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Competitiveness and effectiveness concerns in water charge implementation: a case study of the Paraíba do Sul River Basin, Brazil

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Abstract

Policymakers should be aware of the potential trade-off between environmental effectiveness and competitiveness concerns involving water charge implementation. This trade-off can be particularly important in countries such as Brazil, which adopt a decentralized and participative water management approach through River Basin Committees. In such a regulatory framework, it is crucial for the consensus reaching process to evaluate in advance potential impacts of water charge schemes. This paper aims at assessing the economic and environmental impacts of industrial water charges in Brazil. The analysis is based on a survey of 488 plants located within the Paraíba do Sul River Basin. The survey indicates that a significant proportion of the industrial plants approves the water charge mechanism and that increasing water costs are already inducing them to undertake conservation measures. Simulations based on an econometric water demand model suggest that water charges can induce significant industrial water demand reductions with limited impact on firms' costs. Regarding pollution control, the estimated marginal effluent treatment costs are far above the current values established for the pollution-related component of the water charge. These results indicate that competitiveness conflicts will not necessarily pervade the political economy of water charges in Brazil.

Keywords: Brazil; Competitiveness; Industrial water demand; Pollution control costs; Water charge

1. Introduction

Following the approval of the Federal Water Law of January 1997, the Brazilian water management system has been going through a wide-ranging reform. Among the several institutional and policy

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innovations promoted by the law, one of the most prominent is the introduction of quality- and quantity-related water charges into the regulatory framework.

Brazilian water sector policy has been historically based on the use of "command-and-control" mechanisms, and water charges represent the first application of economic instruments for water resources management. The aim of introducing this new policy instrument is twofold. First, water charges are supposed to provide funding to projects related to pollution control and water availability within river basins. Second, following the "user-pays" and "polluter-pays" principles, water charges are also aimed at making users internalize water pollution and use costs.

Charges were first implemented in March 2003 within the Paraíba do Sul River Basin, and use of this policy instrument should be extended to other river basins in the near future (see Féres & Seroa da Motta, 2004). In such a context, evaluating the impacts of the charge system is crucial to support water managers' decision-making with respect to the system implementation path.

Competitiveness concerns on charge level setting will depend on users' economic evaluation of the net compliance costs. The higher the direct cost agents incur to meet the policy requirements, the more likely they will be opposed to this policy. This means that higher water charge values should face more resistance since they will increase water-related expenditures that users will face, thus reducing their competitiveness. But if benefits associated with environmental-quality improvements are high, acceptance will be eased. For example, pollution charges may promote water quality improvements, thus reducing users' costs of treatment prior to water use[1]. In the case of industrial users, firms may have incentives to adopt environmentally friendly positions as an effective way to reinforce their public image and to increase consumer goodwill[2]. In addition to these externalities, firms may perceive benefits when a portion of the water revenues is reintroduced into the river basin system as, for example, subsidized credits. In all these examples, the expected benefits associated with the policy instrument will facilitate acceptance among users.

Competitive concerns may be at odds with the environmental objectives of water charges. In fact, if charges are set at high levels so as to reinforce their signalling role on the scarcity value of water resources, the economic impacts on industrial and agricultural users' competitiveness may be high enough to put at risk the acceptability of the charge. On the other hand, low charge levels with minor economic impacts on users' cost may ease the acceptability, but at the same time can fail to provide incentives for agents to adopt sustainable water use practices.

The potential trade-off between effectiveness and competitiveness can be particularly important in countries such as Brazil, which adopt a decentralized and participative water management approach. Actually, following the French experience (see Thomas *et al.*, 2004), the Brazilian Federal Water Law of January 1997 defined the river basin committee as the cornerstone of the sector's institutional arrangement. The principle of decentralization is clearly observed in the committees' composition, since the public administration holds less than half of the representatives. This means that any water-related decision, including water charge levels, should reach a reasonable degree of consensus between public authorities, users and stakeholders in order to be approved by the committee. While this negotiation process facilitates users' acceptability, the participative decision-making process may prevent the adoption of a more stringent water charge. Users will be opposed to any measure that may represent increases in their costs, hindering the

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[1] With water quality improvements in the river bodies, water utilities may reduce their costs in making water potable for household consumption. Industries that require high water quality standards to use within their applications may also reduce their water pre-treatment expenditures.

[2] See Seroa da Motta (2006) for the case of Brazil.

implementation of environment-improving policies. In this way, decentralization of the water management system may favour policy acceptability to the detriment of its environmental effectiveness. Therefore, it is crucial for the consensus reaching process to assess in advance potential impacts of water charges.

The literature on industrial water demand in developing countries has been mostly focused on the effectiveness of environmental policies. In general, the empirical evidence suggests that pricing policies may be an effective mechanism for water conservation in these countries. Wang & Lall (2002) estimate an average water demand price elasticity of about -1.0 for Chinese firms, indicating that firms are responsive to water price increases. Similar results were found by Féres & Reynaud (2005) for the Brazilian industrial sector and Kumar (2006) for the Indian case. Analysing water pollution abatement costs for Chinese firms, Dasgupta *et al.* (1996) conclude that charges of US\$3 ton^{-1} of total suspended solids and US\$30 ton^{-1} of BOD (biochemical oxygen demand) would be sufficient to induce 90% abatement of these effluents. Although these results provide some evidence that both quantity- and quality-related water charges may be an effective instrument for achieving environmental objectives, little is known about the economic impact of such pricing policies on firms' production costs and their implications in terms of water use levels.

The main contribution of this paper is in assessing the potential conflict between competitiveness and effectiveness of industrial water charges in Brazil. The analysis is based on a survey of 488 industrial plants located within the Paraíba do Sul River Basin. In Section 2, a brief overview of water management in Brazil is presented. Section 3 describes the pioneer water charge implementation in the Paraíba do Sul River Basin. Section 4 reports survey results regarding industrial water use patterns and users' receptiveness to water charges. The following two sections evaluate the potential economic and environmental impacts of water charges in the Paraíba do Sul River Basin through the analysis of industrial water demand (Section 5) and the estimation of water pollution control costs (Section 6). A summary of the main conclusions and policy implications are presented in the last section.

2. An overview of water management in Brazil[3]

The Federal Water Law of January 1997 deeply modified the Brazilian water management system. To handle the externality problems resulting from water pollution and conflicts of use in an integrated and decentralized approach, the river basin was chosen as the basic administrative unit. The underlying reasoning was that water management organization should reflect the physical unity of water bodies in order to account for potential sources of conflicts. Following the French experience, the decentralization principle was put into practice by defining the River Basin Committees as the cornerstone of the sector's institutional arrangement.

River Basin Committees constitute the loci where conflicts related to water quality and availability can be solved. The various agents concerned with water management are represented therein: water users, the public administration and stakeholders. The principle of decentralization is clearly observed in its composition, since the public administration holds less than half of the representatives. By assembling the interested parties established in the river basin, the decisions of the River Basin Committees are expected to reflect the general interest of all users and stakeholders. Each River Basin Committee has its own water agency, which acts as its executive branch.

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[3] For a full description of water management in Brazil, see Féres & Seroa da Motta (2004).

The participative nature of the committees' composition has important implications both in terms of acceptability and effectiveness regarding water regulation. The fact that any water-related issue must be decided and voted on by the River Basin Committee facilitates its acceptability by users, since they can actively take part in the discussions. Actually, water management decisions at the basin level are the outcome of the negotiation process between users, the public administration and stakeholders, since they are all represented at the River Basin Committees. This means that any decision should reach a reasonable degree of consensus in order to be accepted and approved by all parties involved. The negotiation process legitimizes the decisions taken by the committees. Such institutional arrangement, by easing water users' acceptance, is supposed to avoid the problems of regulation enforcement presented by the previously centralized water management system.

On the other hand, the participative decision-making process may prevent the adoption of a more stringent water regulation. Users will be opposed to any measure that may represent increases in their costs, hindering the implementation of environment-improving policies. In this way, decentralization of the water management system may favour policy acceptability resulting from fear of weakening competitiveness to the detriment of environmental effectiveness.

Charge criteria and values must be approved by the River Basin Committees in the context of the elaboration of the river basin management plans[4]. As already discussed, given the participative character of the committees' composition, this approval is supposed to guarantee that the interested parties accept the charges, hence legitimizing their application.

The above discussion shows that the issues of competitiveness and effectiveness of water policy instruments are particularly important in countries such as Brazil, which adopt a participative water management approach. The pioneer implementation of the new policy framework, and its charges application, is taking place in the Paraíba do Sul River Basin.

3. Water charges in the Paraíba do Sul River Basin

The Paraíba do Sul River Basin is located in the south-east region of Brazil. It has a drainage area of about 55,500 km^2, distributed across the states of Minas Gerais (20,700 km^2), Rio de Janeiro (20,900 km^2) and São Paulo (13,900 km^2). About 5 million people live within the basin, distributed among large cities and smaller rural municipalities. The basin represents 0.7% of the country's surface but, despite its modest size, it is important because of its geographical situation. The valley of the main river connects the two most important Brazilian metropolitan areas, Rio de Janeiro and São Paulo. There are approximately 8,500 industrial plants located in the basin region, and the intense economic activity within the basin accounts for about 10% of the country's GDP.

Water pollution is identified as the main problem of the basin, primarily due to industrial and domestic effluents. This situation can be largely attributed to discrepancies between the socio-economic development of the region and insufficient measures to preserve environmental quality.

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[4] Based on an evaluation of the river basin situation in terms of water availability and demand patterns, the River Basin Management Plan defines the environmental objectives for water availability and quality for a five-year horizon. The management plan also indicates the type, size and schedule of water-related investments that are needed to achieve the objectives. Water charge values are defined according to the basin's investment needs and environmental targets.

The rapid demographic growth experienced by the majority of basin urban areas was not accompanied by adequate planning and sanitation measures, resulting in the indiscriminate occupation of riverbanks and the lack of sanitation infrastructure. According to the Paraíba do Sul Water Resources Plan, 69.1% of households in the urban areas are connected to the municipal sewage network, but only 12.3% of collected domestic wastewater is treated before its release into water bodies. It is estimated that domestic effluents are responsible for a BOD discharge of 240 t/day in the river basin.

The same trend can be observed in the industrial activities, whose development was not accompanied by the adequate pollution control measures. The estimated daily BOD discharge related to industrial activities is about 40 t/day.

Given the critical situation of water quality and the importance of the river's geographical position, the federal government decided to define as a priority the implementation of the new water management approach in the Paraíba do Sul River Basin. The reorientation towards a decentralized and participatory framework started in 1996 with the creation of the Paraíba do Sul River Basin Committee (CEIVAP). Since 2000, negotiations about the water charge methodology have proceeded according to the participatory principle. The water resources plan was finished by July 2002, while the basin's Water Agency was created later in the same year.

In the definition of the water charge methodology, CEIVAP adopted simple rules both in conceptual and operational terms. This simplicity is intended to increase users' familiarity with the water charge system, and to learn more about the way their behaviour can be modified. The option for simplicity also makes possible the implementation of the water charge over a short-term horizon, since sophisticated methodologies would require data on water quantity and quality aspects, which are not currently available. According to the Paraíba do Sul Water Resources Plan, the discussion of the water charge methodology within CEIVAP was based on the following principles:

- *Simplicity:* Conceptual and operational simplicity, as mentioned above, were the main guidelines for defining the water charge methodology. The charge mechanism should be based on directly measurable parameters in order to allow clear understanding by the users.
- *Acceptability*: Acceptability by all users is a fundamental requirement in order to legitimize the water charge mechanism. The participatory approach in the CEIVAP, which is responsible for the definition of the water price methodology, facilitates this task.
- *Signalling*: Water charges are supposed to act as signals about the economic value of water resources and the importance of sustainable use, both in terms of quantity (withdrawal and consumption) and quality (effluent dilution).
- *Minimization of economic impacts*: The signals, however, must not be so strong as to jeopardize acceptability. Therefore the pricing criteria were defined in order to minimize the economic impacts on users in terms of cost increases. So far this has been accomplished by adopting low values for the water charges.

One can easily notice that the question of acceptability and minimization of economic impacts are clearly at odds with the signalling role of water charges. These contradictory criteria indicate that the trade-off between acceptability and stringent environmental policy was an important issue during the debate on the water charge formula. The water charge methodology was approved in 2001 and became effective in 2003. Charges are applied for both water use and water effluents (measured in terms of BOD).

As a result of the consensus process in the committee, charges were set at this initial period of implementation at very low levels with the expectation that they will increase in subsequent periods.

Currently, industrial users and water utilities pay R\$0.008 m^{-3} for water withdrawal and R\$0.02 m^{-3} for water consumption (i.e. proportion of withdrawn water that is not returned to water bodies). The effluent discharge component depends on the percentage and efficiency of the effluent treatment and may reach a maximum of R\$0.02 m^{-3} for untreated effluents.

The agricultural sector was the most reluctant in accepting the water charge mechanism. To facilitate acceptability, charge values were defined in order not to exceed 0.5% of rice and sugar cane production costs, the two most important irrigated crops within the basin. The sector benefited from a very low charge value of R\$0.0002 m^{-3} for water withdrawal.

4. The Paraíba do Sul industrial water use survey

Given the importance of industrial activities in the Paraíba do Sul River Basin and the lack of data concerning the sector's water use patterns, the Institute for Applied Economics Research (IPEA), with the collaboration of the National Institute of Agricultural Research (INRA), decided to undertake a survey of industrial water use within the basin. The survey intended to fill the gap in understanding of the role of water within industrial activities and to provide a first appraisal of industrial users' receptiveness to water charges.

The survey collected comprehensive water-related information on 488 industrial facilities[5]. The sample was chosen in order to reflect the river basin industrial characteristics in terms of sector composition, and fieldwork took place between September 2003 and January 2004. The questionnaire covered several dimensions of industrial water use, including water intake, pre-treatment, recirculation and end use, plus wastewater treatment and discharge. Surveyed intake volume amounted to 33.2 million m^3/year; 96% of this quantity corresponded to self-supplied firms' withdrawals. The percentage of plants that reported the adoption of water reuse technologies was quite modest (14%), and the practice is mostly restricted to large facilities. The survey also provided some worrying evidence on industrial pollution control practices: among the 118 industrial plants that discharge effluents directly into water bodies, 47% (55 plants) declared that they did it without any treatment.

Cost information on each water use parameter is shown in Table 1. As should be expected, the average unit price of network-supplied water is considerably higher than direct-supplied water.

Cost and quantity data on the use of four cost components, namely, labour, materials, energy and water, were also collected. As can be seen in Table 2, materials and labour together represent more than 90% of variable input expenditures, while the water share represents just 1% of production cost.

The survey also asked whether firms approved of the charge system. Results indicated that the degree of acceptance varies according to the size of the industrial plant. Approval rate was about 71% among large users but around 45% in small and medium plants[6].

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[5] For a more detailed analysis of the survey results, see Féres *et al.* (2005).

[6] Plant size is defined according to the number of workers. Small plants are those with less than 100 employees, medium plants have between 100 and 500 employees and large plants have more than 500 workers.

Table 1. Average water cost.

Supply source	Water use component	Average water cost (R$ m^{-3})
Network-supplied plants	Network water	3.09
Self-supplied plants	Water intake, surface	0.26
	Water intake, groundwater	0.33
	Pre-treatment	0.62
	Reuse	0.55
	Effluent treatment/discharge	0.75

Table 2. Input cost shares.

Input	Cost share (%)
Labour	40
Materials	53
Energy	6
Water	1

Such results can reflect the higher importance attributed to environment-related issues among large firms, which see environmentally friendly positions as an effective way to reinforce their public image. A second explanation is based on information grounds, since small and medium plants are less well informed about the importance of the water charges for sustainable resource management.

Regardless of the degree of opposition to the charge system, firms have somehow internalized it in their production decisions. The surveyed firms were asked whether the water charge implementation had induced them to undertake investments in water conservation practices and/or pollution control. Again, as shown in Table 3, results varied according to the size of the plant, and charge-induced conservation and abatement practices were acknowledged in approximately 40% of large and medium plants, almost double the percentage indicated for small firms. It is a plausible pattern, since small firms incur more stringent financial constraints with new investments than the larger ones.

Generally speaking, the survey results suggest that the water charge in the Paraíba do Sul River Basin seems to have found a good receptivity among large firms, which indicates that charges may attain satisfactory results in terms of revenue generation and as a mechanism to induce rational water use. On the other hand, more efforts should be made in order to include a larger share of small and medium industrial firms in the charge system. Such inclusion would reinforce the participative character of the charge system, legitimizing the use of water charges.

Table 3. Charge-induced water conservation practices and/or pollution control.

Answer	Small plants (%)	Medium plants (%)	Large plants (%)
Yes	19.8	39.2	36.4
No	80.2	60.8	63.6

5. Econometric analysis of industrial water demand

This section presents the econometric analysis of the impact of water charges on industrial users. In particular, we are interested in answering the following questions:

(a) How does industrial water demand in the different sectors of activity react to water price increases that would be generated by the implementation of water charges?
(b) What are the substitution possibilities between water and the other inputs to the production process?
(c) What is the impact of water price increases on firms' production costs?

In order to address these questions, we estimate an econometric model based on the cost structure of the surveyed plants where water can be viewed as an input to the production process. From the estimated parameters, water demand price elasticities and substitution possibilities between water and other inputs are computed. These elasticities are then used to simulate the impact of water price increases on costs and the demand for the different production factors.

5.1. Methodology and data

5.1.1. The conceptual framework. Assessing how water enters the production process of a firm requires specification of the production technology. We consider that firms use five inputs: capital (*K*), labour (L), energy (E), materials (M) and water (W). Firms choose input quantities in order to minimize their costs. Production technology is represented by a short-run translog cost function, where capital is considered to be a fixed input[7]:

$$\ln \mathrm{TC} = \alpha_0 + \alpha_i \sum_i \ln(P_i) + \frac{1}{2}\sum_i\sum_j \gamma_{ij}\ln(P_i)\ln(P_j) + \sum_i \gamma_{iK}\ln(P_i)\ln(K)$$

$$+ \sum_i \gamma_{iY}\ln(P_i)\ln(Y) + \alpha_Y \ln Y + \frac{1}{2}\gamma_{YY}\ln Y^2 + \alpha_K \ln K + \frac{1}{2}\gamma_{KK}\ln K^2 + \mu \qquad (1)$$

where TC is the total cost, Y is the production level, K is the (fixed) capital stock and P_i, P_j represent the price of (variable) inputs i and j (i, j = L, E, M, W), respectively. All variables are specified in terms of their logs. The parameters to be estimated are α, β and γ, while μ is a stochastic term.

By differentiating the cost function given by Equation (1) with respect to the log of the input price P_i and applying Shephard's Lemma[8], we have:

$$\partial \ln \mathrm{TC}/\partial \ln P_i = P_i/\mathrm{TC}(\partial \mathrm{TC}/\partial P_i) = P_i X_i/\mathrm{TC} = S_i = \alpha_i + \sum_j \gamma_{ij}\ln P_j + \gamma_{iK}\ln K + \gamma_{iY}\ln Y + \nu_i \qquad (2)$$

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[7] The translog cost function is a second-order approximation of the true cost. Since capital is considered to be a fixed input that cannot be adjusted, the cost function can be interpreted as a short-term representation of firm's technology. In the long run, the establishments should be able to adjust their capital quantities to input price and/or production level changes.

[8] Shephard's Lemma states that the cost-minimizing demand for input i is given by the derivative of the cost function with respect to input i's price P_i. In our notation, this means that $X_i = \partial \mathrm{TC}/\partial P_i$.

where X_i is defined as the demand for input i, $S_i = P_iX_i/\mathrm{TC}$ is the cost share represented by expenses with input i and ν_i is a stochastic term. The econometric model to be estimated is given by the *translog* function (Equation (1)) and the input share equations represented in Equation (2).

Once the model parameters have been estimated, demand price elasticities can be computed as follows:

$$\varepsilon_{ij} = (\gamma_{ij} + S_iS_j)/S_i \quad \text{for the cross} - \text{price elasticities} \tag{3a}$$

$$\varepsilon_{ii} = (\gamma_{ii} + S_i^2 - S_i)/S_i \quad \text{for the own} - \text{price elasticities} \tag{3b}$$

When an increase in the price of input *i* results in an increase in the demand for factor *j* (i.e. when the cross-price elasticity is positive), inputs are said to be substitutes. When the cross-price elasticity is negative, an increase in input *i*'s price will imply in a decrease in the demand for input *j*. In this case, factors are considered to be complements.

With the elasticity estimates at hand, factor and input demand reactions to water price increases can be also calculated. Changes in water demand will be estimated from the water own-price demand elasticity and the substitution possibilities between water and the other production inputs.

5.1.2. Data and estimation method. Data reliability reduced the applied sample to 424 plant observations. Variables were constructed as follows:

- Short-run production cost (C): calculated as the sum of the annual expenses on labour, energy, materials and water
- Factor i cost share (S_i): the proportion represented by the expenditures on the i-th input ($i = \mathrm{L, E, M, W}$) with respect to the production cost C
- Labour price (P_{L}): given by the average labour cost, i.e. the total wage paid to workers (including social charges), divided by the number of employees
- Energy price (P_{E}): given by the average KWh price, i.e. total expenditures on electricity divided by the total consumed energy
- Materials price (P_{M}): defined as the expenditures on materials divided by the annual revenue
- Water price (P_{W}): average water cost, computed as total water expenditures divided by the total water use. Total water expenditures were calculated as the sum of expenditures with water intake, treatment prior to use, recycling and effluent treatment/discharge, including water charge
- Capital (K): defined as the value of the fixed assets divided by the annual revenue
- Output (Y): given by the total production value

The econometric model was estimated using the seemingly unrelated regression (SUR) method[9]. The symmetry and price homogeneity constraints were imposed using the usual parametric restrictions. Estimation results are presented in the Appendix.

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[9] For details on the estimation method, see Féres & Reynaud (2005).

Table 4. Input demand price elasticities.

	Water	Energy	Labour	Materials
Water	−0.5847 (0.0736)	0.0109 (0.017)	0.0078 (0.0026)	0.0020 (0.0014)
Energy	0.0760 (0.1208)	−0.7163 (0.0541)	0.0757 (0.0085)	0.0194 (0.0044)
Labour	0.3790 (0.1265)	0.5166 (0.0583)	−0.2223 (0.0124)	0.0977 (0.0062)
Materials	0.1357 (0.0941)	0.1886 (0.0432)	0.1387 (0.0088)	−0.1192 (0.0073)

Note: Elasticities computed at the mean sample. The values indicate the changes in the demand for the input in the columns, given a 1% increase in the price of the input in the line. Standard errors in parentheses.

5.2. Price elasticities of industrial water demand

Table 4 presents the input demand price elasticities which were computed from the estimated parameters. All the own-price elasticities (the diagonal entries) have the expected negative sign, indicating that an increase in the input price results in a decrease in its own demand. The water demand price elasticity is −0.58, meaning that a 1% increase in the water price will reduce the water demand by 0.58%. It is important to remark that the estimated elasticity is significantly different from zero, which means that the industrial water demand is not perfectly inelastic, even though water-related expenditures represent a small share of total costs. The computed elasticity value is in line with other results found in the literature. For example, Grebenstein & Field (1979) estimated elasticity values ranging from −0.33 to −0.80 for US industries. Reynaud (2003), analysing several French industrial sectors, found demand elasticities varying between −0.10 and −0.79. Dupont & Renzetti (2001) found similar results for Canadian firms.

Regarding the water demand cross-price elasticities (off-diagonal terms in the first line of Table 4), the positive sign indicates that water is a substitute input to labour, energy and materials. The positive sign of the Allen substitution elasticity estimates, as shown in Table 5, confirms the substitution patterns. This means that when the water price increases, firms will induce water substitution by increasing the demand for labour, energy and materials. Similar substitution patterns were found by Dupont & Renzetti (2001) for the Canadian industry and also by Guerrero & Thomas (2005) for the Mexican case. It is worth pointing out that water price increases have the stronger substitution effect on energy use.

Water demand elasticity, as expected, presents a considerable degree of heterogeneity across industrial sectors. As shown in Table 6, the estimated elasticities vary from −0.04 to −0.82. The higher elasticities are found in food and beverages, pulp and paper, and chemical industrial sectors[10].

5.3. Simulating the impact of water price increases

As firms adjust input allocation in response to water price changes, acceptability of the charge system will be eased by reducing their intake water demand by changing their input mix. In this case, water charges may act as an effective mechanism in inducing water conservation. To analyse these options, simulation exercises based on the estimated econometric model[11] are carried out.

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[10] Although they are water-intensive sectors, other sectors that are also intensive, such as metallurgy and clothing, exhibit elasticities around the sample average.

[11] Details of the simulation method can be found in Féres & Reynaud (2005).

Table 5. Allen elasticity of substitution.

	Water	Energy	Labour	Materials
Water	–	1.3418 (2.1330)	0.9651 (0.3275)	0.2473 (0.1716)
Energy	1.3418 (2.1330)	–	1.3368 (0.1510)	0.3438 (0.0787)
Labour	0.9651 (0.3275)	1.3368 (0.1510)	–	0.2528 (0.0160)
Materials	0.2473 (0.1716)	0.3438 (0.0787)	0.2528 (0.0160)	–

Note: Elasticities computed at the mean sample. Standard errors in parentheses.

Table 6. Price elasticities of water demand by sector of activity.

Sector	Water demand elasticity
Food and beverage	−0.82
Textiles	−0.04
Clothing	−0.31
Wood, rubber and plastics	−0.40
Pulp and paper	−0.76
Chemicals	−0.71
Non-metal minerals	−0.22
Iron and steel	−0.48
Mechanical industry	−0.31
Transport equipment	−0.51
Others	−0.33

Note: Elasticities computed at the mean sample.

Table 7 presents the impacts of different water price increases on water demand and production costs for the industrial sector as a whole, where ΔP_W and ΔX_W represent the water price and demand variation, respectively, and ΔC is the change in production costs. As can be seen, a 10% price increase will entail a reduction of 3.23% in water demand. Impacts on costs are not expressive, since a 10% water price increase will represent only a 0.05% increase in costs. When faced with a 50% water price increase, firms will reduce their water demand by approximately 15%, and their production costs will have an increase of 0.26%. These figures suggest that water charge implementation in the Paraíba do Sul may attain satisfactory results in terms of water demand reductions with limited impact on production costs.

This general picture does not change by disaggregating the analysis at the sector level, although simulated impacts vary considerably across activities, reflecting a diversity of substitution possibilities. For illustration purposes, Table 8 shows the simulated input demand variations and cost impacts of a 20% water price increase for each sector. The most expressive water demand reductions occur in food and beverages (13.2%), paper and pulp (12.4%) and iron and steel sectors (10%) whereas mechanical industry and clothing experienced small demand variations.

As already suggested by the estimated water demand elasticities, all sectors will increase the demand for other inputs in response to a water price increase[12], in particular for the case of energy.

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[12] One may note some negative numbers for the variations in materials demand in Table 8. However, they are observed in the less water-intensive sectors, where water cost shares are close to zero. In this case, statistical problems associated with the estimation method can lead to imprecise estimates. So, these values should be treated with caution.

Table 7. Impacts of water price increases on industrial water demand and production costs.

	$\Delta P_W = 10\%$	$\Delta P_W = 20\%$	$\Delta P_W = 30\%$	$\Delta P_W = 40\%$	$\Delta P_W = 50\%$
ΔX_W (%)	−3.23	−6.38	−9.40	−12.28	−14.99
ΔC (%)	0.05	0.11	0.16	0.21	0.26

Note: ΔP_W, water price variation; ΔX_W, water demand variation; ΔC, production cost variation.

Table 8. Impact of a 20% water price increase on input demands and production cost, by sector of activity.

Sector	$\Delta P_W = 20\%$				
	ΔX_W (%)	ΔX_L (%)	ΔX_E (%)	ΔX_M (%)	ΔC (%)
Food and beverage	−13.17	0.34	0.38	0.21	0.28
Textiles	−4.57	0.04	0.14	0.02	0.06
Clothing	−3.65	0.06	0.18	−0.05	0.07
Wood, rubber and plastics	−7.15	0.07	0.14	−0.06	0.08
Pulp and paper	−12.41	0.16	0.26	0.10	0.17
Chemicals	−6.92	0.11	0.20	0.02	0.13
Non-metal minerals	−7.85	0.15	0.19	0.16	0.15
Metallurgy	−10.04	0.10	0.18	0.01	0.11
Mechanical industry	−2.68	−0.00	0.08	−0.08	0.00
Transport equipment	−8.57	0.11	0.18	0.05	0.08
Others	−4.80	0.04	0.15	−0.21	0.05
Total	−6.38	0.13	0.23	0.03	0.11

Note: ΔP_W, water price variation; ΔX_i, variation in the demand for input i (i = W, L, E, M); ΔC, variation in the production cost.

The impacts on costs also differ across sectors. The cost impact for water-intensive sectors (food and beverage, paper and pulp, chemicals, non-metallic minerals, and iron and steel) is still low but above the average cost increase for the whole sample (0.11%).

Simulations for joint output and water price variations were also performed to assess the relation between output increase and water demand. As can be seen in the first line of Table 9, holding the water price constant, an output increase (ΔY) of 5% will raise water demand by 3.4%. However, a water price increase of 10% would offset the resulting water demand increase. These results suggest that water charges can counteract the increasing water demand required by output growth.

Conversely, environmental targets should also be adjusted to take into account output variations. For example, as shown in the second column of Table 9, if the basin needs to target a 10% water demand reduction, holding the output constant, it would be necessary to increase water prices by approximately 30%. However, if output increases by 5%, new water price adjustments would be required to attain the stipulated water reduction. In fact, the water price should be set slightly above 40% over its original price to preserve the quantitative target set by the regulator.

Summing up, these results suggest that the political economy of the setting of water charges does not need to be related to cost impacts. Other concerns, as for example, credibility of the system and allocation criteria for reintroducing charge revenue in the basin may be more important to the consensus reaching process of the next round of charge setting than the fear that water charges will reduce competitiveness.

Table 9. Impact of water price and output variations on water demand.

ΔP_W (%)	ΔX_W (%)				
ΔY (%)	0	5	10	15	20
0	–	3.39	6.66	9.81	12.86
10	−3.23	−0.12	2.86	5.74	8.53
20	−6.38	−3.52	−0.77	1.89	4.46
30	−9.40	−6.75	−4.20	−1.73	0.65
40	−12.28	−9.80	−7.42	−5.12	−2.89
50	−14.99	−12.68	−10.44	−8.28	−6.19

Note: ΔY, output variation; ΔX_W, water demand variation; ΔP_W, water price variation.

6. Industrial pollution control costs and water charge effectiveness

As mentioned above, water pollution is identified as the main problem of the Paraíba do Sul river basin, and pollution control measures within the industrial sector can contribute to the basin's water quality recovery. This section aims to present estimates of the pollution control costs for the industrial users in the Paraíba do Sul river basin to assess whether the current value for the pollution-related component of water charges can be an effective mechanism in inducing firms to undertake pollution control investments.

Following Dasgupta *et al.* (1996), we specify an average effluent treatment cost function and, using the estimated parameters, we then calculate the marginal treatment cost. We assume the effluent treatment cost has a linear functional form:

$$\text{C\_AV} = \alpha_0 + \alpha_1\,\text{PERC\_TREAT} + \alpha_2\,\text{SECTER} + \alpha_3\,\text{PERC\_TREAT}^{*}\text{SECTER} + \alpha_4 X + \varepsilon \qquad (4)$$

where $\alpha_i (i = 1,2,3,4)$ are parameters to be estimated, C_AV is the effluent treatment unit cost, PERC_TREAT is the percentage of effluent that is treated within the plant, SECTER is a dummy variable which indicates whether the establishment adopts secondary and/or tertiary effluent treatment methods[13], PERC_TREAT*SECTER is the interaction effect between variables PERC_TREAT and SECTER and, finally, X is a vector of firm-specific characteristics that may affect treatment cost (sector of activity, basic water end use, etc.).

Based on the estimated cost function given by Equation (4), the following relation can be applied to compute the marginal cost of treating an additional m^3 of effluent emissions:

$$\text{C\_MARG} = \text{VOL\_TREAT}\,x\,\frac{\partial \text{C\_AV}}{\partial \text{VOL\_TREAT}} + \text{C\_AV} \qquad (5)$$

where C_MARG denotes the marginal effluent treatment cost, VOL_TREAT the total treated effluent volume and (∂C_AV)/(∂VOL_TREAT) is the partial derivative of the average treatment cost with respected to the total treated volume[14].

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[13] See McConnell & Schwarz (1992) for a description of secondary and tertiary treatment methods.

[14] For more details on the derivation of the marginal treatment cost, see Féres *et al.* (2005) and Dasgupta *et al.* (1996).

Table 10. Percentage of treated effluent and unit cost of effluent treatment, by sector of activity and effluent treatment method.

Sector of activity/Effluent treatment method	Unit effluent treatment cost		Percentage of treated effluent	
	Average (R$ m^{-3})	Std. deviation	Average (%)	Std. deviation
Total sample	1.10	1.41	85	28
Food and beverage	1.12	1.84	85	32
Textiles	0.61	0.73	88	25
Wood, rubber and plastic	0.67	0.89	91	18
Chemical	0.36	0.53	89	30
Iron and steel	1.37	1.76	83	32
Mechanical industry	0.79	0.56	88	11
Only primary method	1.03	0.98	81	31
Secondary/tertiary method	1.15	1.66	87	25

Table 11. Marginal effluent treatment cost by sector of activity.

Sector of activity	Marginal cost (R$ m^{-3})
Food and beverage	0.99
Textiles	0.49
Wood, rubber and plastic	0.53
Chemical	0.32
Iron and steel	1.26
Mechanical industry	0.60
Total sample	0.95

Note: marginal costs computed at the mean sample.

The treatment cost regression (Equation (4)) was estimated using data on 318 surveyed plants that provided information on effluent discharges. Table 10 presents descriptive statistics for the average treatment cost and the percentage of treated effluents. The average treatment cost varies considerably across sectors. This heterogeneity is not surprising, since the pollution content of effluents differs across industrial activities, requiring distinct pollution control technologies. Another expected result is that plants that adopt secondary and/or tertiary treatment methods have a higher average effluent treatment cost than those that use only primary treatment.

Marginal effluent treatment costs were estimated using the Tobit method in order to account for the fact that 244 plants declared that they did not treat their effluents[15].

As can be seen in Table 11, the estimated marginal cost for the 74 plants that treat their effluents was R$0.95. The highest values were found in the iron and steel (R$1.26) and food and beverage (R$0.99) sectors[16].

Marginal cost estimates were also computed according to effluent treatment method. Plants using only primary treatment methods have a lower marginal cost, around R$0.89 m^{-3}, compared with those employing secondary or tertiary methods, on average R$0.99 m^{-3}.

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[15] In fact, for these establishments, effluent treatment cost is equal to zero.

[16] Given the small number of observations, sector elasticity estimates should be treated with caution.

These computed marginal treatment costs are far above the charge of R$0.02 applied to effluents discharged without any treatment into the water bodies. Such a discrepancy suggests that, if water charges are meant to act as an effective pollution control incentive mechanism, they have to increase sharply from their actual values.

7. Conclusion

The potential trade-off between effectiveness and competitiveness concerns entailed by water charge implementation can be of particular importance in countries such as Brazil, which has adopted a decentralized and participative water management approach through River Basin Committees. In this framework, negotiations on water charge formulae and values should reach a reasonable degree of consensus between public authorities, users and stakeholders in order to be approved by the river basin committee. While the negotiations facilitate users' acceptability, this participative decision-making process may prevent the adoption of a more stringent water charge. Therefore, it is crucial for the consensus-reaching process to assess in advance potential impacts of water charges.

The Paraíba do Sul River Basin case is a pioneering experiment with water charges in Brazil. The outcome achieved by this case will be a determinant for the generalization of water charge implementation across the country. This paper provides a first assessment on the potential impacts of water charges on industrial users in this watershed.

The survey applied to a sample of industrial users indicated that water cost represents a very minor fraction of total production costs. Self-supplied plants are responsible for 96% of total industrial water intake volumes, but only 50% of these plants carry out effluent control practices. The charge system is approved by 70% of large firms, although small- and medium-sized companies are less receptive, with 45% rate of approval. It was also indicated that charges are already motivating conservation practices in 40% of the surveyed large and medium plants against 20% in small ones. This may be a reflection of the high importance placed on the firm's environmentally related image and the less restrictive financial constraints experienced by large firms.

A translog cost function derived a water demand price elasticity of -0.58, meaning that a 1% increase in the water price will reduce the water demand by 0.58%. This result is in line with other results found in the literature.

Simulations based on the econometric water demand model suggest that water charges can induce significant industrial water demand reductions with limited impact on firms' costs. For example, a 10% water price increase will entail a reduction of 3% in water demand with only a 0.05% increase in costs. When faced with a 50% water price increase, firms will reduce their water demand by approximately 15%, and their production costs will experience an increase of 0.26%. Although it varies across sectors, the same pattern holds for sector estimates. Given the low impact on costs and the responsiveness of water demand to prices, water charges may be both acceptable by firms and act as an effective instrument for water conservation.

The estimated marginal effluent treatment costs are far above the current values established for the pollution-related component of the water charge, indicating that the charge level should increase to affect effluent emission abatement in a significant manner.

In sum, the simulation results suggest that the political economy of the setting of water charges does not need to deal with the potential conflict between competitiveness and environmental effectiveness effects of water charges. Other concerns, for example, credibility of the water charge system and allocation criteria for reintroducing charge revenue in the basin, may have a more crucial influence.

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A. Appendix: Estimation results of the translog cost model

- Estimation method: iterated seemingly unrelated regressions
- Parameter constraints: symmetry and cost homogeneity restrictions imposed
- Number of observations: 424

Cost equation: dependent variable $\ln C$.

Variable	Estimate	Std error	t-statistic	p-value
$\ln Y$	0.9089	0.0188	48.19	0.000
$\ln K$	0.0915	0.0433	2.11	0.035
$\ln Y \times \ln Y$	0.0320	0.0033	9.69	0.000
$\ln K \times \ln K$	0.0032	0.0049	0.65	0.515
$\ln Y \times \ln K$	−0.0036	0.0037	−0.98	0.329
$\ln P_{\mathrm{W}}$	0.0088	0.0059	1.49	0.137
$\ln P_{\mathrm{L}}$	0.1503	0.0231	6.50	0.000
$\ln P_{\mathrm{E}}$	0.1112	0.0197	5.62	0.000
$\ln P_{\mathrm{M}}$	0.7295	0.0186	39.05	0.000
$\ln P_{\mathrm{W}} \times \ln P_{\mathrm{W}}$	0.0033	0.0006	5.53	0.000
$\ln P_{\mathrm{L}} \times \ln P_{\mathrm{L}}$	0.1511	0.0048	31.35	0.000
$\ln P_{\mathrm{E}} \times \ln P_{\mathrm{E}}$	0.0128	0.0030	4.19	0.000
$\ln P_{\mathrm{M}} \times \ln P_{\mathrm{M}}$	0.1822	0.0040	45.54	0.000
$\ln P_{\mathrm{W}} \times \ln P_{\mathrm{L}}$	−0.0001	0.0010	−0.11	0.915
$\ln P_{\mathrm{W}} \times \ln P_{\mathrm{E}}$	0.0001	0.0009	0.16	0.873
$\ln P_{\mathrm{W}} \times \ln P_{\mathrm{M}}$	−0.0033	0.0007	−4.38	0.000
$\ln P_{\mathrm{L}} \times \ln P_{\mathrm{E}}$	0.0073	0.0033	2.23	0.026
$\ln P_{\mathrm{L}} \times \ln P_{\mathrm{M}}$	−0.1584	0.0034	−46.53	0.000
$\ln P_{\mathrm{E}} \times \ln P_{\mathrm{M}}$	−0.0204	0.0024	−8.33	0.000
$\ln Y \times \ln P_{\mathrm{W}}$	0.0002	0.0006	0.47	0.640
$\ln Y \times \ln P_{\mathrm{L}}$	−0.0765	0.0029	−25.94	0.000
$\ln Y \times \ln P_{\mathrm{E}}$	−0.0033	0.0020	−1.57	0.117
$\ln Y \times \ln P_{\mathrm{M}}$	0.0795	0.0028	27.47	0.000
$\ln K \times \ln P_{\mathrm{W}}$	0.0025	0.0031	0.81	0.417
$\ln K \times \ln P_{\mathrm{L}}$	0.0069	0.0075	0.91	0.363
$\ln K \times \ln P_{\mathrm{E}}$	0.0167	0.0075	2.22	0.026
$\ln K \times \ln P_{\mathrm{M}}$	−0.0038	0.0045	−0.86	0.392
$D_{\mathrm{FOOD}} \times \ln P_{\mathrm{W}}$	0.0162	0.0024	6.73	0.000
$D_{\mathrm{PAPER}} \times \ln P_{\mathrm{W}}$	0.0097	0.0069	1.40	0.162
$D_{\mathrm{CHEM}} \times \ln P_{\mathrm{W}}$	0.0085	0.0033	2.57	0.010
$D_{\mathrm{FOOD}} \times \ln P_{\mathrm{L}}$	−0.0249	0.0076	−3.25	0.001
$D_{\mathrm{CLOTHES}} \times \ln P_{\mathrm{L}}$	0.0509	0.0139	3.65	0.000
$D_{\mathrm{NONMET}} \times \ln P_{\mathrm{L}}$	−0.0758	0.0184	−4.10	0.000
$D_{\mathrm{CLOTHES}} \times \ln P_{\mathrm{E}}$	−0.0230	0.0060	−3.82	0.000
$D_{\mathrm{RUB\&PLAST}} \times \ln P_{\mathrm{E}}$	0.0024	0.0037	0.66	0.512
$D_{\mathrm{NONMET}} \times \ln P_{\mathrm{E}}$	0.0124	0.0073	1.69	0.092
Intercept	0.9164	0.0819	11.19	0.000

RMSE (root mean squared error): 0.30 R^2: 0.97

Water share equation: dependent variable S_W.

Variable	Estimate	Std error	t-statistic	p-value
ln Y	0.0002	0.0006	0.47	0.640
ln K	0.0006	0.0006	1.07	0.286
ln P_W	0.0033	0.0006	5.53	0.000
ln P_L	−0.0001	0.0010	−0.11	0.915
ln P_E	0.0001	0.0009	0.16	0.873
ln P_M	−0.0033	0.0007	−4.38	0.000
D_{FOOD}	0.0162	0.0024	6.73	0.000
D_{PAPER}	0.0097	0.0069	1.40	0.162
D_{CHEM}	0.0085	0.0033	2.57	0.010
Intercept	0.0088	0.0059	1.49	0.137
RMSE (root mean squared error): 0.02 R^2: 0.15				

Labour share equation: dependent variable S_L.

Variable	Estimate	Std. error	t-statistic	p-value
ln Y	−0.0765	0.0029	−25.94	0.000
ln k	0.0034	0.0034	0.98	0.328
ln P_W	−0.0001	0.0010	−0.11	0.915
ln P_L	0.1511	0.0048	31.35	0.000
ln P_E	0.0073	0.0033	2.23	0.026
ln P_M	−0.1584	0.0034	−46.53	0.000
D_{FOOD}	−0.0249	0.0076	−3.25	0.001
$D_{CLOTHES}$	0.0509	0.0139	3.65	0.000
D_{NONMET}	−0.0758	0.0185	−4.10	0.000
Intercept	0.1503	0.0231	6.50	0.000
RMSE (root mean squared error): 0.11 R^2: 0.74				

Energy share equation: dependent variable S_E.

Variable	Estimate	Std error	t-statistic	p-value
ln Y	−0.0033	0.0021	−1.57	0.117
ln K	0.0060	0.0023	2.61	0.009
ln P_W	0.0001	0.0009	0.16	0.873
ln P_L	0.0073	0.0033	2.23	0.026
ln P_E	0.0128	0.0030	4.19	0.000
ln P_M	−0.0204	0.0024	−8.33	0.000
$D_{CLOTHES}$	−0.0230	0.0060	−3.82	0.000
$D_{RUB\&PLAST}$	0.0024	0.0037	0.66	0.512
D_{NONMET}	0.0124	0.0073	1.69	0.092
Intercept	0.1112	0.0198	5.62	0.000
RMSE (root mean squared error): 0.07 R^2: 0.13				

Variables description: ln C, log(cost); ln Y, log(output value); ln K, log(capital); ln P_W, log(water price); ln P_L, log(labour price); ln P_E, log(electricity price); ln P_M, log(materials price); S_W, water cost share; S_L, labour cost share; S_E, electricity cost share; S_M, materials cost share; D_{FOOD}, dummy for the food and beverages sector; D_{PAPER}, dummy for the pulp and paper sector; D_{CHEM}, dummy for the chemical sector; D_{NONMET}, dummy for non-steel minerals sector; $D_{CLOTHES}$, dummy for the clothing sector; $D_{RUB\&PLAST}$, dummy for the rubber and plastic products sector.