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The Role of Economic Instruments for Environmental Management: Water Charges in the Paraíba do Sul River Basin, Brazil

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Following the approval of the Federal Water Law (Law 9433 of 1997), Brazil has recently implemented a wide-ranging water sector reform, including the introduction of quality- and quantity-related water charges in its regulatory framework. 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. In such context, evaluating the impacts of the charge system is crucial to support water managers' decision-making concerning the system implementation path.

The assessment of the impact of water charges both in terms of resource conservation and revenue generation requires the characterization of water demand patterns in the different Brazilian use sectors. So far, little efforts have been devoted to this subject. Actually, knowledge about water demand patterns is a fundamental requirement not only for the evaluation of the impact of water charges, but also for the assessment of any demand-side management policy instrument.

This research project aimed at investigating water use patterns in the industrial and agricultural sectors, so as to inform water policy implementation in Brazil. Concerning the industrial sector, the project focused on the question of water recirculation and how this practice can alter use patterns. Knowledge about the determinants of water reuse is fundamental in order to assess the potential of water charges in inducing watersaving investments.

Moreover, understanding how the behaviour in terms of water intake differ between firms who have invested in such technologies and those who have not is of great value to assess the environmental gains in terms of water conservation. Regarding the agricultural sector, the research addressed the question of agricultural productivity, water supply uncertainty and production risk. Specifically, we were interested in investigating whether irrigators that withdraw water from dams are less exposed to production risk associated to water supply uncertainty than the ones that relied on rivers with unstable water regimes.

In assessing the issue of industrial water reuse, we assume that firm´s decision-making may be represented by a two stage process. First, the firm must decide whether or not to reuse water. Second, the firm must choose the quantity of water intake, conditional on the previous decision concerning water reuse. We represent this decision-making process by specifying a switching regression model, where we first estimate a *Probit* model for the analysis of the water reuse decision and then estimate distinct water demand equations for firms that reuse water and those which do not. The model is estimated for a sample of 477 industrial facilities located in the Paraíba do Sul river basin area.

Regarding the agricultural sector, in order to assess the relationship between production risk and water supply uncertainty, we also adopt a two-stage procedure. First, we specify a reduced-form equation for the average agricultural productivity. We then compute the squared residuals of the regression. The computed squared residuals may be seen as an estimate of the unexplained average productivity variance, which is a *proxy* for the production risk. In the second stage, by regressing the squared residuals on a set of explanatory variables, we are able to assess the role played by some factors in increasing/decreasing production risk. In particular, we were interested in addressing the question of whether farmers that withdraw water from dams are less exposed to production risk than the ones who rely on rivers with uncertain water regimes. We estimate the model for a sample of 129 municipalities in the rice-growing region of Rio Grande do Sul, in the south region of Brazil.

Our results for the industrial sector show that the amount of water needs will be an important determinant to the water reuse decision. Input prices also seem to be relevant to the plant´s choice regarding water reuse. Specifically, reuse decisions seems to be affected by water and capital prices. These findings provide some evidence that the water charge mechanism implemented in the Paraíba do Sul river basin may act as an effective instrument for inducing firms to undertake water reuse investments. Since plants are more likely to adopt water reuse the higher the water price, policymakers could increase the value of water charges so as to provide firms with incentives to implement water reuse practices. Alternatively, as reuse decisions seem also to be influenced by the capital price, part of the water charge revenues collected within the Paraíba do Sul river basin could be used to provide subsidized credits to firms intending to adopt water reuse practices.

The water demand equations demonstrate the expected negative elasticity with respect to the freshwater price, meaning that an increase in the freshwater price results in a decrease of the water demand. In addition to that, the estimated water price elasticity is larger for plants that reuse water than for those which do not. This result indicates that water charges will have a more effective impact in terms of water demand reduction among plants that reuse water.

Concerning the agricultural sector, the econometric analysis shows that an increase in the percentage of rice irrigators that withdraw water from dams reduces the agricultural productivity variance. This finding provides some evidence that farmers that withdraw water from a dam are less exposed to water supply uncertainty and the associated production risk than the ones relying on rivers with uncertain water regimes.

The analytical framework proposed for the agricultural sector can be seen as the first step of a simple methodology for measuring the benefits associated with water supply security provided by dams. Actually, the analysis of the unexplained productivity variance, so that one can infer whether there are benefits associated to the reduction in production risk. Once this benefits have been verified, the second step would consist in estimating a hedonic price regression model in order to assess the economic value of these benefits.

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