Calculation of total revenue from tariff at the optimal level of consumption based on Price Elasticity
III. Estimation of average tariff at the optimal level of consumption

This example is purely hypothetical, despite the attempt to utilize data available on the city of Ribeirao Preto.

a) Price Elasticity of water demand

Price Elasticity for water was defined using the lower and upper range found in the literature (see discussion on p. 11), as follows:

Price Elasticity	Estimate
Upper bound	*-0.1*
Lower bound	*-0.5*

b) Calculation of total revenue from tariff at the optimal level of consumption based on Price Elasticity

Total revenue from tariff at the optimal level of consumption was calculated using secondary data from *Villar and Ribeiro (2009)*. Villar and Ribeiro (2009) described that Ribeirao Preto level of water consumption from Aquifer was at 95,700,000 m^3, but the recharge levels of the aquifer was three times lower (31,900,000 m^3). To calculate total revenue from tariff at the optimal level of consumption, the following variables will be considered:

ε = Price Elasticity of water demand for Ribeirao Preto	[-0.5; -0.1]
$\mathbf{Q_1}$ = Actual level of water consumption	95,700,000 m^3
$\mathbf{Q_2}$ = Ideal level of consumption based on the Aquifer's recharge levels)	31,900,000 m^3
$\mathbf{P_1}$ = Total revenue from water tariff practiced (BRL 2.39/ m^3*95,700,000 m^3)	BRL 228,723,000.00
$\mathbf{P_2}$ = Total revenue from tariff at the optimal level of consumption	**?**

Transforming the equation of price elasticity, we can find the total revenue from tariff at the optimal level of consumption. It is important to remember that in situations like this, instead of using the Q1 and P1 as the divisor, it is conventionally used the Midpoint.

Using **ε** = -0.5

$$\varepsilon = \frac{\%\Delta \text{ Quantity Demanded}}{\%\Delta \text{ Price}} = \left|\frac{(Q2 - Q1)/(Q1)}{(P2 - P1)/(P1)}\right| \leftrightarrow$$

$$0.5 = \left|\frac{(31{,}900{,}000 - 95{,}700{,}000)/(95{,}700{,}000)}{(P2 - 228{,}723{,}000)/(228{,}723{,}000)}\right|$$

$$P2 = \left|\left(\left|\frac{0.666}{-0.5} * 228{,}723{,}000\right|\right) + 228{,}723{,}000\right|$$

$$P2lower = 304{,}659{,}036 \ + \ 228{,}723{,}000 \ = \ \boldsymbol{BRL\ 533{,}328{,}036}$$

Using **ε** = -0.1

$$\varepsilon = \frac{\%\Delta \text{ Quantity Demanded}}{\%\Delta \text{ Price}} = \left|\frac{(Q2 - Q1)/(Q1)}{(P2 - P1)/(P1)}\right| \leftrightarrow$$

$$-0.1 = \left|\frac{(31{,}900{,}000 - 95{,}700{,}000)/(95{,}700{,}000)}{(P2 - 228{,}723{,}000)/(228{,}723{,}000)}\right|$$

$$P2 = \left|\left(\left|\frac{0.666}{-0.1} * 228{,}723{,}000\right|\right) + 228{,}723{,}000\right|$$

$$P2upper = 1{,}523{,}295{,}180 \ + \ 228{,}723{,}000 \ = \ \boldsymbol{BRL\ 1{,}752{,}018{,}180}$$

c) Estimation of average tariff at the optimal level of consumption

Based on the previous equations, we find that total revenue from tariff would amount to a range of BRL 533,328,036.00 to BRL 1,752,018,180.00, at a water consumption level of 31,900,000 m^3. At that level, *Average water tariff (BRL / m^3)* at optimal level would range between **BRL 16.71 / *m^3*** and **BRL 54.92 / *m^3***.

The difference between the tariff currently practiced (BRL 2.39 / *m^3*) and the optimal tariff (between BRL 16.71 / *m^3* and BRL 54.92 / *m^3*) is the Pigouvian tax (between BRL 14.32 / *m^3* and BRL 52.53 / *m^3*)

Appendix III

List of Associations and Institutions Analyzed

Urban supply

Associação Brasileira das Concessionárias Privadas de Serviços Públicos de Água e Esgoto – ABCON
Secretaria Nacional de Saneamento Ambiental
Instituto Trata Brasil

Mineral water users

Associação Brasileira da Indústria de Água Mineral (ABINAM)
Associação Brasileira das Indústrias de Refrigerantes e de Bebidas não Alcoólicas (ABIR)

Industries:

Associação Brasileira de Metalurgia, Materiais e Mineração (ABM)
Instituto Aço Brasil
Associação Nacional dos Fabricantes de Veículos Automotores (ANFAVEA)
Associação Brasileira da Indústria Têxtil e de Confecção (Abit)
Confederação Nacional da Indústria (CNI)

Agribusiness:

Confederação Nacional da Agricultura (CNA)
Confederação Nacional dos Trabalhadores Rurais Agricultores e Agricultoras Familiares (Contag)
Associação Brasileira das Indústrias Exportadoras de Carnes (ABIEC)
Associação Brasileira de Criadores (ABC)
Associação Brasileira de Celulose e Papel (BRACELPA)

Environmental Groups:

ONG Cáritas Brasileira
Fundação SOS Mata Atlântica
Comissão Pastoral da Terra – CPT
Instituto Brasileiro de Proteção Ambiental (PROAM)

Governmental Agencies

Agência Nacional de Águas (ANA)
Companhia de Pesquisa de Recursos Minerais (CPRM)
Embrapa
Ibama

Other

Associação Brasileira de Recursos Hídricos (ABRH)

Appendix IV

Summary of Market Agents Positions

Water Users / Economic Agents	Risk perception of a water collapse	Risk perception of economic impacts			Risk perception of changing the status quo
		Short-term	Long-term	Production Cost	
Governmental Agencies (National Water Agency (ANA), National Water Resources Council)	Have a high concern on quantity and quality water availability. Need more resources.	May perceive positively a Pigouvian Tax for fostering rational use.	May perceive positively a Pigouvian Tax for generating more needed resources and changing water users' behavior.		A Pigouvian Tax would not substantially change the water charge system in place. May be against Cap-and-Trade because it could recreate a private ownership of water, as well as cause market and regulation insecurity.
Agribusiness Sector	Have an increased concern on water availability and advocate for more policies that rewards positive environmental practices.			May be against a Pigouvian Tax or a Cap-and-Trade for fear of increasing water access costs.	May be against a Pigouvian Tax because water charges would be more dictated by environmental needs, than political arrangements where the sector has a lot of power. May be against Cap-and-Trade because it could bring unpredictability to water price. However, may be in favor of a Cap-and-Trade in situations of water scarcity because the sector could increase its bargain power, compared to the present regulation that defines priority of water use to human and animal consumption.
Family-Based Agriculture Sector **Environmental Justice Groups**	Have an increased concern on water availability and advocate for more policies that	Perceive any market-based approach as privatizing the	Perceive any market-based approach as privatizing the		Would be against changing the current regulatory system because would interpret as benefiting more

	rewards good environmental practices.	access to water and impacting low-income groups.	access to water and impacting low-income groups.		powerful economic and political groups.
Environmental groups	Have an increased concern on water availability and advocate for more policies that rewards good environmental practices.	May perceive positively economic mechanisms for fostering rational use from the public	May perceive positively economic mechanisms for fostering the implementation of new technology from utility companies and appliances		May favor a change in Pigouvian Tax because it would push for a more stringent water charge. May be against Cap-and-Trade because the Bills under consideration would recreate a private ownership of water.
Urban Water Supplier	Have an increased concern on water availability due to the recent water crisis.	May perceive positively economic mechanisms for fostering rational use from the public	May perceive positively economic mechanisms for fostering the implementation of new technology from utility companies and appliances	May perceive an increase in cost as an adjustment to efficiency costs	May not be very resistant to a change in Pigouvian Tax because it perceives as needed. May be against a Cap-and-Trade because it already has the priority of water use (the current law defines priority of human and animal consumption) in cases of scarcity.
Municipal representation (Confederação Nacional de Municípios (CNM) / Frente Nacional de Prefeitos (FNP))	Mayors' risk perception of a water collapse is limited to their mandate.	May be against a Pigouvian Tax because it can increase water tariff for constituents, creating	Even if a Pigouvian Tax could represent a solution in the long-run, Mayors tend to only have		

		negative pressure on Mayors. May be against a Cap-and-Trade due to the chance of increase in water tariff and increase power lost in terms of water allocation	incentives to act on issues that will be perceived during the mandate.		
Industrial Sectors	Have an increased concern on water availability and advocate for more resources to regulatory agencies to monitor water bodies		May perceive positively economic mechanisms for fostering the implementation of new technology.	Are concerned with the increase in production costs that policies can generate and advocate for a limit in water charge. Might be against Cap-and-Trade if it brings uncertainty to costs of production.	May be resistant to market-based approaches if they do not bring predictability to the market.