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The Regulation of Public Utilities of the Future in Latin America and the Caribbean:

Water Resource Regulation in Brazil

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Abstract*

This paper examines the desirability and feasibility of creating water markets to promote the efficient reallocation of water in Brazil, a country with abundant but unevenly distributed water. A first-principles analysis shows that water markets may dominate other instruments, including water pricing (that is, a price above and beyond the cost of storing and transporting water, to reflect water scarcity). To assess the feasibility of water markets, a readiness assessment is conducted to identify the main barriers to the creation of water markets in Brazil. Policy recommendations are then provided to overcome the barriers identified in the analysis. For illustration purposes, the gains are simulated from a water market in the São Marcos River Basin, where agriculture and hydroelectricity generation activities compete for existing water resources.

JEL classifications: Q01, Q58
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1. Introduction

Brazil is known for its abundance of water. In fact, about 12 percent of the world's freshwater is located in Brazilian territory. However, water resources are unevenly distributed due to the country's geographic heterogeneity. In some places water demand exceeds supply, creating conflicts among multiple users. Such conflicts tend to be aggravated as demand increases and climate change intensifies, therefore making cases of scarcity more frequent.

In the national context, at both federal and state levels there is competition for water allocation among multiple uses such as irrigation, urban water supply, industries and hydropower generation. Water management in Brazil follows the doctrine "first come, first served," giving the right of water use to the user who requests it first. In cases of scarcity, however, there is no legally established mechanism for water reallocation among multiple users. In practice, reallocation is negotiated on a case-by-case basis, regardless of whether or not it leads to economic efficiency (maximization of social welfare). Thus, from an economic point of view, the absence of a reallocation mechanism limits the efficient use of water.

Water resource management faces problems that are characterized as market failures. Depending on water availability, the use of water by an individual located upstream in a river basin may make it impossible for another individual downstream to use the water. This is defined as an externality. In addition, the indiscriminate use of water resources by its different users can lead to a sub-optimal result and cause scarcity, which harms everyone. This is known as the tragedy of the commons. These failures impede achievement of efficient allocation, which is also not solved by the allocative mechanism that is currently used. Therefore, it is necessary to think of reallocation mechanisms typically used to manage scarce resources that are capable of remedying market failures, achieving feasible and efficient allocations.

A common trend over the years and across the developed world is to introduce market mechanisms to improve the allocation of water across users and to provide a price signal for its scarcity value. As the creation of a water market is an example of this kind of mechanism, this paper analyzes the feasibility of implementing this solution to promote efficient reallocation. For illustration purposes, the particular case of the São Marcos River Basin is presented. As occurs extensively in other basins, agriculture and hydroelectricity generation activities compete for the existing resources in the São Marcos River Basin. This case study aims to simulate market gains in a basin where conflict over water use exists.

This study is organized as follows. After this introduction, Section 2 address the economic aspects of natural resource management and the instruments capable of promoting efficient allocation. Section 3 describes the Brazilian water resource management framework and analyzes its limitations. Seeking inspiration from a successful water market creation, Section 4 presents the case of Australia's Murray Darling River Basin. Section 5 presents a readiness assessment, aiming to identify the main barriers to the creation of water markets in Brazil. Section 6 offers policy recommendations to deal with the identified barriers, and the São Marcos River Basin case study is discussed in Section 7. We describe the case and assess the potential gains from the implementation of water markets in that basin.

2. Managing a Scarce Resource

In this section we discuss the need of an economic mechanism that leads to an optimal allocation of water in the presence of scarcity. We start by analyzing the current mechanism and why it poses a problem to an efficient allocation. We then proceed to discuss how a competitive market may solve the problem in question. Finally, we expose the possible barriers to its full implementation and compare it with an alternative price setting approach. To preserve clarity, we let the technical notes with the formal derivations in the Appendix.

2.1 The Current Mechanism in Brazil: A First Come, First Served Approach

We start by exploiting the bottlenecks of the current system. Brazilian water resource management currently takes a "first come, first served" approach.[1] The main economic problem of this approach is the lack of a redistribution scheme. Since the water supply is limited, inefficient allocation may arise from this distribution process.

To illustrate the problem, suppose that demand for water exceeds water availability. This scarcity (excess demand) may present a problem if no market and price system is present. Since there is no link between efficiency and the timing of permit requests, there is nothing to prevent less efficient producers from claiming rights for water use, leaving the most efficient producers without permit. If the most efficient producers—i.e., those who with higher value in the marginal use of water—cannot buy water rights from the less efficient, total welfare will not be maximized.

[1] See more in Subsection 3.4.

2.2 In Defense of a Water Market: The Competitive Framework

In a competitive market, efficient allocation is achieved by trading. The existence of a market for water rights allows the most efficient users to buy rights from their less efficient counterparts, and the competitive equilibrium is achieved with a price at which supply matches demand. Since all participants face the same price, the trading scheme needs little information to work properly.

In the simple case of quasilinear utility, the quantity demanded by each participant is the one that equates marginal utility to price. Since it must be true for all consumers in the market, marginal utility must be the same for all consumers. Note that if one consumer has higher valuation than another for an additional unit of water, an increase in social welfare can be achieved by trading. The individual with lower valuation can sell a one-unit amount of water to the one with higher valuation by a price that is higher than the lower valuation and smaller than the higher valuation. In this case, both consumers end up with a higher utility level after trading the water right.

A similar analysis can be made regarding producers. Suppose water is an input for an industry. With an amount of water x, the producer can produce a quantity $F(x)$ of some good to be sold at price p. To take one example, the production of rice requires water, and the optimal amount of water required by the producer is the one that maximizes its profits. The condition of optimality imposes that the value of the marginal productivity of water must be equal to its cost.

If this is not the case, an opportunity to increase profit is available. If the value of marginal productivity of water is greater than its price, the producer can buy an additional amount of water and pay w while he increases the revenue by the value of marginal productivity of water that is greater than w. In this fashion, the producer can increase profits.

Since this must be true for all profit maximizing producers, the value of marginal productivity must be the same for all of them. The condition of equal marginal value between firms is a condition of Pareto optimality. If marginal valuation differs, then there is an opportunity of reallocation that can increase welfare for all.

2.3 Some Remarks About Equity Concerns

In the previous section we showed how the possibility of trades can improve social welfare—an illustration of the First Social Welfare Theorem. The theorem, however, is silent about equity concerns, which can be addressed in the distribution of water rights. The possibility of trade will

naturally transfer the rights from less productive to more productive users, and the less productive will receive the value from sales of their water rights.

2.4 Computing Total Gains from Trade

To compute total gains from trade, we need to integrate over the marginal benefits of the quantity traded, that is, sum up the differences in the value of marginal productivity for all traded quantities. If we assume that marginal productivity remains constant for the trading quantity, then total gains from trade is just the difference in value of marginal productivity times the quantity traded. In formula,

$$\Delta W = \left(p^i c^i - p^j c^j\right) q$$

In Section 7 we present a simulation of the possible gains from trade using the available SMRB data. There we consider a way to evaluate the value of marginal productivity of water for each irrigator.

2.5 A Possible Barrier to a Competitive Water Market: Externalities

One important result in economics is that the competitive equilibrium is Pareto efficient under some mild conditions. It means that after trade there is no way to increase utility of a market participant without reducing the utility of another. One possible threat to efficiency in the competitive equilibrium is the existence of externalities.

When the action of an agent directly affects the environment of another agent, we say that there is externality. In a consumption externality the utility of one consumer is directly affected by the actions of another consumer. In the production externality the production set of one firm is directly affected by the actions of another agent.

There are basically two reasons to consider an analysis of externality in the use of water. The first is that, in the absence of a proper water market, the use of water from one producer may directly impact the available quantity for other producers. If the good is not excludable but rival, then exhaustion may result in an inefficient outcome. This is the known case in the economic literature of the tragedy of the commons. The second reason is that, since the abstraction of water may generate pollution, its implications for the production of others may also be relevant.

The abstraction of water is different from consumption since water is only temporarily unavailable. Also, since the return of water to the river system may occur with the water in a different state (degree of pollution), an evaluation of externality is required.

To illustrate the problem, consider two producers that use water as input. One abstracts water upstream and produces some amount of pollution (i.e., the water returned to the system does not have the same quality), and another consumes water downstream.

To maximize profit the producer upstream will produce the quantity that equates marginal costs to prices. Since the cost of pollution is zero, the quantity of pollution produced will be up to the point where costs of production are minimized. Presumably, increasing the quantity of pollution lowers the cost of production of the good to be sold. The producer downstream cares but has no control of pollution produced upstream. It can just decide the quantity of the product to be produced and sold downstream.

A social planner should take into consideration the impact of the amount of pollution produced in the costs of the producer downstream. In this way, a welfare maximization problem should maximize the sum of both profits. Since only the private costs are taken into consideration under a missing market for externality, pollution will be overproduced when compared to the social optimum. That occurs because the optimal amount of pollution must consider not only the private costs, but also the social costs generated by the externality.

Two possible solutions to the externality problems are i) distribution of property rights and ii) taxation. The first, as the name suggests, considers the creation of a market for the externality. The idea is to determine a quantity of the externality that is acceptable for trading. With well-established property rights, producers could trade the amount of pollution to be generated.

Since pollution imposes a cost to the producer downstream, it may wish to pay for the pollution right if the damage of pollution exceeds the benefits for the producer upstream. On the other hand, if the benefits of pollution for the producer upstream exceeds the damage caused to the producers downstream, the producer upstream would be willing to pay for the pollution rights from the producer downstream.

In any case, since the social costs of pollution reflected by its price, would be considered by all market participants, the optimal amount of pollution can be achieved with this mechanism. The exact distribution of property rights is not relevant for efficiency, it would only matter for

equity concerns. The irrelevancy of property rights distribution to efficiency is known as the Coase Theorem.

The taxation mechanism considers imposing a tax to the negative externality—in this case, pollution. The idea is to impose a linear tax on the pollution quantity with a marginal tariff equal to the marginal cost of pollution. This mechanism which theoretically could also achieve efficiency in the presence of externality is known as a Pigouvian tax.

The distribution of property rights that can be traded is usually preferred over the imposition of taxes for two reasons. First, to achieve efficiency through a Pigouvian tax the government must know the exact marginal social cost of the externality, which requires private information from producers. Second, the imposition of new taxes is usually not well received by society. Third, the government is susceptible to the pressure of political groups that may not represent society's best interests.

2.6 Some Caveats to a Water Market Implementation in Brazil

Some caveats must be stated with respect to the feasibility of a water market in Brazil. For trade to be possible, property rights must be given (or sold) and enforced. That means that what is to be traded must be well defined by law and enforced by the State. Some monitoring costs are always present in any legal system to avoid property rights violation by third parties. A secure database must also be created to manage the register and exchange of property rights. Last but not least, a delivery system must be created for the exchange of rights to be effective.

With respect to the latter concern, it is important to note that no effective delivery system is available in Brazil. The other caveats are addressed more thoroughly in Section 5, "Readiness Assessment of Brazilian Water Resource Management." Since a river system brings water from upstream to downstream, a natural delivery system allows trade from upstream to downstream but not the contrary in the absence of a proper delivery system. This feasibility constraint must be considered when evaluating the introduction of a water market without further intervention on the infrastructure side.

2.7 Alternative Approaches: Price Setting and Price Discrimination

Price setting occurs when the government determines the price that must be paid for the use of water. This usually occurs by the imposition of a tax per amount of water used, and there are many

ways to set a price with economic meaning. One good price candidate is the competitive equilibrium price. If the government set the price of water equal to the competitive price, then efficiency can be achieved.

The government may also want to set a price in order to maximize the value of permits sold. If this is the objective, then the price set must be a monopoly price which is higher than the competitive price. In this case, the government maximizes tax revenue, but it sacrifices social welfare in turn. Total welfare is reduced, since with a higher price not all available water is used. There is one possible way that, at least theoretically, the government could maximize tax revenue without sacrificing social welfare. It is the case where the government could perfectly discriminate the use of water. Price discrimination involves selling different units of the same good at different prices, either to the same or different consumers. For price discrimination to be implementable, the firm, in our case, the government, must be able to sort consumers and prevent resale.

There are three types of price discrimination. **First-degree price discrimination (or perfect price discrimination)** involves charging the maximum willingness to pay for each unit of the good sold. **Second-degree price discrimination (or non-linear pricing)** involves charging different prices for different amounts of the good purchased. **Third-degree price discrimination** involves charging different prices for different purchasers, but each consumer faces a constant price per unit sold.

As we discuss in Section 3, the current water charge structure in São Francisco River Basin resembles a third-degree price discrimination description. Before we examine this type of price discrimination, we first consider the other two cases. Theoretically, efficiency can be achieved with first-degree price discrimination. The difference between this case and the competitive market is that with perfect price discrimination all the surplus is captured by the seller. Unfortunately, the practical implementation of this mechanism relies on the assumption that the government (seller) would know the willingness-to-pay (value of marginal productivity) for each producer for each unit of water sold. Since this precise information is very difficult to obtain, perfect price discrimination is not feasible.

In second-degree price discrimination, the government's problem is to differentiate the large buyer that has higher willingness-to-pay from the smaller buyer, with lower willingness-to-pay for the same amount of water. The main practical problem is that, since the government does not know which buyer has higher willingness-to-pay for water, the price for the small buyer must

be greater than it would be in an observable willingness-to-pay scenario. This price premium is necessary for the higher willingness-to-pay producer to consume the amount of water intended for him. The welfare loss caused by this price premium is known in the economic literature as an information rent.

Finally, in the third-degree price discrimination, if the government were to maximize its profits (total value of permits sold), it should charge a higher price for consumers with lower elasticity of demand. There are two reasons why the government should not pursue this approach. First, to maximize profits it must use its monopoly power and charge a price for the use of water potentially higher than the social optimum. Second, users with less elasticity of demand are usually those for whom water is essential, which may pose an equity problem.

There are also other important reasons for the government not to pursue a price-setting mechanism in general. Price-setting mechanisms rely on the capacity of the government to obtain precise information as a good estimation of the demand curve. It makes the government susceptible to the pressure of economic and political agents that may have private interests that differ from social interest. After the price is set, there is no guarantee that changes in demand will make the price efficient even if it was efficient before those changes.

In that regard, a water market seems to be a better solution to manage scarce water resources since it requires less information to work properly and efficiency is attained even with changes in demand. In fact, there are already several cases of successful water market implementations, such as Murray Darling Basin in Australia, Western United States and Limarí Valley in Chile (Grafton et al., 2010a).

3. Brazilian Water Resource Management

This section presents the context of Brazil's water resource management. It analyzes the legal, regulatory and policy framework, aiming to identify the key challenges.

3.1 Overall Availability and Use of Water

Around 12 percent of world's freshwater resources are located in Brazilian territory. However, water is highly unequally distributed across the country. For example, the average annual water flow in the Amazon Hydrographic Region reaches 73,700 m^3/s, while in the Oriental Northeast

Atlantic Hydrographic Region the flow is 92 m³/s (ANA, 2015).[2] Moreover, the most populous and economic developed region, the Paraná Hydrographic Region, drains 5,956 m³/s.

Regarding water quality, domestic wastewater discharge is the main problem. Currently, 40 percent of the population still lacks sewage collection, and only 45 percent of sewage is treated (SNIS, 2016). As a result, about 4.5 percent of rivers have a high concentration of organic matter, which restricts the uses of those waters can have (ANA, 2017a).

Total water abstraction amounts to 2,083 m³/s in 2017 (ANA, 2017b). Agriculture is the major water use, representing around 50 percent of water demand. Urban water supply is the second, accounting for 23 percent of total abstraction. Water use efficiency is also a concern. Losses in irrigation can reach 70 percent (FGV EESP, 2016), and currently 38 percent of the drinking water produced in the country does not reach consumers (SNIS, 2016).

Hydropower represents 12 percent of Brazil's energy matrix (EPE, 2018), and there are 644 hydropower plants in the country. Even though hydropower is a non-consumptive use, it nonetheless impacts river flow conditions.

3.2 Legal Framework

According to the Federal Constitution, all waterways that cross states within the country, that serve as boundaries with other countries, or that extend into foreign territory—including riverbanks and beaches—fall under the responsibility of the federal government. States are responsible for surface or subterranean waters, flowing, emerging or in deposit, except for those resulting from work carried out by the federal government. Thus, the water resource management framework operates at both national and state levels.

This double jurisdiction adds complexity to the water resources management system. As river basin[3] boundaries do not always coincide with state boundaries, there is more than one body responsible for water resource management. Due to river basins' natural characteristics, upstream decisions impact downstream conditions. Thus, the higher the number of bodies in charge of

[2] Brazil is divided into 12 Hydrographic Regions: Amazon, Tocantins-Araguaia, Northeast Atlantic – west region, Parnaíba, Northeast Atlantic – east region, São Francisco, East Atlantic, Southeast Atlantic, Paraná, Paraguai, Uruguai and South Atlantic. Each hydrographic region water availability can be seen in ANA (2015).

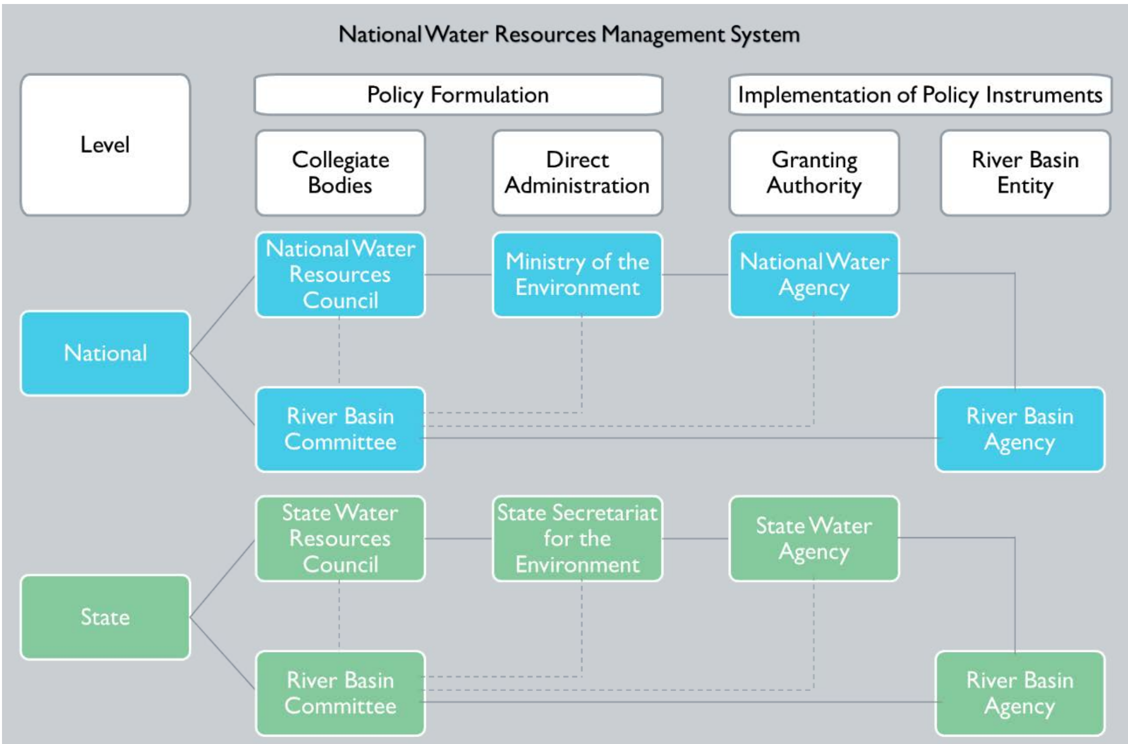
[3] A river basin is the portion of land drained by a river and its tributaries.

different sections of a river basin, the higher the need for coordination between them to properly manage the water resource.

3.3 Institutional Framework

The 1997 Water Act (Federal Law 9433) set the institutional framework for water resources management in Brazil. Figure 1 describes the National Water Resources Management System. The role of each institution is presented below.

Figure 1. The National Water Resource Management System



Source: Fundação Getulio Vargas, Centro de Estudos e Regulação em Infraestrutura (FGV CERI).

3.3.1 Ministry of the Environment / State Secretariats for the Environment

The Ministry of the Environment formulates water policy at the federal level. State secretariats undertake this role at the state level.

3.3.2 National / State Water Resources Councils

The National and State Water Resource Councils are normative and deliberative bodies. Their functions include the co-ordination of water resource plans with other sector plans (such as sanitation, agriculture and industry), the approval of the creation of river basin committees and the definition of general criteria for granting water permits and water charges.

Some State Water Resource Councils were created before the establishment of 1997 Water Act, especially in the Northeast due to the water scarcity, and in the Southeast due to pollution problems. Some examples are the Ceará State Water Resource Council, which was created in 1992, and the São Paulo State council, established in 1987. According to OECD (2015), the maturity of the councils varies. Some states have developed their water management system (Ceará and São Paulo States), while others are still discussing their composition and their role.

3.3.3 River Basin Committees

River basin committees (both at national and state levels) are deliberative and consultative bodies for water resources management at the river basin's scale. They are responsible, among other things, for arbitrating disputes between the different water resource users within the river basin's limits and for approving river basin plans. In addition, these committees establish the charge[4] structure and propose the amounts to be collected. Committees are made up of representatives from the federal, state and city governments, as well as from water users and civil society. The composition and number of representatives vary across river basin committees.

Some concerns arise regarding the composition of committees. First, there are regularly new members on committees due to the political cycle. Thus, continuity and institutional memory are a challenge (OECD, 2015). Second, there is a governance problem, as there is no guarantee that a member of the committee will have the technical expertise required to perform committee roles nor that their decisions will be taken regardless of their own interests. Therefore, some relevant decisions, such as the water charge setting, can become political, resulting from negotiation among water users and members of other river basin committees. We discuss this further below in the section on water charge.

[4] Water charge is an instrument for water resource management in Brazil. It refers to the value paid by the users of raw water. The water charge is collected by the water resource regulatory agency. It differs from water tariffs paid by final consumers to water utilities.

3.3.4 River Basin Agencies

River basin agencies (both at national and state levels) may be established to act as executive secretariats for the committees; otherwise, this role is performed by state water agencies.

3.3.5 National / State Water Agency

Finally, the National Water Agency regulates water resources under federal responsibility, whereas state water agencies are executive bodies for managing water at the state level.

Regarding the role of the National Water Agency, a provisional measure[5] (PM) that adds a new responsibility to this body is currently being discussed. It states that the National Water Agency will also be responsible for establishing national benchmarks for sanitation service regulation. This PM provides an umbrella framework that may lead to more consistent regulation nationwide. Moreover, the PM may be an initiative to manage both water resources and the water and sanitation sectors in an integrated way, as the latter represents the priority water user.

3.4 Policy Framework

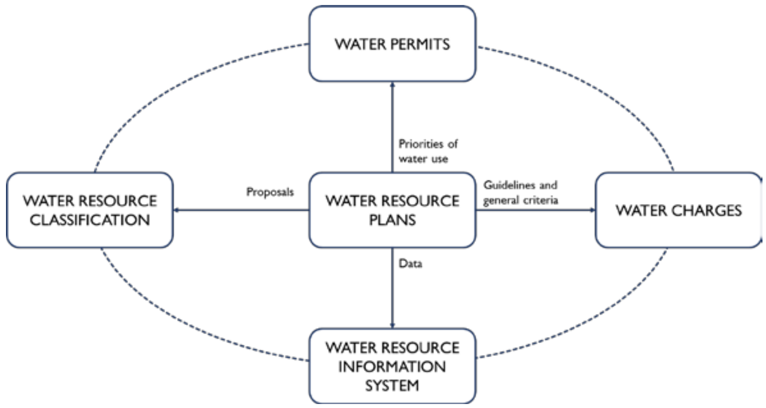
The 1997 Water Act established the National Water Resource Policy, which is based on the following key principles:

- Water resource management should promote multiple uses of water;
- The river basin is the territorial unit for the policy's implementation; and
- In situations of water scarcity, the top priority among multiple users is human needs and animal consumption.

The 1997 Water Act introduced six water resource management instruments: i) water resource plans, ii) water permits, iii) water charges, iv) water resource classification into classes according to the main water use, v) compensation for cities and vi) a water resource information system. Figure 2 depicts how these instruments relate to one another. We analyze only the former three instruments since they have the greatest effect on the water allocation process, which is the goal of this paper discuss.

[5] Provisional Measure 868/2018.

Figure 1. National Water Resource Policy's Instruments



Source: ANA, 2017a.

3.4.1 Water Resource Plans

As shown in Figure 2, the water resource plan integrates all other instruments instituted by the 1997 Water Act. Water resource plans are developed for river basins on both state and federal scales. Despite its importance, the water resource plan has not been used as an efficient instrument for water resource management. There are two main reasons. First, these plans fail to drive water allocation decisions, since they are often ill-crafted, incorporating projects that are not feasible (either technically or economically or both) and fail to define the criteria for prioritizing allocations. Second, even well-crafted plans are rarely implemented due to limited funding, technical capacity, monitoring and enforcement (OCED, 2015).

3.4.2 Water Permits

Water permits provide the user the right of use,[6] ensuring reliable water availability for permit holders. Permits are issued through an administrative act by the National Water Agency and by the state water agencies at federal and state levels, respectively (see Box 1). The permit specifies the amount of water each permit holder can utilize for different purposes (e.g., abstraction,

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[6] Water rights differs from property rights in economic sense. As per economics, property rights are the theoretical and legal ownership of a good by individuals and the ability to determine how such property is used, so trades are allowed. In the case of water in Brazil, water rights are not tradable. They guarantee the user only the right of use water and they do not imply the partial appropriation of water. As already mentioned, the Union and the states issue water rights, so we can understand that water is a "property" of the Union and the states.

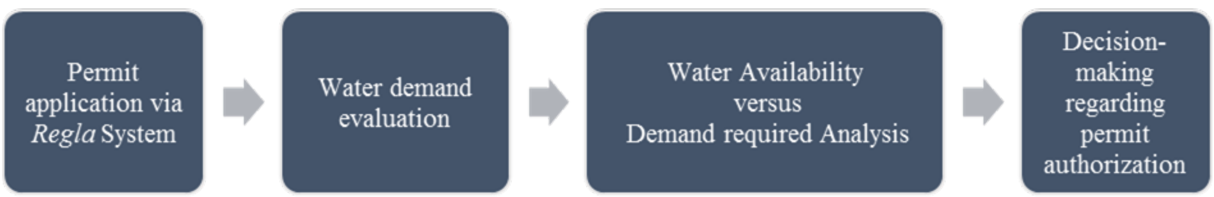
consumption and dilution) and its conditions. The use of permits is the primary allocation mechanism adopted in Brazil.

Box 1. Permit Granting Process at the Federal Level

The permit granting process at the federal level[7] begins with a request sent by the permit applicant to the Federal System of Regulation of Use (REGLA).[8] Based on information given by the applicant himself, the National Water Agency's team analyzes whether or not the water flow requested is suitable for the requested use. For example, if the user requires water for irrigation purposes, the agency estimates its water consumption based on information such as the type of crop, irrigated area and irrigation technique. In order to avoid overuse of water, the NWA tries to match this estimated consumption with the requested flow.

The requested flow, once approved, is then checked against the river basin's water availability, which is measured in terms of a reference flow. The decision-making process on whether to grant a permit is based on a water balance system that is updated with every new user added. Figure 3 presents the schematic permit process analysis conducted by the National Water Agency.

Figure 3. Permit Process Analysis



Source: FGV CERI.

As water resources in a basin belong to either the state or federal government, interaction between NWA and state agencies is essential during the permit granting process. However, this integration had not been effective until November 2017, when the REGLA system was implemented. By that date, besides federal information, data from the states of Maranhão, Pará, Piauí, Rio de Janeiro, Rio Grande do Norte and Tocantins were included in the system.

Water permit follows the doctrine "first come, first served." This doctrine does not take into account that water value varies across different water users. Thus, it is not guaranteed that Pareto optimality will be achieved. In the current regulatory framework, permits cannot be traded, which limits efficient allocation.

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[7] Information based on interview an interview with a specialist from the National Water Agency.
[8] This system is available at:< http://www.snirh.gov.br/cnarh/index.jsf.>

3.4.3 Water Charges

The water charge is a value that permit holders have to pay in order to use water. According to the 1997 Water Act, the water charge must i) signal water as an economic good, ii) encourage the rationalization of water use and iii) be sufficient to finance programs and interventions defined by the river basin's plans.

The amount charged is calculated by multiplying the water abstraction, consumption and/or disposal volume (metered and/or permitted) by the Unitary Public Prices (UPP) (see Box 2). The UPP is the price charged per m³ of water, and it is proposed by the river basin committees. There are two issues concerning the setting of UPP. First, the committees usually carry out only an assessment based on the impact of the charge on water users' costs. Thus, the amount charged does not reflect opportunity costs nor externalities due to water use. Second, as water users are also members of these committees, the UPP decision is not entirely independent. As a consequence, this decision is predominantly political. The water charge as it is currently applied fails to meet the first two goals defined by the legal framework.

Box 2. São Francisco River Basin's Water Charge Structure

Water abstraction and consumption are charged differently.

Water Abstraction

The amount charged for water abstraction in the São Francisco River Basin is calculated as follow:

$$Charge_{abstraction} = Q_{permit} \text{ x UPP x } K_s^*$$

K_s^* comprises coefficients that are specific for each user, as it takes into account the user's sector, his location (if it is a rural or urban area) and the classification of the river from which the user is abstracting water. In the specific case of the agriculture sector, this coefficient varies according to irrigation techniques, and water and soil management.

In the cases where water abstraction is metered, Q_{permit} is replaced by a weighting between metered water abstraction and permitted flow.

Water Consumption

The amount charged for water consumption is calculated by the following formula:

$$Charge_{consumption} = Q_{consumption} \text{ x UPP x } K_s^*$$

For the agriculture sector, due to the difficulty of estimating the water consumption, the amount charged is calculated by multiplying the permitted flow by a coefficient that varies according to the irrigation method. For further details, see CBHSF (2017).

Although established by different committees, water charges in Brazil are overall similar in terms of their values and generally lower than necessary (see Box 3). Given the low value of the charges, there is no incentive for users to reduce their consumption. Moreover, a study conducted by NWA demonstrates that, until 2016, the value collected at the federal level was able to cover only about 10-15 percent of the financing needed to implement actions foreseen in water resources plans, such as studies, projects or construction works (ANA, 2016). As a consequence, additional financial resources are needed to fill financing gaps, demonstrating that this instrument also fails to reach target 3.

Box 3. PPU in Federal River Basin Committees

Table 1 presents the UPP charged for water abstraction and consumption by each of the federal committees that have already implemented water charging.

Table 1. UPPs Charged for Water Abstraction and consumption

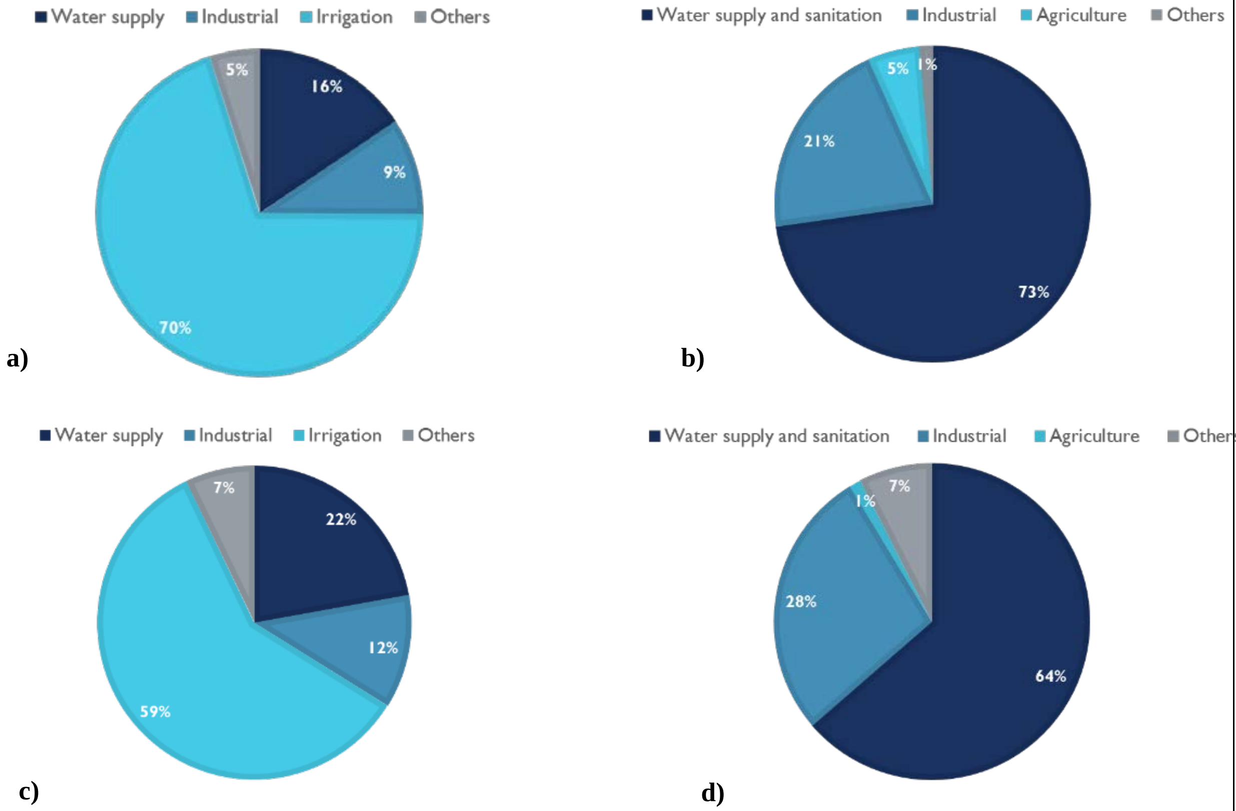
	Paraíba do Sul	São Francisco	Doce	PCJ	Paranaíba	Verde Grande
Abstraction (R$/m³)	0.01	0.012	0.0308	0.01	0.015	0.0101
Consumption (R$/m³)	0.02	0.024	-	0.02	-	0.0202

Source: CBH-Verde Grande (2015); CBH-Paranaíba (2016a); ANA (2010a); CBHSF(2017) and CBH-DOCE(2018)

Another issue that deserves attention is the perverse subsidy provided for irrigators, as presented in Box 3. This subsidy discourages the rational use of water in the agriculture sector. As shown in Figure 4, even though irrigators are the main users of water, they pay only 5 percent of the amount collected by state agencies and only 1 percent of the amount collected by the National Water Agency. Under the current regulatory regime, farmers pay only 2-5 percent of what other users pay on a volumetric basis (OECD, 2017). This has to do with the application of a reduction coefficient introduced at the price charged for the agricultural sector.

Box 3, continued

Figure 2. Comparison between Water Permits and Water Charge



Source: ANA(2017b).
Note: a) and b) show water permits issued by the NWA and the amount collected through the water charge at federal level, respectively; c) and d) show water permits issued by state agencies and the amount collected through the water charge at state level, respectively.

This coefficient is designed so as not to impact the competitiveness of agricultural products. However, there is no solid evidence that the amount charged would truly impact irrigators' costs. The agriculture sector's low share of payments may be due to its influence on the decision-making process rather than an assessment of its impact on water users. Given our discussion thus far, we can conclude that the water charge in Brazil does not drive decisions on how much water each user consumes. Thus, we cannot refer to it as a price regulation. The water charge as currently implemented in Brazil is a simple mechanism to generate revenues rather than a water policy tool.

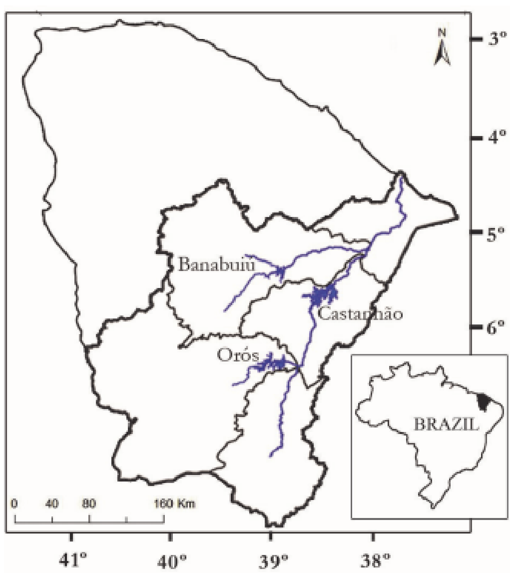
After discussing three of the instruments adopted in the water resource management in Brazil, we notice that they seem to have been designed based on an abundancy water framework. The allocation of water through permits does not take into account any efficiency criteria, and this design does not consider the possibility of not having enough water to meet all demand. As water resource policy does not provide for any reallocation mechanism, allocative efficiency remains limited. We conclude that the current instruments are not sufficient to cope with the increasing conflicts over water use and water stress situations (see Box 4).

Box 4. Agricultural Conflicts in the State of Ceará

We present this case aiming to illustrate a situation where it was made necessary to create a new instrument to cope with water scarcity.

The Jaguaribe and Banabuiú Valleys are located in the State of Ceará, Brazil's semi-arid region. The Orós, Banabuiú and Castanhão Reservoirs are responsible for water supply in these valleys (Figure 5). This region experienced a severe drought in the early 2000s.

Figure 3. Location of Orós, Banabuiú and Castanhão Reservoirs



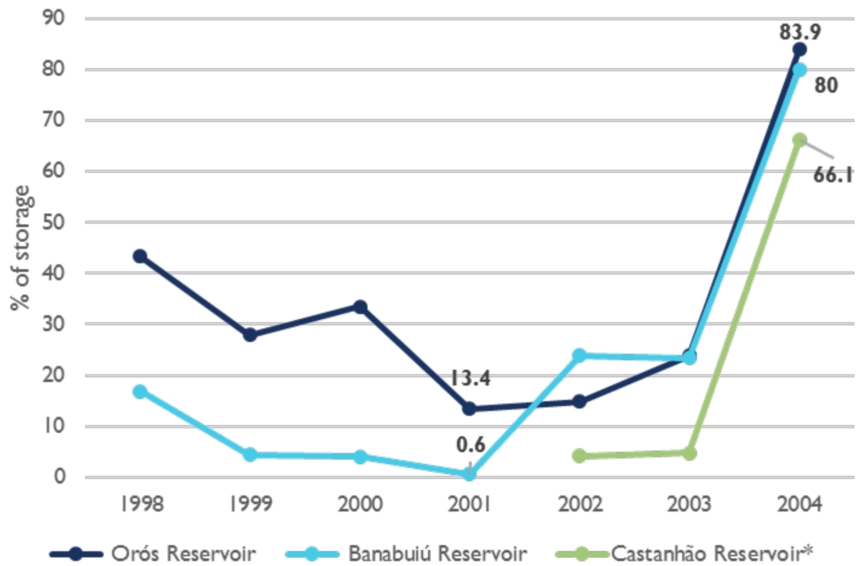
Source: Fernandes et al. (2017).

At that time, the main water use in the Jaguaribe River Basin was irrigation, which represented 83 percent of total abstraction. The Jaguaribe and Banabuiú Valleys covered 26,000 ha of irrigated land, mostly irrigated by the low-efficiency method of flooding. Rice production occupied approximately 45 percent of this area (Da Silva et al., 2006).

In 2001, when the rainy season (February to June) ended, the volume stored in the Orós and Banabuiú Reservoirs, as shown in Figure 6, was insufficient to meet irrigation demand. Thus, it was necessary to adopt a rationing plan that involved the Water Resources Company (COGERH), the State Secretariat for Agriculture, Rural Development and Development (SEAGRI), the Secretariat of Water Resources of the State of Ceará (SRH) and the National Water Agency (NWA).

Box 4, continued

Figure 4. Orós, Banabuiú and Castanhão's Storage



Source: FGV CERI based on Da Silva et al.(2006)
Note: Castanhão Reservoir started operation in 2002.

In 2001, when the rainy season (February to June) ended, the volume stored in the Orós and Banabuiú Reservoirs, as shown in Figure 6, was insufficient to meet irrigation demand. Thus, it was necessary to adopt a rationing plan which involved the Water Resources Company (COGERH), the State Secretariat for Agriculture, Rural Development and Development (SEAGRI), the Secretariat of Water Resources of the State of Ceará (SRH) and the National Water Agency (NWA).

In the Banabuiú Valley, it would not be necessary to adopt strategies for water reallocation, since the water availability had been sufficient to meet only human needs. In this case, there was no doubt how to allocate the scarce resource. Thus, in order to preserve water availability for human consumption (priority use), all other users were rationed. The irrigators were then compensated for the non-use of water in agriculture.

In the Jaguaribe River Valley, another approach was adopted since there were conditions for the partial service of irrigation demand. The decision was to prioritize fruticulture instead of rice production, as the former was worth more than the latter considering the economic and social aspects (e.g., employment), and the economic value of each cubic meter (m^3) of water

Box 4, continued

used in fruit production is higher than that of rice (Kelman, 2009). Under this mechanism, rice farmers were compensated for refraining from planting. This compensation was either non-pecuniary (involving the provision of training and identifying regions suitable for planting less water-intensive crops) or financial (i.e., credits to start planting in the new identified region). Fruit producers partially funded this program, agreeing to contribute since the amount to be paid would be well below the cost of rationing (Kelman, 2009). Water supply returned to normal by the following year with the recovery of water storage, which then experienced a significant increase in the 2003-2004 period.

This case study shows the introduction of a new approach to water resource management through the use of economic incentives. Although it is not widespread in the country, perhaps due to lack of a supporting legal and regulatory framework, this case illustrates that allocation of water by economic mechanisms, even in the absence of formal markets, can lead to positive results.

The main conclusions to be drawn about Brazilian water resource management are as follows:

- The Water Resource Management Policy's instruments were designed without taking into account the possibility of water scarcity. Although the country is known for its water abundance, there are problems regarding the spatial distribution of water. Water users are concentrated away from the main sources of water.
- Double jurisdiction requires appropriate integration of federal and state information. However, there is a lack of coordination between state and federal management bodies, which endangers water resource management as a whole.
- Water resource plans do not define priority criteria for water use and thus fail to guide the permit granting process. As a result, the allocative instrument (water permit) is based solely on a “first come, first served” doctrine.

- The absence of economic mechanisms to allocate water among multiple uses and the previously mentioned lack of coordination between state and federal management bodies compromise the efficiency of water allocation.
- The low institutional capacity of River Basin Committees weakens water resource management instruments. While the committees hold responsibilities that depend on technical skills, their decisions, such as the definition of the water charge, are often based on political influence. This compromises the effectiveness of the instrument.
- The water charge as currently implemented is an instrument adopted to generate revenues rather than a water policy tool. It does not send the right price signals to users, undermining efficiency in water use.
- Water scarcity and conflicts over water use have become increasingly frequent, even in well-developed regions. The instruments currently adopted in Brazil's water resource management seem ill-equipped to cope with these situations. There are, for example, no reallocation mechanisms provided for in the country's Water Resource Management Policy.

In the next sections we focus on the latter topic, analyzing the feasibility of creating water markets to promote efficient reallocation.

In fact, management bodies already limit the total amount of water abstraction by defining the maximum number of permits that can possibly be issued. The assignment of property rights, which is a prerequisite for the introduction of a water market, is already in place through water permits. Although the current regulatory regime does not allow for water trades, Brazil is already on its way to changing it. Therefore, this is the solution to be discussed in this paper. It is worth noting that we do not believe that this mechanism fits the reality of all Brazilian river basins. We therefore aim to analyze how allowing negotiation between water users could help the management of water scarcity situations. In particular, the experience of the Australia's Murray-Darling Basin is examined in order to derive lessons that may be relevant to the introduction of water markets in Brazil.

4. The Experience of Australia's Murray-Darling Basin

The Murray–Darling Basin (MDB), located in southeastern Australia, is the country's largest and most complex river system. Its drainage includes almost 15 percent of Australia's territory, including four Australian states and one territory: Queensland, New South Wales, South Australia, Victoria and the Australian Capital Territory (Figure 7). In addition, the MDB has an important economic role. More than 2.6 million Australians live in the Basin area, and agriculture in the Basin produces AU$24 billion every year. There are approximately 9,200 irrigated agriculture businesses and about 2 million hectares of irrigated agricultural land in the Basin. Tourism is also a relevant economic activity, which adds AU$8 billion dollars annually to the Basin (MDBA, 2018).

Figure 7. Murray-Darling Basin

Source: MDBA (2018).

As the Murray-Darling Basin is located in a semi-arid region, many supply strategies, such as water markets, have been developed and implemented to mitigate water scarcity (Grafton et al., 2012). In order to make water reallocation strategies possible, several reforms were necessary. In the late 1880s, Australia's states had transformed riparian water rights into statutory water rights (called water entitlements). By the 1980s the pressure for water rights to be separated from land rights, and for those rights to be tradable, increased due to overallocation of statutory water rights.

During this decade water markets were established in the four states of MDB (Grafton et al., 2012). One should recall that water resource management is a state responsibility in Australia.

Further reforms in water trading took place in 1994 with the Council of Australian Governments' (CoAG) Water Reform Framework, and again in 2004 with the National Water Initiative—NWI (Grafton et al., 2012). The latter is an intergovernmental agreement between the federal government and the Australian States and Territories to increase water use efficiency. Under the NWI, governments commit to: i) prepare comprehensive water plans, ii) achieve sustainable water use in over-allocated or stressed water systems, iii) introduce registers of water rights and standards for water accounting, iv) expand trade in water rights, v) improve pricing for water storage and delivery and vi) better manage urban water demands.

The 2007 Water Act established the MDB Authority as an independent expertise-based statutory agency. The Authority's responsibilities include the following: i) the integrated plan for the sustainable use of the Basin's water resources, ii) operating the Murray River system and efficiently delivering water to users on behalf of partner governments, iii) measuring and monitoring the Basin's water resources quality and quantity, iv) advising the Australian and State Governments on water resource matters and v) providing water rights information to facilitate water trading across the Basin (MDBA, 2018).

The Water Act 2007 also defined three different types of tradeable water rights (entitlements):

1. Water access right, which is any right conferred by or under a law of a state to hold and/or to take water from a water resource. This kind of right includes the following rights:
    a. Stock and domestic rights;
    b. Riparian rights;
    c. Water access entitlement: a perpetual or ongoing entitlement, by or under a law of a state, to exclusive access to a share of the water resources of a water resource plan area; and
    d. Water allocation: a specific volume of water allocated to water access entitlements in a given water accounting period.
2. Water delivery right, which is a right to have water delivered by an infrastructure operator; and

3. Irrigation right, which is a right that a person has against an irrigation infrastructure operator to receive water.

Water rights can have different levels of reliability; as previously mentioned in this paper, it is related to the probability of rationing water rights holders. As explained in Grafton et al. (2012), water entitlements provide their holders with "a share of a consumptive pool, but the actual quantities of water that holders of entitlements are permitted to divert depend on the seasonal allocation that is assigned each year to the water entitlement." The seasonal allocation defines which entitlements holders have and how much water may be diverted considering water entitlements' level of reliability. The higher the reliability of water entitlements, the higher the chances the volume of water allowed to be diverted will be equal to the water entitlement.

In Australia, both water entitlements and seasonal allocations can be traded. They are respectively called permanent and temporary trade. Seasonal allocations have generally represented the majority of trades since access to water is more assured with this kind of right. The trade price represents the value of the water access right and is not regulated. According to the Basin Plan water trading rules, the seller must notify the approval authority of the trade price (ACCC, 2016).

According to the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2018), high reliability water entitlement trades in 2016-2017 were on average AU$ 2,559.00/ML, while medium and low reliability were, respectively, AU$ 2,150.00/ML and AU$ 434.00. However, in the same period, water allocation trades were on average AU$ 77.6/ML. It is important to mention that water market prices also vary with catchment.

The MDB market is mainly composed of irrigators, and the main beneficiaries are orchard and vineyard farmers. By volume, over 1,499 GL of water entitlements were traded in 2016-2017, while about 6,000 GL of seasonal allocations were traded over the same period. The total value of turnover in entitlement trade was about AU$901 million,[9] and about AU$130 million in terms of seasonal allocations in 2016-2017.

MDB experience shows that, even when a market mechanism is implemented, both economic and environmental sustainability have been reached. The water law reforms that allowed

[9] Price data only available for New South Wales, Victoria and South Australia.

water to be decoupled from land, along with the maturing period of water resources management, were essential to the success of MDB water market. Moreover, in this case is it is worth highlighting the importance of the integration between federal and states roles. Finally, the connection between water market and water planning provides more security for the holders of water rights and for environmental outcomes.

5. Readiness Assessment of Brazilian Water Resource Management

The implementation of water markets as an instrument for water resource management requires a prior design of institutional arrangements. The necessary reforms to design and implement successful water markets must follow a certain sequence that will lead to robust and adaptive water governance. According to Young (2014), introducing trade without fixing the flaws in the water allocation regime that is already in place may not be a good starting point. Moreover, Wheeler et al. (2017) states that implementing water trading without fully strengthening institutional and administrative capacity may result in high transaction costs[10] and may reinforce resistance to the introduction of market policies.

The degree of water market regulation must nonetheless be properly balanced. On one hand, excessive regulation can result in high transaction costs and reduce the benefits of water trading. On the other hand, inadequate regulation can impose unacceptable costs on third parties or on the environment (Rosegrant and Gazmuri, 1995).

The feasibility of developing water markets depends on the interactions between the hydrological, infrastructural, legal and political regimes (Rosegrant and Gazmuri, 1995). Regarding hydrological matters, effective market-based reallocation policies require public information on water availability for consumptive uses and existing rights. Hydrological monitoring, data collection and a registered system that includes all permitted users are desirable. In addition, “water trades require connected (natural or built) infrastructure to facilitate the movement of water from the sellers to the buyer” (Grafton and Peterson, 2007).

[10] Transaction costs include, for example, bureaucratic administrative costs, identification of potential buyers/sellers, obtaining hydrological information related to water availability, and negotiating and recording transactions (FGV-EAESP, 2018).

Water trading must be provided for in the legal framework. This also depends on the existence of clear operational rules: how, where and how much water can be either used or traded. Relationships between rights must be well defined so that users understand their rights to water and how to transfer it. It should be clear that if a user wishes to access a higher amount of water than the amount already established in the permit, they should convince another user to use less water.

Moreover, water rights must be enforced by not allowing new rights to interfere with already existing ones without proper compensation. This can be achieved by monitoring and controlling water uses to ensure all users comply with the conditions pre-established in their permits. These rights must also ensure a reliable level of water access. From a market perspective, there should be secure and predictable delivery.

Finally, political factors such as the different degrees of government willingness to empower people, different perceptions regarding the degree of regulatory interference in managing resources and the political interests of the main stakeholders are important in determining whether, and to what extent, marketable trades will be established (Rosegrant and Gazmuri, 1995).

Considering the mentioned requirements, we carried out an evaluation in the national context aiming to identify barriers and opportunities for the introduction of market-based policies in Brazil. The evaluation, based on Wheeler et al. (2017) and Matthews (2004), takes into consideration the following components: i) the water rights regulatory framework, ii) institutional governance, iii) data collection, iv) operational rules, v) the market for water-trading and iv) arrangements to deal with externalities. Table 2 summarizes the questions we aim to answer in each of these areas.

Table 2. Water Market Readiness Assessment: Questions

Water Rights Regulatory Framework	• Are water rights clearly defined? • Can water rights be decoupled from land property?
Institutional Governance	• Are the decision-making processes of water resource regulatory agencies reliable? • Can irregular water use be detected? • Can penalties be imposed? • Are permits enforced?
Data Collection	• Is the hydrology system well documented? • Is the hydrology data published?
Operational Rules	• Are the operational rules clear and well known? • Are there mechanisms for water delivery in scarcity situations? • Are there mechanisms that allow water trading?
Markets for Water Trading	• Are there (enough) buyers and sellers willing and able to trade?
Arrangements to deal with externalities	• Are the externalities evaluated? • Are the externalities mitigated?

Source: FGV CERI.

We recall that water resource management at the state level has varying degrees of maturity in the country. Therefore, the proposed assessment expresses an overview based on evidence and information provided by NWA but does not necessarily reflect the reality of the country as a whole.

5.1 Water Rights Regulatory Framework

Water rights are issued through permits, so it can be considered clearly defined. Moreover, water rights are dissociated from land rights. As already pointed out, water rights differ from property rights in an economic sense as the first is not tradable.

Barrier #1: Water permits are not tradable.

5.2 Institutional Governance

The lack of database integration and/or information sharing between federal and state management bodies often undermines the reliability of decisions in the permit granting process. As presented in Box 1, the NWA only recently began gathering information from some states in the REGLA system. However, there are still cases in which the state water regulators/agencies[11] resist sharing information databases with the NWA.

Water resource regulatory agencies monitor water uses under their jurisdiction in order to identify violations[12] and prosecute irregular users. The regulator establishes the bodies of water in which users are required to implement a monitoring system. In such cases, the user must report their abstraction and effluent volumes through the Annual Water Use Statement (DAURH) on an annual basis. During inspections, this declaration is taken into consideration.

Beyond carrying out periodic inspections and checking complaints, water regulators detect irregular uses by proxy information such as electric power usage. According to information provided by NWA, water uses located in critical areas[13] are also monitored through satellite images on an annual basis. Although there are several ways of controlling irregular water uses, it is not possible to determine if all state regulatory bodies carry out the same types of inspections or with the same frequency. Also, given the extent of some basins, it is unlikely that all irregular uses can be detected. It is reasonable to claim that state agencies lack sufficient human capital and access to information on a reliable basis to properly audit and enforce the permits granted.

If any violation is identified, the irregular user is subjected to a penalty applicable through a due administrative process. Penalties are established in the 1997 Water Act for infringements in the management of federal rivers. However, the amounts are often considered insufficient to inhibit infractions. In the case of NWA, the agency preferentially adopts educative measures rather than imposing penalties.[14] This indicates that the penalties previously pointed out are not regularly applied, at least not at the federal level. Penalties for violations in state rivers are established in

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[11] In some cases, the lack of information sharing between states and the federal regulator may lead to over allocation of water. This is a critical problem due to the dual jurisdiction in the allocation of water rights mentioned in section 3.2.

[12] Examples of violations include abstracting water without a permit, non-compliance with the permits' established conditions, as well as committing fraud on the declaration of consumed volumes.

[13] ANA (2013) presents the areas located in federal rivers where there is imbalance between water resource supply and demand of water. Those areas are called critical areas for water management.

[14] Information based on an interview a specialist from the National Water Agency.

state-level legislation, and those penalties are generally equal to or more restrictive than those established for federal rivers.

Problems in the enforcement of water rights can be assessed according to two criteria: i) whether the permit can be declared void for any reason other than non-compliance with the pre-established conditions and ii) if the entry of a user or higher abstraction from an existing one can impair a user's rights.

As established in the Water Act, a permit may be partially or totally suspended in the following cases: i) non-compliance with pre-established conditions, ii) absence of use for three consecutive years or iii) need for water to address catastrophic situations, to prevent or reverse environmental degradation, to meet priority uses and to maintain conditions for navigational uses.

Water permits in Brazil are relatively insecure, as suspensions due to any of the reasons indicated above do not entitle the user to any compensation. This adds to the perception of risk, undermining investment incentives. In addition, the non-use of the permit may result in its partial or total suspension, following the "use it or lose it" doctrine.

This doctrine perpetuates the insecurity involved in water rights. If a water market is created and this doctrine continues to be followed, the risk perception for a potential buyer in the market increases. Moreover, the water abstraction point may change after a water trade is made, and potential risk then arises because the regulator supervises use at the abstraction point granted on the permit. If the regulator is not notified of the abstraction point change, the regulatory body may infer that the user is not abstracting water anymore and therefore suspend the water permit. Because of this, water trades are not secure and therefore market is limited. The notion/possibility of the suspension of a user's rights in cases of non-use has to be addressed if the option is to implement markets for water (Matthews, 2004).

As per the interference a new permit may have over an existing one without compensation, the lack of regular inspections makes it difficult to identify those interferences and, consequently, to inhibit them. The risk of not having water available for a permitted user, due to the entry of a new one, makes the water rights insecure.

Barrier #2: The "use it or lose it" doctrine is a potential limiting factor for the adoption of water markets as it limits the tradability of water rights.

5.3 Data Collection

Through the National Information System on Water Resources (SNIRH),[15] the federal regulator collects and makes hydrological data available. The system also registers the valid permits issued by the National Water Agency. The database of permitted users is called CNARH40. This system replaced the former CNARH database, which previously gathered information on users who did not hold permits. The collection and publication status of hydrological data by state agencies is not uniform. While some agencies make this information available on their websites, others make it available only upon request. This insufficient transparency of information is relatively common, as is the lack of registry standardization.

Barrier #3: The lack of transparency in information on water availability and valid water permits hinders the creation of water markets.

5.4 Operational Rules

Water permits clearly state the operational rules that users should follow, including information about types of interference (e.g., abstraction), location of water use, validity period, quantity and general use conditions.

In Brazil, there is no established system for prioritizing water among multiple uses/users in cases of scarcity apart from human and animal water consumption. For instance, if a drought occurs, each competent regulatory entity makes its own decision regarding the delivery of water. As there is no legal provision that allows for water trading, the relationship among different users' water rights is not properly defined.

A new piece of legislation to amend the 1997 Water Act, which introduces water markets as an additional instrument for the management of water resources, is under discussion in Congress.[16] The motivation for this proposal is the need to enact mechanisms to reallocate water from low-value to high-value uses.

The Proposed Legislation allows for monetary compensation between users located in the same basin or sub-basin for a certain amount of time. As transactions are restricted to the boundaries of the basin, the river basin committees would be responsible for preparing and

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[15] The data can be accessed through the following link: http://www.snirh.gov.br/
[16] Proposed Legislation number 495/2017.

submitting proposals for the creation of water markets in their area of competence to be approved by the granting authorities (NWA and state agencies).

The operation of water markets in Brazil would allow for active participation by river basin committees and water resource regulatory bodies (granting authorities). Subject to regulatory approval and oversight, river basin committees could be allowed to operate markets, register water trading and provide information on demand, such as water availability and users interested in negotiating their rights.

Barrier #4: The Brazilian regulatory framework has no established mechanism for prioritizing water among multiple uses/users in cases of scarcity apart from human and animal water consumption.

Barrier #5: The lack of definition of market instruments in the legal framework makes them difficult to implement.

Barrier #6: The proposed legislation empowers river basin committees, which are bodies that already do not properly perform their current roles. Adding a new responsibility to this body can jeopardize the operation of the market.

5.5 Existence of Market for Water Trading

The existence of a potential market must be analyzed on a case-by-case basis. Areas where there are water conflicts may have enough buyers and sellers willing to trade, and some river basins have already been identified as suitable for implementing water markets on a pilot basis due to the heterogeneity of users' demands and/or to the "over allocation" of water in the basin (FGV EAESP and ANA, 2018). This is the case of the PCJ,[17] Paraíba do Sul and São Marcos river basins.

It is important to mention that the implementation of markets, even as pilot projects, may face resistance from users and society as a whole in Brazil. This resistance is due to the lack of knowledge about how water markets work and what benefits they can bring once implemented.

Barrier #7: Social resistance due to the lack of knowledge about how water markets work and their benefits.

[17] Piracicaba, Capivari and Jundiaí River Basins.

5.6 Existence of Arrangements to Deal with Externalities

The lack of legislative provisions allowing for water trading hinders a proper handling of external effects imposed from one user onto another. However, the Proposed Legislation 497/2017 still does not address the need for monitoring, mitigating or eliminating the possible effects and externalities on third parties.

Barrier #8: There is no provision for the monitoring and mitigation of externalities and effects on third parties in the current policy nor in the Proposed Legislation.

The readiness assessment is summarized in Table 3.

Table 3. Water Market Readiness Assessment: Conclusions

Water Rights Regulatory Framework

- Water rights are clearly defined and dissociated from land rights, but it is not tradable;

Institutional Governance

- The lack of data integration between federal and state regulatory bodies hampers their decision-making processes reliability;
- NWA has a robust monitoring process for detecting irregular water use in critical areas. As per state agencies, it is reasonable to claim that they lack sufficient human capital and access to information on a reliable basis to properly audit and enforce the permits granted;
- There is legal ground for applying penalties under Brazilian law, however the imposed amounts are not sufficient to change user's behavior;
- The "use it or lose it" doctrine is a potential limiting factor for the adoption of water markets as it limits the tradability of water rights.

Data Collection

- The lack of transparency in information on water availability and valid water permits hinders the creation of water markets.

Operational Rules

- There are clear operational rules established in water permits;
- The Brazilian regulatory framework has no established mechanism to prioritize water among multiple uses/users in cases of scarcity apart from human and animal water consumption;
- There is no definition of market instruments in the current legal framework, however there is a Proposed Legislation under discussion in Congress in order to allow the creation of water markets.

Markets for Water Trading

- Some river basins have already been identified as suitable for implementing water markets on a pilot basis;
- There may have social resistance to the implementation of water markets due to the lack of knowledge about how water markets work and their benefits.

Arrangements to deal with externalities

There is no provision for the monitoring and mitigation of externalities and effects on third parties in the current policy nor in the Proposed Legislation under discussion in Congress.

Source: FGV CERI

6. Policy Recommendations

Achieving excellence in water resource management requires adherence to mechanisms that can overcome inefficient allocation among users due to market failures. Although Brazil is known for its abundance of water resources, conflicts regarding water allocation exist and are accentuated by climate change and soaring demand. Moreover, as discussed in previous sections, the current institutional and regulatory framework has vulnerabilities that need to be addressed. This study presents the introduction of water markets in Brazil as a viable mechanism. Prior to water market implementation, some functional features need to be established in order to secure the proper functioning of the market, such as data availability, definition of a suitable market design and management mechanisms to deal with scarcity. In parallel, it is important to focus on public opinion and to disseminate the benefits of water market implementation to the population, which is often resistant to change.

After identifying the barriers to the introduction of water markets in Brazil, we present policy recommendations to overcome these water market constraints. To address the barriers identified through the readiness assessment, we provide the following policy recommendations to overcome these water market constraints.

6.1 Promote Greater Understanding Regarding the Benefits of Implementing Water Markets

The Ministry of the Environment, which is responsible for Brazilian water policy, should encourage more in-depth discussions and disclosure on the benefits of implementing water markets. Although water is a resource used by the entire population, most do not know the rules governing its use. While any change in the status quo might face some resistance from society, users will be more likely to accept changes if they understand the following concepts:

1. The water market allows for the entry of new users and/or consumption increases for those users who already hold permits, even in river basins where water is fully allocated.
2. Markets include economic rationality in the reallocation process. Thus, users no longer depend on administrative decisions in times of water scarcity, which is the current procedure.
3. Water markets empower user by giving them greater freedom of choice to respond to variations in water availability through voluntary transactions.

6.2 Standardize Data Collection

Regardless of how the water market is structured, an integrated water resource management system must have its information collected and published in a standardized and transparent way. Besides facilitating further evaluation and access of information for society, a solid database helps to coordinate information between state and federal agencies, a crucial need given dual jurisdiction over water management in Brazil.

In the specific case of the water market, the standardization and publication of information is fundamental to facilitate the "matching process" between potential buyers and sellers, thus reducing transaction costs. Well-established markets generally present online platforms for trading, where information on the users willing to sell their rights, the prices and the amount of water transferred are available.[18]

6.3 Approve Water Reform

As previously mentioned, well defined and tradable property rights are essential for the creation of a water market. In Brazil, permits have already established property rights, but they are not yet tradable. Congress' approval of the proposed legislation that allows permit trades is critical for implementing water markets in Brazil.

Congress needs to discuss water reform properly and it is important to involve multiple water users in this process. In addition, as water management must be done in the scale of the river basin, water reform should establish general guidelines for market creation and leave more specific regulation to be defined at the local level.

6.4 Implement Right Incentives for Water Markets through Adequate Legal and Regulatory Frameworks

In river basins, where water markets are implemented, the "use it or lose it" doctrine should be eliminated, as it does not provide the correct incentive to promote water trades. This doctrine limits the market since the user may not be abstracting water at the point previously approved by the granting authority due to trades. This doctrine creates insecurity for the buyer/seller and makes the

[18] For example, it is possible to check information about Australia's Murray Darling trades in https://www.waterexchange.com.au/.

market unfeasible, because at any moment a permit can be taken from its user, since the supervising body would not know that the water is being abstracted elsewhere.

In any case, this doctrine is a perverse incentive, as it encourages the user "to use water regardless of his/her need, of the efficiency of its use or of the potential consequences in medium and long term, in order to avoid the permanent loss of rights" (FGV EAESP and ANA, 2018).

6.5 Review Water Management Mechanisms in Times of Scarcity

During water shortages, as water supply decreases, it is necessary to reduce water demand, i.e., the volume allowed for use in water permits. As already mentioned, in situations of water scarcity, the only established priorities among multiple users are human needs and animal consumption. There is no rule to determine the allocation of water among other uses. It is currently defined on a case-by-case basis (negotiations) between the NWA and/or state agencies and water users. However, those negotiations would not be required if the government decide to create a water market as they would be a more costly mechanism and they could limit trades. Thus, it is necessary to review water management mechanisms in times of scarcity.[19]

Three alternatives for water management rules to deal with scarcity are listed below.

- Use a linear rationing system. In this system, water is delivered to all parties who hold rights, but at a proportionally reduced amount (Matthews, 2004). This means that all permit holders experience the probability of rationing any permit holders is the same. From a water market perspective, water permit trades can promote reallocation to the most efficient use.
- Use the chronological—or queuing—system. In this system, older permits are more secure than new ones. In other words, newer permits would be rationed before older ones. Again, water markets can promote efficiency reallocation. The difference between this system and the linear system is that each entails

[19] That is not a particular characteristic of the water market. Energy markets also deal with scarcity by means of management mechanisms. For instance, California Public Utilities Commission uses a set of complementary mechanisms – Interruptible Load Programs and Rotating Outage Program – to improve the reliability of California's electric system. The first one is a voluntary utility program in which large users agree willingly to reduce their electric usage on demand in return for a monetary payment or bill reduction. The Rotating Outage Program addresses (systematically and fairly) the need for forced reductions in electric use by curtailing electric service to customers when reductions obtained from the Interruptible Load Programs are not enough. For more details, see SEUC (2001).

different probabilities of rationing permit holders. Then, water permits market price may vary.

- Issue permits with different probabilities of access. For example, three preference categories could be created: i) category 1 would be entitled to receive water 90 percent of the time; ii) category 2, 50 percent of the time; and iii) category 3, 20 percent of the time. The creation of such permits depends on a proper knowledge of river basin hydrological data. That would require a change in the Brazilian water allocation process, as nothing like this three-tiered system currently exists.

6.6 Study Water Market Designs

This study will discuss a potential water market for the São Marcos River Basin, but further and more specialized studies are needed in order to develop proper market design for each area where the government plans to create water markets as a reallocation mechanism in Brazil.

It is necessary to define rules for water trading. These rules should consider local characteristics, such as the existence of delivery infrastructure. The involvement of water users during the process of defining those rules is also essential so that they can comprehend how the market will work and provide support or objective comments.

In addition, water governance must be taken into account. There should be a proper independent and technical body to monitor water use and trades, as well to evaluate and to control third parties' impacts.

The design of the water market should also consider how potential externalities would be mitigated when changing the point of diversion, the point of return flow, or the place of use could cause impact on the availability of water to other users. An option to address this problem and to guarantee water to downstream users is to maintain the return flow of water by allowing only the consumptive volume of the permit to be traded.

6.7 Select Suitable Areas to Host Pilot Markets for Water Permits Trading

Where there is imbalance between water supply and demand or when a river basin is fully allocated, water markets emerge as a suitable economic instrument to deal with water scarcity and to reallocate the resource

Even though international experiences provide a solid benchmark for designing water markets in Brazil, local characteristics must be taken into account. As markets represent a new economic instrument for the country's water management system, they may face some resistance. This paper proposes that pilot markets in Brazilian river basins are key to resolving water users' doubts and to testing water market performance. In Section 7 we present the São Marcos River Basin case study, offering insights on how this market could be designed and the potential gains from its creation.

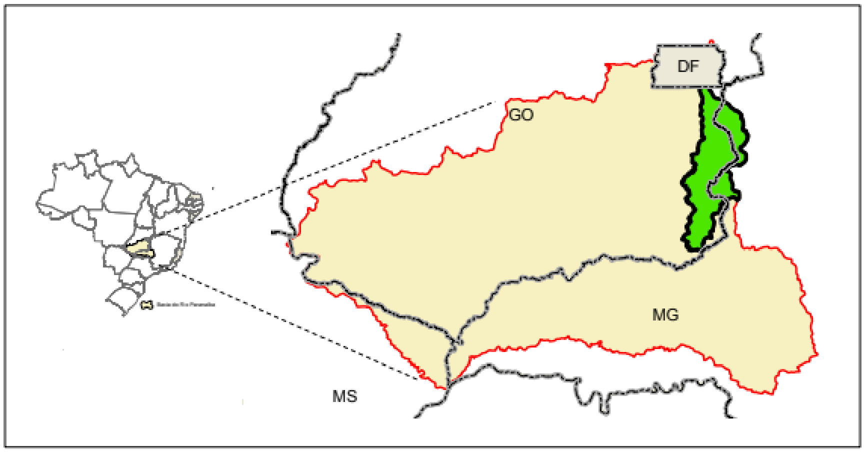
7. São Marcos River Basin Case Study

The São Marcos River Basin (SMRB) is a small river basin that is part of the Paranaíba River Basin. The São Marcos River is a federal river, as it is a border between the states of Goiás and Minas Gerais (Figure 8). There is a current conflict between agriculture and hydroelectricity generation in the SMRB upstream area due to over-allocation and overuse of water resources. According to the HPP's permit, the allowed water consumption upstream from the Batalha HPP is equal to 9.42 m^3/s. However, NWA estimates that the water demand for irrigation purposes in the same area equals to 10.78 m^3/s.

The decision to focus on this conflict is threefold. First, the two competing sectors have important roles in the Brazilian economy and conflicts like this may also occur in other river basins20. Second, this conflict was identified in 2010 and since then it has been worsening. Additionally, the importance of agriculture in the region demonstrates that the existing conflict between the two user sectors may arise in future among the irrigators themselves. Finally, the SMRB is one of the critical areas for water management as defined by NWA.[21]

[20] For example, there is also a conflict between agriculture and hydroelectricity generation in Preto River, which is a tributary of Paracatu River. Preto River is also a federal river as it is a border between the states of Goiás and the Federal District. See more in Machado (2009).
[21] See footnote 12.

Figure 5. The São Marcos River Basin's Location



Source: ANA (2013b).

Below we present the main characteristics of the two competing users in SMRB: agriculture and hydroelectricity generation. Then, we describe the background of the conflict. Finally, we discuss the water market's potential and estimate gains from its creation.

7.1 Agriculture in the SMRB

The SMRB, especially its upstream area (known as Alto São Marcos), has a well-developed agricultural activity. One should recall that the municipality of Cristalina, GO, is located within the SMRB and ranked 11th position in terms of value of agricultural production in the national context with approximately 1.9 billion Brazilian Real (BRL) (IBGE, 2018).

In the SMRB there are approximately 104,828 hectares of irrigated area and 1,273 central pivots, the most widely used irrigation technique in the region (ANA, 2017b). Of this total irrigated area, 82,906 hectares (79 percent) and 1,011 central pivots are located in Alto São Marcos (upstream from the Batalha HPP).

7.2 Hydroelectricity Generation in the SMRB

The Batalha HPP is a hydroelectric power plant located on the São Marcos River, specifically on the border between the municipalities of Cristalina, in the state of Goiás, and Paracatu, in the state of Minas Gerais. The plant is located upstream from the Serra do Facão HPP, also located on the São Marcos River. The Batalha HPP has 52.5 MW of installed capacity. Despite its low power

capacity, Batalha's reservoir regulates the river flow and allows for energy gains through the cascade of plants located in the Paranaíba River (Figure 9).

Figure 6 - HPPs located in Paranaíba River Basin

Source: CBH-Paranaíba (2018).

7.3 SMRB Water Conflict Background

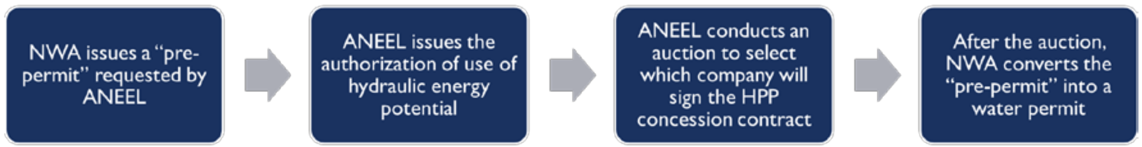
The permit-granting process for hydroelectricity generation purposes differs from the one presented in Figure 3 as it involves the authorization of use of two natural resources: water resource and hydraulic energy potential. The former is under the authority of NWA, while the latter is under the National Electric Energy Agency (ANEEL).

First, NWA has to enact a "pre-permit"[22] so that ANEEL can issue the authorization of use of hydraulic energy potential. The "pre-permit" sets up the available flow for consumptive uses (e.g., irrigation) upstream from the plant until the end of concession. After that, ANEEL conducts

[22] In Portuguese the "pre-permit" is called *Declaração de Reserva de Disponibilidade Hídrica* (DRDH). It is a document that precedes the permit in the case of hydroelectricity generation. After the auction organized by the National Electric Energy Agency (ANEEL), the DRDH is converted into a water permit.

an auction to select the company that will sign the concession to explore the HPP. Figure 10 summarizes the permit-granting process for hydroelectricity generation purposes.

Figure 10. Permit-Granting Process for Hydroelectricity Generation Purposes



Source: FGV CERI.

In the case of SMRB, NWA enacted Batalha HPP's "pre-permit" of in 2005. The auction conducted by ANEEL occurred in that same year and Furnas-Centrais Elétricas won it. In 2008, NWA converted the "pre-permit" into a water permit, which included the same upstream Batalha HPP water consumption restrictions as the "pre-permit" (ANA, 2008).

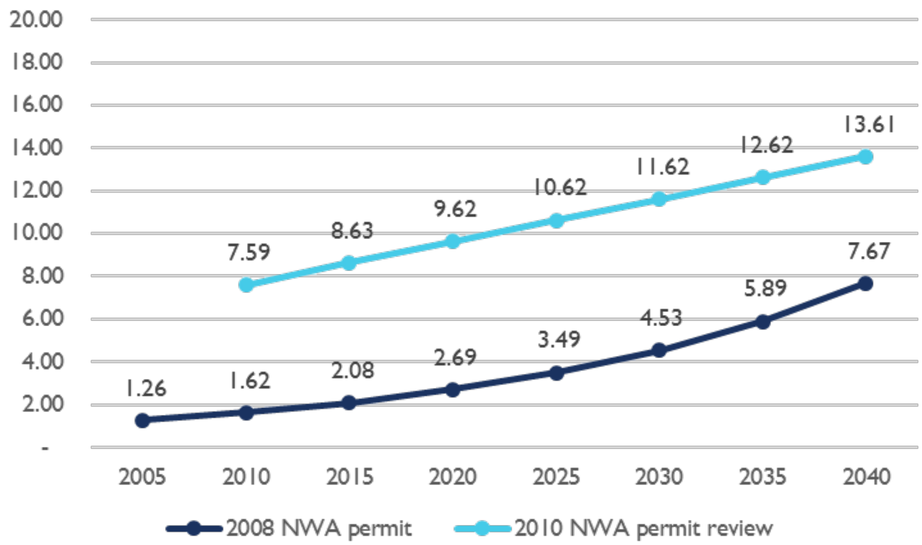
In 2010, the monitoring of irrigated areas conducted by NWA revealed that the existing consumption upstream from the Batalha HPP had already approached the limit fixed for 2040 (end of concession). NWA also identified that the increasing agriculture in the Alto São Marcos area could impact the electricity generation of the plants located downstream in the basin. Due to the acknowledgement of the conflict over water use, NWA conducted a series of studies and inspections.

The regulatory agency conducted an economic valuation of the water in the SMRB. This study revealed that irrigation had a higher value use, indicating potential gains from reallocating water in favor of agriculture (ANA, 2010b). Then, the NWA published the SMRB Water Resource Framework[23] aiming to propose a water reallocation strategy for the river basin (ANA, 2010c). This proposal led to the Batalha HPP's permit revision in 2010 (ANA, 2010d). The NWA increased the upstream consumption flow's limit, as presented in Figure 11. Consequently,

[23] A Water Resource Framework is a set of rules for the use of water resources. It is defined by the granting authorities in coordination with water users and the involved river basin committees. Developing a Water Resource Framework is necessary among other cases when there is an already existing, or potential, conflict.

Batalha's physical guarantee reduced. According to the electricity sector's legislation,[24] the 2010 review could only decrease to a maximum of 10 percent of Batalha's physical guarantee. Thus, Batalha's HPP permit was amended so that the maximum reduction would be reached in 2040.

Figure 7. Limits of Consumptive Uses Upstream from Batalha HPP



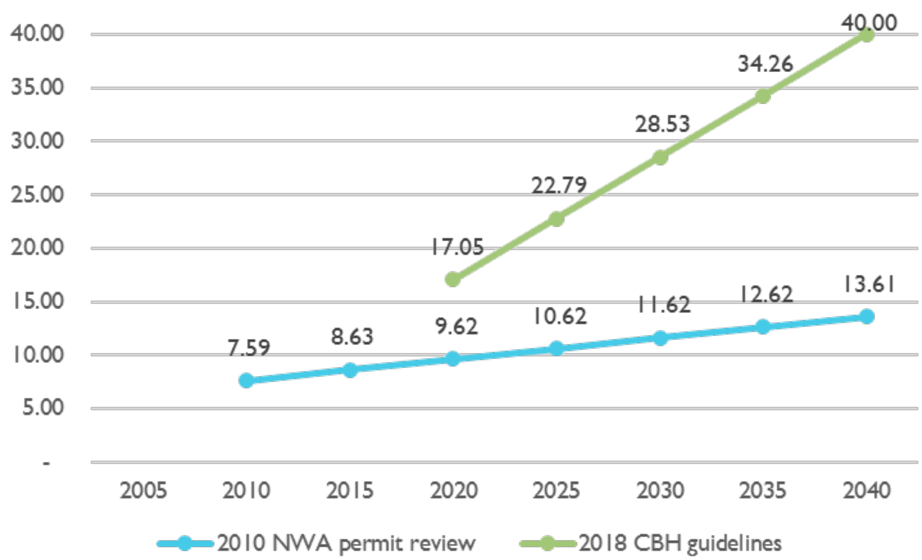
Source: FGV CERI.

Even though NWA has increased the flow limit of the upstream consumption, the value would not be sufficient to supply irrigation water demand. According to a projection conducted by NWA of the growth of irrigated areas, which was based on the evolution observed between 1986 and 2011, the basin would reach 205,000 hectares of irrigated areas in 2040, with 170,000 hectares of irrigated area upstream from the Batalha HPP. If we consider the irrigators' average standard consumption,[25] this area would correspond to a consumptive flow of 22.1 m^3/s, which would exceed the limit fixed for 2040 by more than 60 percent.

[24] Article 21 of Decree nº 5555/1998 established that the physical guarantee of each plant may be revised every five years so as not to imply a reduction of more than 5 percent. However, the reductions are limited to 10 percent of the basic amount as stated in the concession agreement during its term.
[25] According to ANA (2010b), the irrigators' average standard consumption in SMRB is 0.13 L/s/ha.

With these considerations in mind, in 2016, the Paranaíba Basin Committee[26] (CBH Paranaíba) defined that irrigation would be the priority use upstream from the Batalha HPP (CBH-PARANAÍBA, 2016b). Two years later, based on this statement, the CBH Paranaíba published guidelines for the water resource regulatory agencies (NWA, Minas Gerais state agency and Goias state agency) to increase the water flow for irrigation purposes upstream from the Batalha HPP (CBH-PARANAÍBA, 2018). The limit increases for consumptive uses upstream from the Batalha HPP suggested by the River Basin Committee are shown in Figure 12. It is still uncertain if the suggestion proposed by CBH Paranaíba's guidelines will result in a formal review of Batalha's permit, which the NWA has not undertaken so far..

Figure 8. Limits of Consumptive Uses Upstream from the Batalha HPP

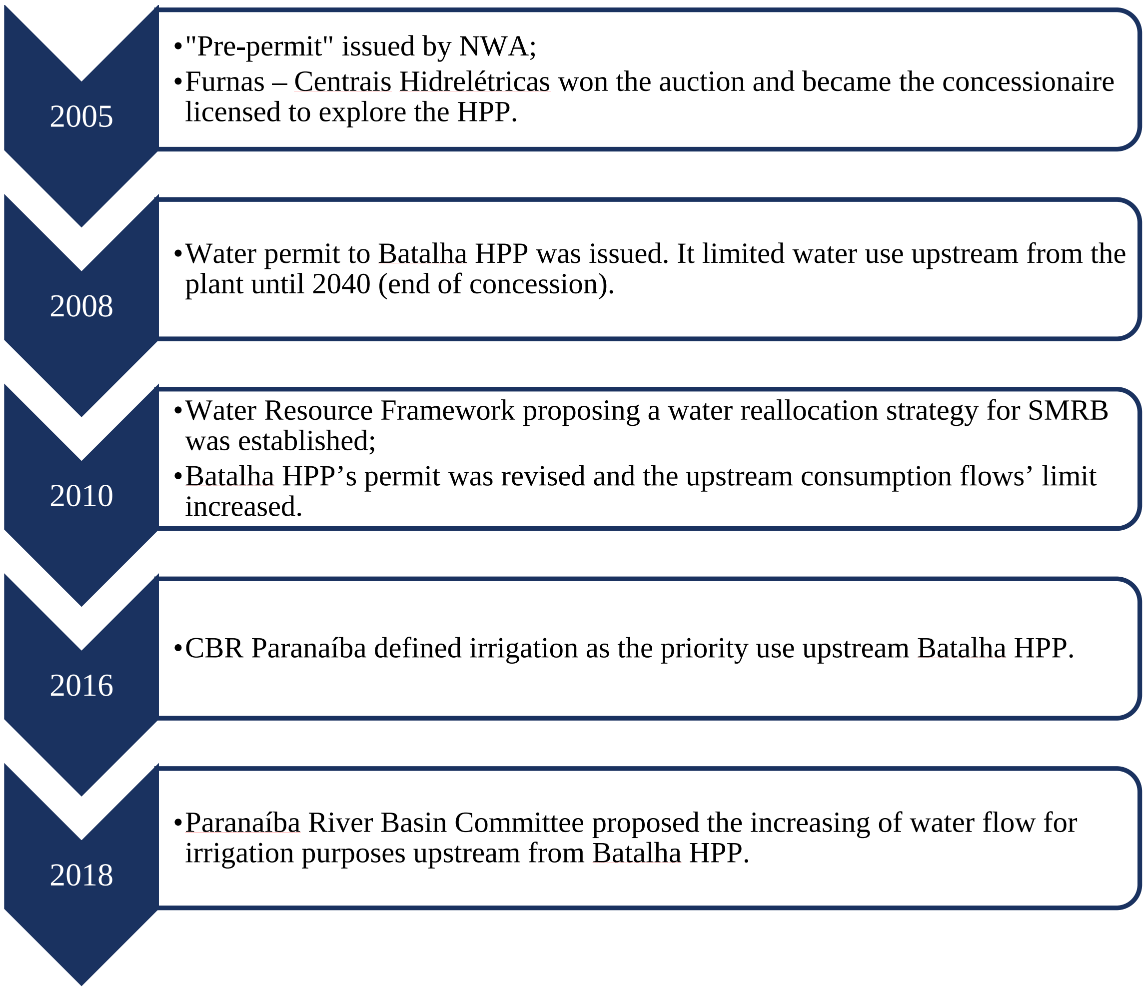


Source: FGV CERI.

The timeline presented in Figure 13 summarizes the dispute between irrigators located upstream from the Batalha HPP (Alto São Marcos area of SMRB) and the Batalha HPP.

[26] The São Marcos River flows to the Paranaíba River, so the Paranaíba River Basin Committee also covers the São Marcos River area.

Figure 9. Timeline



Source: FGV CERI.

The NWA currently estimates that the water demand for irrigation purposes in SMRB totals 10.78 m^3/s,[27] including permitted and non-permitted volumes. However, the allowed water consumption upstream from the Batalha HPP, which was defined on its permit, amounts to 9.42 m^3/s. SMRB is a river basin that is fully allocated, so we can assume that the permitted flow equals water resource supply. As there is an imbalance between demand and supply, we believe that the creation of a water market could help to deal with this problem.

[27] This information was calculated multiplying the irrigated area by the average irrigator water consumption – 0.13 L/s/ha (ANA, 2010a).

7.4 The Size of SMRB Potential Water Market

As already mentioned, there are two sectors competing for water in the upstream area of SMRB: hydroelectricity generation and irrigation. The regulatory framework does not define priority of use except for human needs and animal consumption. However, our analysis is limited to trades among irrigators.[28] Problems such as the 2014 water shortage in São Paulo[29] highlight the need for an approach that includes the hydroelectric generator. Future analyses will include other uses such as power generation.

Both federal and states agencies manage SMRB water resources. The creation of a water market in this basin would include users who received their permits from both domains (federal and states). As information on users permitted by state agencies was not available,[30] the analysis of this paper is limited to users granted permits by NWA. As more than 80 percent of the water uses in SMRB occur in state rivers, the sample of market players that we consider is much lower than the actual total. Current NWA permitted users and their main characteristics are presented in Table 4.[31]

[28] OECD (2015) also suggests this water market design.

[29] In 2014 the National System Operator (in Portuguese, *Operador Nacional do Sistem*a, ONS) lowered the Ilha Solteira Reservoir's quota to a level lower than the minimum quota of 325.40 meters established as an operating constraint to guarantee navigation level. This occurred because ONS decreased the outflow of HPPs located upstream from the Ilha Solteira HPP in order to fill up their reservoirs. As a result, navigation was interrupted for 20 months (from May 2014 to January 2016). Shipping companies estimate that the negative economic impact caused by this action was over R$ 200 million (GloboRural, 2016).

[30] The information provided by the Goiás State agency was insufficient to meet the goals of this paper. The Distrito Federal and Minas Gerais States agencies did not respond to the information request before the deadline of this project.

[31] There are 10 more permits in Alto São Marcos; information is missing, however, on annual volume and/or monthly permitted volume. The permit resolutions are: 1355/2013; 1005/2015; 647/2016; 318/2017; 65/2018; 691/2018; 1296/2018; 1439/2018; 1673/2018; and 1996/2018.

Table 4. Current NWA Permitted Users in Alto São Marcos

Irrigator	Permit Resolution	Annual Volume (m³)	Irrigated Crop	Irrigated Area (ha)	Estimated Irrigation Period[32]
1	402/2015	240,200	Bean	50	March-July
2	452/2015	1,302,841	Corn	197.4	May-Oct
3	212/2016	1,881,659	Corn	260	May-Sept
4	263/2016	1,785,000	Soybean	185.2	April – Oct
5	781/2016	1,606,050	Corn	213	May-Sept
6	816/2017	748,440	Corn	104	April-Sept
7	1156/2017	1,957,890	Corn	244.5	May-Sept
8	1468/2017	698,850	Bean	125	April-Oct
9	1492/2017	1,443,960	Bean	150	March-Sept
10	2210/2017	257,418	Bean	34	May-Sept
11	304/2018	652,344	Bean and corn	77	May-Oct
12	1044/2018	601,990	Soybean	80	Jan-Dec
	Total water volume (m³)	**13,800,342**	**Total irrigated area (ha)**	**1,720.10**	

Source: ANA.

As mentioned above, users presented in Table 4 represent only a portion of the potential water market players. A thorough analysis of the size of the market requires access to information on permits issued by state agencies.

7.5 Estimating Water Value in SMRB

In order to understand how water market among the irrigators would work we calculate/estimate the water economic welfare for each permitted irrigator (Table 4). We adopted the residual imputation approach, suggested by Young (1996). The author states that this is the most frequently-used approach for applying shadow pricing for irrigation water. NWA has also adopted a similar approach to estimate the value of water in the upstream area of SMRB.

[32] We analyzed the monthly permitted volume to estimate the irrigation period.

7.5.1 The Residual Imputation Approach

The microeconomics involved in the maximization of irrigator's profit are as follows:

$$\max_{(x_1,\dots,x_n,x_w)} \left\{ P \cdot f(x_1, \dots, x_n, x_w) - P_w \cdot x_w - \sum_{i=1}^{n} P_i \cdot x_i \right\} \quad (1)$$

where P represents price of the crop; f is the production function; P_i is price of the production factor i; x_i represents quantity of production factor *i* (e.g., labor, land, etc.); P_w is price of water; and x_w is quantity of water.

On the assumption that crops and all production factors markets are perfectly competitive, prices may be treated as constants. We get, by applying the first order condition for each production factor:

$$P_w = P \cdot \frac{\delta f}{\delta x_w} \quad (2)$$

$$P_i = P \cdot \frac{\delta f}{\delta x_i} \quad (3)$$

This means that the price of water or any other production factor is equal to its value, that is, the value of the factor marginal productivity.

If the production function f is homogeneous in the first degree (i.e., f(tx)=tf(x)), we can apply Euler's theorem (compute the first derivative with respect to t and evaluate it at t=1). So, the production functions can be written as:

$$f(x_1, \dots, x_n, x_w) = x_w \frac{\delta f}{\delta x_w} + \sum_{i=1}^{n} x_i \cdot \frac{\delta f}{\delta x_i} \quad (4)$$

Multiplying (4) by P and substituting it with (2) and (3), we may obtain:

$$P_w = P \cdot \frac{\delta f}{\delta x_w} = \frac{P \cdot f(x_1, \dots, x_n, x_w) - \sum_{i=1}^{n} P_i \cdot x_i}{x_w} \quad (5)$$

So, in the residual imputation approach, the value of the marginal productivity of water (or water value) is the difference between the revenue and the expenses of the crop production divided by the consumption of water.

7.5.2 SMRB Data

As presented in Table 4, we have information about water demand, irrigated area, cultivated crops and irrigation periods for permitted users located in Alto São Marcos. We use the valid permits issued by NWA to estimate the water's economic welfare for each irrigator. It consists of calculating the net income of the irrigator per volume of permitted water.

To estimate the irrigator's revenue per area (ha), we multiply crop productivity (kg/ha) by the irrigated area (ha) and by the crop price (R$/kg). The productivity of beans, corn, soybeans and wheat produced in the SMRB is presented in Table 5, according to ANA (2010).[33] We access information on irrigated areas directly from the permits issued by NWA. Crop prices were then checked on the Agrolink website[34] on February 25, 2019 (Table 5).

Table 5. Crop Average Productivity Adopted to SMRB Irrigated Areas and Crop Price

Crop	Average Productivity (kg/ha)[1]	Price (R$/kg)[2]	Revenue per area (R$/ha)
Bean	3,000	0.52	1,560
Corn	10,250	1.14	11,685
Soybean	3,300	4.13	13,629

Source: [1]ANA (2010b); 2 Agrolink website.

To estimate crop expenses, we use the average costs of production presented in Machado (2009) and also adopted in the NWA's study of water value in the São Marcos River. Crop expenses (total cost) are calculated by adding the costs of inputs and services by the central pivot[35] depreciation and by energy expenses. The inputs and services include seeds, fertilizers, planting and harvest in the calculations. We adjust their values using the inflation index.[36] The values are shown in Table 6.

[33] This study used productivity estimated by Machado (2009).
[34] Available at https://www.agrolink.com.br/.
[35] Central pivot is the irrigation technology used in the SMRB.
[36] We adjusted the prices by the General Market Price Index (IGPM) using the Citizen Calculator available at https://www3.bcb.gov.br/CALCIDADAO/publico/exibirFormCorrecaoValores.do?method=exibirFormCorrecaoValores

Table 6. Crop Inputs and Services Costs

Crop	Input and Services Cost (R$/ha)
Bean	2,869.76
Corn	2,378.45
Soybean	3,474.94

Source: ANA (2010b) and Machado (2009), adjusted by the General Market Price Index (IGPM).

According to an estimation conducted by ANA (2010b), annual depreciation costs are R$ 565.84/ha and energy costs are equal to R$ 152.96/1,000 m³. Both costs have also been adjusted for inflation.[37]

As the quantity of the productive cycle during the year influences the calculation of both gross revenue and cost of production, this variable was assumed based on the estimated irrigation period. After conducting this methodology for each permitted irrigator located in the São Marcos River, we obtain the results presented in Table 7.

[37] See footnote 39.

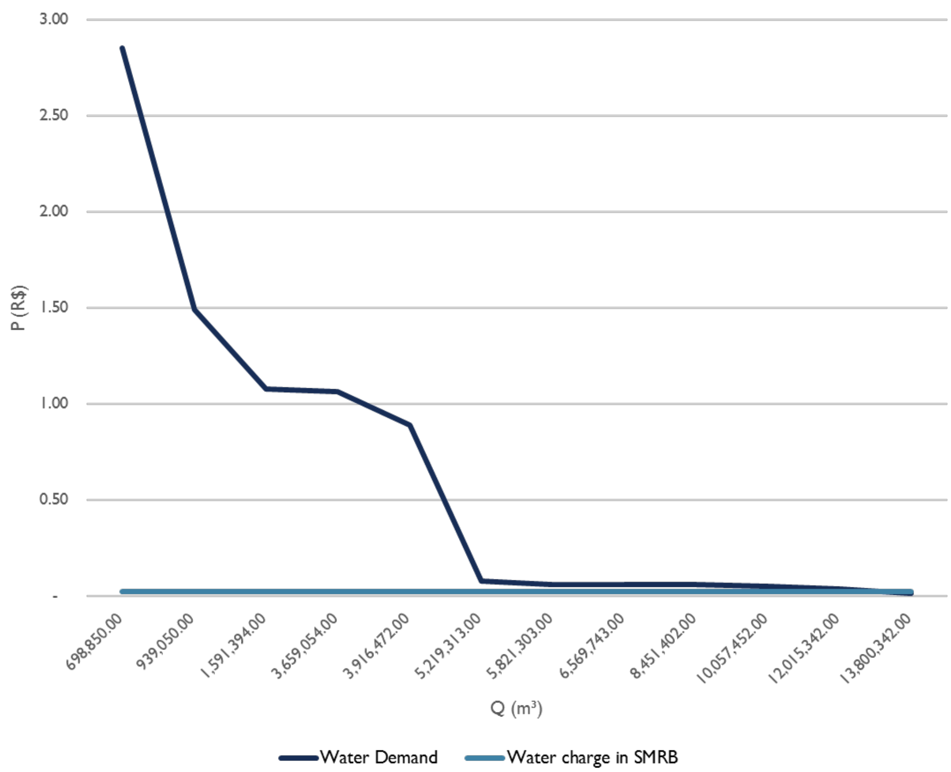
Table 7. Economic Benefits of Each Irrigator in the São Marcos River

Irrigator	Permit Resolution	Annual Volume (m^3)	Irrigated Crop	Irrigated Area (ha)	Irrigation Period	Productive Cycle	Gross Revenue (R$)	Production Expenses (R$)	Net Revenue (R$)	Economic Benefit (R$/$m^3$)
9	1468/2017	698,850	Bean	125	April - Oct	2	3,097,508.75	1,104,224.61	1,993,284.14	2.85
1	402/2015	240,200	Bean	50	March-July	1	619,501.75	261,665.43	357,836.32	1.49
12	304/2018	652,344	Bean and corn	77	May-Oct	2	1,364,292.74	661,865.36	702,427.37	1.08
10	1492/2017	2,067,660	Bean	150	March-Sept	2	3,717,010.50	1,523,731.56	2,193,278.94	1.06
11	2210/2017	257,418	Bean	34	May-Sept	1	421,261.19	193,139.91	228,121.28	0.89
2	452/2015	1,302,841	Corn	197.4	May-Oct	1	1,051,757.56	951,419.60	100,337.96	0.08
13	1044/2018	601,990	Soybean	80	Jan-Dec	3	899,071.80	864,395.26	34,676.54	0.06
7	816/2017	748,440	Corn	104	April-Sept	1	554,117.46	511,282.56	42,834.90	0.06
3	212/2016	1,881,659	Corn	260	May-Sept	1	1,385,293.65	1,279,913.16	105,380.49	0.06
5	781/2016	1,606,050	Corn	213	May-Sept	1	1,134,875.18	1,058,976.01	75,899.17	0.05
8	1156/2017	1,957,890	Corn	244.5	May-Sept	1	1,302,708.84	1,234,064.72	68,644.11	0.04
4	263/2016	1,785,000	Soybean	185.2	April - Oct	2	2,081,351.22	2,064,339.82	17,011.39	0.01

Source: FGV CERI.

With these values at hand we can construct the theoretical factor demand function for water. The inverse demand for water (i.e., its quantity as a function of its price) can be visualized in Figure 14. For illustration purposes, we also present in Figure 14 the value of water charge defined by CBH-Paranaíba.

Figure 14. Theoretical Factor Demand Function for Water



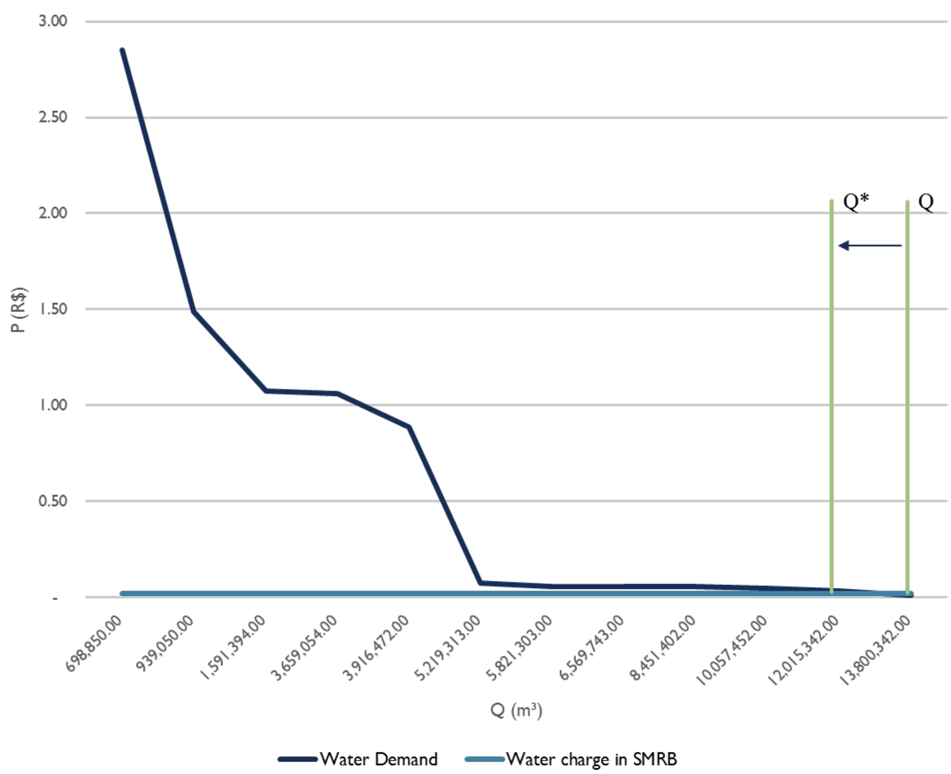
Source: FGV CERI.

For a fixed supply of water determined by the river basin availability, a competitive price that equates demand to supply can be easily computed. In a case of excess offer, that is, in case of water availability exceeds its demand, there is no concern with respect to misallocation. Misallocation occurs in the presence of scarcity, when there is no price system and market to naturally allocate the resources in a sound manner. This is the case in Brazil, where water charge does not signal water scarcity. Figure 14 illustrates the conclusions pointed out in Subsection 3.4:

i) in a scarcity situation, the water charge is very low, and ii) the way the water charge is implemented is not an economic tool for managing water resources.

In the current situation, due to the "use it or lose it" doctrine, presented in Section 5.2 , we can assume that the water supply is equal to the total permitted flow (point Q in Figure 15). In the presence of water scarcity, suppose the regulator—in this instance NWA—fixes a water supply Q*, as illustrated in Figure 15. In this case, in a competitive market, the more productive firms would be willing to pay a price P* that equates demand to supply, that is, P* solves $Q^d(P^*)=Q^s$.

Figure 15. Simulation of Regulator Reducing Water Supply in a Scarcity Situation



Source: FGV CERI.

The gains from a water market are simulated with a scenario where the market regulator impose a restriction in the use of water that generates an excess demand of 30% with prices set to zero.

7.5.3 Simulating the Gains of Creating a Water Market

We simulate two cases to compare the possible benefits of a water market. In the first case, we consider that a proportional reduction in the water availability is imposed on all users. That is, we consider that all users suffer a 30 percent restriction in the use of water. We call this case a case of linear rationing.

The second case is that of misfortune. In this simulated environment we consider that all the lower productive firms have rights of water use and the most productive ones have to restrict their use in favor of the less productive ones. Note that, while this is undoubtedly an extreme case, a "first come, first served" approach may result in misfortunes such as the one considered here.

In both cases we compute the producer surplus and compare it with the benchmark case of a competitive market with water trading rights. The total surplus with no water rationing is just the sum of all positive net revenue, which is R$ 5,919,733.00. With no water rationing, total demand for water is 13,800,342 m^3. With 30 percent excess demand in the simulated environment, total water supply is 9,660,239.40 m^3. In the competitive benchmark case, the price of water is 0.05 R$/$m^3$ and total surplus is R$ 5,769,698.00, as shown in Table 8.

Table 8. Results of Competitive Benchmark Scenario

Irrigator	Volume of Water (m^3)	Accumulated Volume (m^3)	Marginal Benefit (R$/$m^3$)	Surplus (R$)
8	698,850	698,850	2.85	1,993,284
1	240,200	939,050	1.49	357,836
11	652,344	1,591,394	1.08	702,427
9	2,067,660	3,659,054	1.06	2,193,279
10	257,418	3,916,472	0.89	228,121
2	1,302,841	5,219,313	0.08	100,338
12	601,990	5,821,303	0.06	34,677
6	748,440	6,569,743	0.06	42,835
3	1,881,659	8,451,402	0.06	105,380
5	1,208,837	9,660,239	0.05	11,520.45

Source: FGV CERI.

Here we must observe that surplus differs from net revenues since net revenue with a water price of 0.05 R$/$m^3$ equals (marginal benefit – 0.05)*(Volume of water). The value of the permits computed by multiplying the price of water by the accumulated volume is also part of the surplus.

Therefore, the computation of total surplus is just the sum of the products of marginal benefits with the volume of water.

An important result from this benchmark case is that, besides the reduction of 30% in the use of water, if a market for water exists and works in a competitive way, the total loss of welfare is only of 2.5 percent, or R$ 150,034.22. That occurs because the competitive framework ensures that the reduction of water reduces the production only of the less efficient producers.

On the other hand, if linear rationing is adopted, 30 percent reduction in the use of water by all producers, including the most efficient ones, would ultimately reduce total surplus in an amount of exactly 30 percent to a total of R$ 4,143,812.83 or a total reduction of R$ 1,775,919.78.

The worst-case scenario would be if the reduction of 30 percent of total availability of water would impact the most productive users. In this case, the total surplus of the 70 percent less efficient producers is only R$ 427,561.71, which accounts for a reduction of 92.8% from total welfare.

Table 2. Results of the Worst-Case Scenario

Irrigator	Volume of Water (m^3)	Accumulated Volume (m^3)	Marginal Benefit (R$/$m^3$)	Net Revenue (R$)
4	1,785,000	1,785,000	0.01	17,011.39
7	1,957,890	3,742,890	0.04	68,644.11
5	1,606,050	5,348,940	0.05	75,899.17
3	1,881,659	7,230,599	0.06	105,380.49
6	748,440	7,979,039	0.06	42,834.90
12	601,990	8,581,029	0.06	34,676.54
2	1,079,210	9,660,239	0.08	83,115.11

Source: FGV CERI.

Table 10 summarizes the total surplus and total loss of welfare of each simulated scenario.

Table 3. Comparison among the Simulated Scenarios

Scenario		Total Surplus (R$)	Total loss of welfare
No rationing		5,919,733	-
30% rationing	Competitive benchmark	5,769,698	-2.5%
	Linear rationing	4,143,812.83	-30.0%
	Misfortune scenario	427,561.71	-92.8%

Source: FGV CERI.

Since the value of the marginal productivity of water is a great amount in the river basin to say the least, varying from 0.01 to 2.85 R$/m^3, the potential benefits of a water market are astonishing.

8. Conclusion

Conflicts over water use are a reality in many areas across Brazil, and they are likely to be aggravated by climate change and soaring demand. Additionally, the existing mechanisms for addressing water scarcity are inefficient in that they do not incentivize the reallocation of water towards its highest value use. In this sense, this paper examines the desirability and feasibility of creating water markets to promote the efficient reallocation of water.

The first-principles analysis shows that water markets may dominate water pricing mechanisms. The readiness assessment undertaken identifies some legal and institutional barriers to the creation of water markets in Brazil. This means that further reforms are required in order to design and implement efficient water markets. Policy recommendations are then provided to overcome the barriers identified in our analysis.

Aiming to assess the potential gains from the implementation of water markets in Brazil, we simulate a market for the São Marcos River Basin. Assuming a scenario where the market regulator imposes a restriction on the use of water that generates excess demand 30 percent with prices set to zero, we find that, if a linear rationing system is applied, total loss of welfare would be 30 percent. However, if a market for water exists and works in a competitive way, we estimate that the total loss of welfare would be only 2.5 percent. The case study highlights how the creation of a water market can overcome inefficient allocation.

References

ANA (Agência Nacional de Águas). 2008. "Resolução nº 489, de 19 de agosto de 2008." Available at: http://arquivos.ana.gov.br/resolucoes/2008/489-2008.pdf

----. 2010a. "Relatório 2009 Cobrança pelo uso dos recursos hídricos na bacia do Paraíba do Sul".

----. 2010b. "Nota Técnica nº 103, de 30 de agosto de 2010."

----. 2010c. "Nota Técnica nº 104, de 30 de agosto de 2010." Available at: http://www3.ana.gov.br/portal/ANA/todos-os-documentos-do-portal/documentos-sre/marcos-regulatorios/nt-sao_marcos.pdf

----. 2010d. "Resolução nº 564, de 25 de outubro de 2010".

----. 2013. "Portaria n° 62, de 26 de março de 2013."

----. 2015. "Conjuntura Recursos Hídricos Brasil."

----. 2016. "Background Report OECD/Brazil Policy dialogue setting and governing economic instruments for water policy". Available at https://www.ana.gov.br/todos-os-documentos-do-portal/documentos-sas/arquivos-cobranca/documentos-relacionados/nota-informativa-no-5-2018-cscob-sas

----. 2017a. "*Atlas Esgotos: Despoluição de Bacias Hidrográficas*". Available at http://arquivos.ana.gov.br/imprensa/publicacoes/ATLASeESGOTOSDespoluicaodeBaciasHidrograficas-ResumoExecutivo_livro.pdf

----. 2017b. "*Conjuntura dos Recursos Hídricos no Brasil 2017*." Available at http://www3.snirh.gov.br/portal/snirh/centrais-de-conteudos/conjuntura-dos-recursos-hidricos/conj2017_rel_ingles-1.pdf.

Australian Bureau of Agricultural and Resource Economics and Sciences. 2018. "Surface Water Allocation Trade, 2016-17. Available at: https://public.tableau.com/profile/australian.bureau.of.agricultural.and.resource.economics.and.sci#!/vizhome/AustralianWaterMarketsDashboard2016-17/AWMR2016-17

Australian Competition and Consumer Commission. 2016. "Review of the Water Charge Rules Final Advice." Available at: http://www.agriculture.gov.au/SiteCollectionDocuments/water/final-advice.pdf

Australian Government. 2018. "Water Act 2007. Available at: https://www.legislation.gov.au/Details/C2018C00247

Cantin, B., D. Shrubsole and M. Aït-Ouyahia. 2005. "Using Economic Instruments for Water Demand Management: Introduction." *Canadian Water Resources Journal* 30(1): 1-10.

CBH-Doce. 2018. "Deliberação CBH-Doce nº 69, de 12 de junho de 2018." Available at: http://www3.ana.gov.br/portal/ANA/todos-os-documentos-do-portal/documentos-sas/arquivos-cobranca/deliberacao-cbh-doce-no-69_18.pdf

CBH-Paranaíba. 2016a. "Deliberação nº 61, de 10 de março de 2016."

----. 2016b. "Deliberação nº 70, de 15 de dezembro de 2016."

----. 2018. "Deliberação nº 88, de 27 de março de 2018."

CBH-Verde Grande. 2015. "Deliberação n° 50, de 5 de maio de 2015."

CBHSF. 2016. "Plano de Recursos Hídricos da Bacia Hidrográfica do Rio São Francisco 2016-2025."

----. 2017. "Deliberação nº 94, de 25 de agosto de 2017."

Da Silva, U.P.Á. et al. 2006. "*A Experiência da Alocação Negociada de á Água nos Vales do Jaguaribe e Banabuiú*." Available at: http://arquivos.ana.gov.br/imprensa/eventosprojetos/AlocacaoNegociadaAguaValeJaguaribe.pdf

Easter, K.W., M.W. Rosegrant and A. Dinar, editors. 1998. *Markets for Water: Potential and Performance*. Dordrecht, The Netherlands: Springer Science & Business Media.

EPE. 2018. *Matriz Energética e elétrica*. *Empresa de Pesquisa Energética*. Available at http://epe.gov.br/pt/abcdenergia/matriz-energetica-e-eletrica .

Fernandes, R.D.O. et al. 2017. "Reservoir Yield Intercomparison of Large Dams in Jaguaribe Basin-CE in Climate Change Scenarios." *RBRH* 22: 11. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2318-03312017000100225&lng=en&nrm=iso&tlng=en

FGV EAESP, ANA. 2018. "Instrumentos Econômicos Aplicados à Gestão de Recursos Hídricos: Caminhos para Sua Adoção em Situações de Conflito pelo Uso da Agua no Brasil." Available at: https://www.researchgate.net/publication/328432690_Instrumentos_economicos_aplicados_a_gestao_de_recursos_hidricos_caminhos_para_sua_adocao_em_situacoes_de_conflito_pelo_uso_da_agua_no_Brasil.

FGV EESP. 2016. "Estudo sobre Eficiência do Uso da Agua no Brasil: Análise do Impacto da Irrigação na Agricultura Brasileira e Potencial de Produção de Alimentos face ao Aquecimento Global." Rio de Janeiro, Brazil: FGV EESP. Available at: https://bibliotecadigital.fgv.br/dspace/bitstream/handle/10438/17675/Efici%C3%AAncia_do_Uso_da_%C3%81gua_no_Brasil_Relat%C3%B3rio_Completo.pdf.

GloboRural. 2016. "Após Quase Dois Anos Hidrovia do Rio Tietê Retoma Transporte de Cargas." Available at: https://revistagloborural.globo.com/Rios-do-Agro/noticia/2016/05/apos-quase-dois-anos-hidrovia-do-rio-tiete-retoma-transporte-de-cargas-2.html.

Grafton, Q., and D. Peterson. 2007. "Water Trading & Pricing." In: K. Hussey and S. Dovers, editors. *Managing Water for Australia: The Social and Institutional Challenges*. Collingswood, Australia: CSIRO Publishing.

Grafton, R.Q. et al. 2010a. "An Integrated Assessment of Water Markets: Australia, Chile, China, South Africa and the USA." NBER Working Paper 16203. Cambridge, United States: National Bureau of Economic Research.

----. 2010b. "Water Markets: Australia's Murray-Darling Basin and the US Southwest." NBER Working Paper 15797. Cambridge, United States: National Bureau of Economic Research.

Grafton, R.Q. et al. 2012. "Comparative Assessment of Water Markets: Insights from the Murray–Darling Basin of Australia and the Western USA." *Water Policy* 14(2): 175-193.

IBGE. 2018. Produção agrícola municipal. Available at: https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=766.

Kelman, J. 2009. *Desafios do Regulador*. Rio de Janeiro, Brazil: Synergia Editora.

Machado, B.G.F. 2009. "Análise Econômica Aplicada à Decisão sobre Alocação de Agua entre os Usos Irrigação e Produção de Energia Elétrica: O Caso da Bacia do Rio Preto." Brasilia, Brazil: Universidade de Brasília. Master's thesis.

Matthews, O.P. 2004. "Fundamental Questions about Water Rights and Market Reallocation." *Water Resources Research* 40(9). Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2003WR002836

Murray–Darling Basin Authority. 2018.. Website available at https://www.mdba.gov.au/

OECD. 2015. *Water Resources Governance in Brazil*. OECD Studies on Water. Paris, France: OECD Publishing.

OECD. 2017. *Water Charges in Brazil: The Ways Forward*. OECD Studies on Water. Paris, France: OECD Publishing.

Rosegrant, M.W., and S.R. Gazmuri 1995. "Reforming Water Allocation Policy through Markets in Tradable Water Rights: Lessons from Chile, Mexico, and California." *Cuadernos de Economía* 32(97): 291-315.

SEUC (Senate Energy, Utilities and Communications Committee). 2001. "Interruptible Service Contract Issues." Sacramento, United States: Senate of California. Available at: https://seuc.senate.ca.gov/interruptibleservicecontractissues

SNIS. 2016. *Sistema Nacional de Informações sobre Saneamento*. Available at http://www.snis.gov.br/.

SNIRH. 2018. *Sistema Nacional de Informações sobre Recursos Hídricos*. Available at: http://www.snirh.gov.br/

Wheeler, S.A. et al. 2017. "Developing a Water Market Readiness Assessment Framework." *Journal of Hydrology* 552: 807-820.

Young, M. 2014. "Trading into Trouble? Lessons from Australia's Mistakes in Water Policy Reform Sequencing." In: K. William Easter and Q. Huang, editors. *Water Markets for the 21st Century*. Dordrecht, The Netherlands: Springer.

Young, R. 1996. "Measuring Economic Benefits for Water Investments and Policies." World Bank Technical Paper 338. Washington, DC, United States: World Bank.

An Analysis of The Possible Benefits of a Water Market in Brazil

The actual Brazilian water resource management works in a "first come, first served" approach. The main economic problem of this approach is the lack of a redistribution scheme (mechanisms for reallocation). Since the water availability is not always sufficient to fully meet its demand, an inefficient allocation may arise from this distribution process.

To illustrate the problem, suppose that actual demand of water amounts to a fixed Q_d. If the supply of water is restricted to $Q_s < Q_d$, the scarcity (excess demand) $Q_d - Q_s > 0$ may present a problem if no market and price system is present.

Missing Markets: An Analysis of Externalities in the Use of Water

There is basically two reasons to consider an analysis of externality in the use of water. The first one is that in the absence of a proper water market, the use of water from one producer may directly impact in the available quantity for other producer. Also, since the abstraction of water may generate pollution, its implications on the production of others may also be relevant. We will restrict our analysis to the first case.

Let i represent a producer with technology described by a production function $f_i(x)$ where x is the quantity of water and $f_i(x)$ is the total production with quantity x of water used. If his/her product is sold by a competitive price p_i and his/her marginal cost of abstraction is c_i, he/she will decide to abstract a quantity x_i that solves

$$\max_x p_i f_i(x) - c_i x \tag{1}$$

subject to

$$x \leq A_i \tag{2}$$

where $A_i > 0$ is the total water available in the water body for producer i.

The solution to this problem is just x_i that solves

$$p_i f_i'(x_i) = c_i \tag{3}$$

if $x_i < A_i$, or $x_i = A_i$.

If the water body has N producers, total demand for water is just

$$Q_d = \sum_{i=1}^{N} x_i \tag{4}$$

Let Q_s be the total amount of water available in the water body. If $Q_s > Q_d$, then no externality is present and there is no need of an economic mechanism for water allocation. On the other hand, if $Q_s < Q_d$, then there will be externality and at least one producer will end up with less water than the desired amount.

To see the externality problem, note that each quantity x_i abstracted from the water body by producer i reduces the available quantity A_j of water available to all other producers $j \neq i$. If the available quantity does not affect the optimal solution of any producer, there is no externality problem. We claim that if $Q_s < Q_d$ there will be an externality problem.

In a "first come, first served" approach, we may index producer 1 as the first to come, that is, the first to abstract water from the water body. He/she will abstract a quantity x_1 that solves

$$p_1 f_1'(x_1) = c_1$$

If

$$x_1 < Q_s$$

Otherwise, he/she will consume

$$x_1 = Q_s$$

and other producers will have no water left to abstract, that is,

$$x_2 = x_3 = ... = x_N = 0$$

If

$$x_1 < Q_s$$

The second to come, that is, producer 2, will abstract x_2 that solves

$$p_2 f_2'(x_2) = c_2$$

if

$$x_2 < Q_s - x_1$$

otherwise, he/she will consume

$$x_2 = Q_s - x_1$$

and all other producers will end up with no water available to abstract. That is,

$$x_3 = ... = x_N = 0.$$

The decision of producer $1 < K \leq N$ in a "first come, first served" approach is just x_K that solves

$$p_K f'_K(x_K) = c_K$$

if

$$x_K < Q_s - \sum_{i=1}^{K-1} x_i$$

or

$$x_K = Q_s - \sum_{i=1}^{K-1} x_i$$

Otherwise.

A clear result from this "first come, first served" approach is that if $Q_d > Q_s$ then

$$x_K = Q_s - \sum_{i=1}^{K-1} x_i$$

for some producer $1 < K \leq N$. Also, if $K < N$, then

$$x_{K+1} = ... = x_N = 0.$$

Externality is then present because at least one producer has the decision affected by the decision of the preceding producers. Since this is truth, the conditions of the First Welfare Theorem are not satisfied anymore and efficiency cannot be guaranteed.

Water Market: The Competitive Framework

In a competitive market, the efficient allocation is achieved by trading. The competitive equilibrium is achieved with a price that equates demand to supply. Since all participants of the market face the same price, the trading scheme needs little information to work properly.

Suppose again that water is an input for a set of N producers. With an amount of water x the producer i can produce a quantity $y_i = f_i(x)$ of his/her good to be sold by a price p_i. One possible example is the production of rice that needs some amount of water to be produced. The optimal amount of water required by the producer is the one that maximizes its profits

$$p_i f_i(x) - wx \tag{5}$$

Where w is the price of water, that is, the cost of one unit amount of water.

The first order condition of this problem is

$$p_i f_i'(x_i) = w \tag{6}$$

in words, the value of the marginal productivity of water must be equal to its cost.

It is clear that if this is not the case, an opportunity to increase profit is available. To see this, note that if $p_i f_i'(x) > w$, the producer can buy an additional amount of water and pay w while it increase the production in an amount $f_i'(x)$ increasing revenue by $p_i f_i'(x)$. With this, profits are increased by $p_i f_i'(x) - w > 0$.

Since this equation must be true for all profit maximizing producers, we must have

$$p_i f_i'(x_i) = p_j f_j'(x_j) \tag{7}$$

That is, the value of marginal productivity must be the same for all producers. This is the exact condition for Pareto optimality.

If equation (7) does not hold, there is value to be created by trade. Just note that if $p_i f_i'(x_i) > p_j f_j'(x_j)$, then both firms can increase profit if firm i can buy one unit amount of water from firm j by a price w where $p_i f_i'(x_i) > w > p_j f_j'(x_j)$. The welfare gains from this unit of trade is just $p_i f_i'(x_i) - p_j f_j'(x_j)$.

Some Remarks About Equity Concerns

In the previous section we showed how the possibility of trades can improve social welfare, but nothing was said about equity. The matter of equity appears in the distribution of water rights. It is important to note that no matter who receives more of the water rights, if the market works in a competitive fashion, the resulting allocation after trade will be efficient. The quantity of rights available to each producer will only determine the distribution of wealth. The optimal distribution of wealth is not part of our analysis here. But in the case of extreme importance, the social planner, in our case, the government, may decide to distribute water rights in an equal fashion to all the producers. The

possibility of trade will naturally transfer the rights to the more productive ones and the less productive will receive the value for the sell of his shares of water rights.

Computing Total Gains From Trade

If we wish to compute total gains from trade we need to integrate over total amount traded, that is, let q be the total amount traded between producer i and j. Then, the gains from trade can be computed from

$$\int_0^q [p_i f_i'(x_i + t) - p_j f_j'(x_j - t)]dt = p_i[f_i(x_i + q) - f_i(x_i)] - p_j[f_j(x_j - q) - f_j(x_j)] \quad (8)$$

This is just the difference in the change of revenue from trade between firms i and j (since costs from trade cancel out). If we assume that marginal productivity remains constant for the trading quantity, that is, if

$$f_i'(x_i + t) = c_i, \quad \forall t \in [0, q] \quad (9)$$

and

$$f_j'(x_j - t) = c_j, \quad \forall t \in [0, q] \quad (10)$$

then total gains from trade is just

$$\int_0^q [p_i f_i'(x_i + t) - p_j f_j'(x_j - t)]dt = (p_i c_i - p_j c_j)q \quad (11)$$

In the evaluation of gains from trade section we will consider a way to evaluate the value of marginal productivity of water for each firm. With that at hand, the gains from trade is just the difference of the values of marginal productivity of water of firms times the quantity of water traded.