Modernization of Irrigation Funded by Water Tariffs Using New Technologies

Raúl Jorge Rosa1 Email: rjr@agro.unlp.edu.ar
FCAyF, CIIAAA – Universidad Nacional de La Plata (UNLP)

Introduction

Water pricing can be an effective tool for achieving more efficient use, provided it is supported by other policies. However, increasing prices does not always achieve the goal of conservation. Farmers often have a low-price elasticity of demand. Therefore, the effectiveness of prices and charges for the use or availability of water for conservation cannot be taken for granted and needs to be evaluated in the context of the specific geographical area, types of crops, institutional arrangements, and agricultural policies. The institutional framework must ensure reliable service so that water prices are appropriate and acceptable to farmers, along with the benefits of transparency in management and the participation and empowerment of farmers in decision-making (Dinar & Mody, 2004; Jeder et al., 2014; Expósito and Berbel, 2017).

This study proposes using water tariffs in the inelastic part of the demand curve to finance modernization that enables efficient water use. By incorporating new technologies (Internet of Things and Blockchain), transparency in management is promoted, given the reduction in perceived risk by farmers for adopting a transparent and reliable governance scheme.

Objectives

The objective of this study is to design a management scheme that enables efficient use of irrigation water through modernization funded by water tariffs and managed with new technologies (Internet of Things IoT and Blockchain).

Materials and Methods

This study is structured in three stages. The first stage involves determining the water price threshold that meets the objectives of the pricing policy without negatively impacting the profitability of the involved producers. The second stage evaluates the producers' willingness to pay to meet the policy objectives. Finally, the scheme is completed by using new technologies to measure and record processes, generate smart contracts, and reduce the risks associated with involvement in the management system.

First Stage: The first stage involves determining a general balance of the supply and demand of water throughout the system before and after modernization in irrigation systems to evaluate improvements in efficiency. Additionally, the theoretical price threshold is estimated using the procedure proposed by Amir and Fisher (1999), which involves estimating the inverse demand curve for water and the distribution of land use at different tariff prices.

Second Stage: The second stage evaluates the producers' willingness to pay to meet the policy objectives. A survey is conducted using a random sample to assess whether producers are willing to fund irrigation modernization because they perceive it will increase their yields and incomes and enable efficient resource use. The statistical model used is the Structural Equations Model (SEM), defined by two sub-models (Foguet & Gallart, 2000): the measurement model and the structural model. The explicit form of the model is as follows:

$\eta=Y11\xi1+Y12\xi2+\zeta\eta=Y11\xi1+Y12\xi2+\zeta$

where $\eta\eta$ represents the willingness to finance, $\xi1\xi1$ represents the investment decision to address water scarcity, $\xi2\xi2$represents the perception of modernization benefits, and $\zeta\zeta$ is the error term.

Third Stage: The third stage involves designing a management scheme for the entire area that incorporates the use of Internet of Things and Blockchain technologies. This aims to create a transparent measurement and recording procedure that enables the use of smart contracts, fostering trust among stakeholders to implement the organizational scheme.

This framework aligns with the conceptual scheme proposed by Williamson (2000), which includes (1) a first level encompassing norms, culture, and habits resulting from social evolution; (2) a second level involving collective and state decisions; (3) a third level analyzing governance structure; and (4) a fourth level studying price formation in resource markets. Hypotheses have been tested to demonstrate the logical link between levels 4 and 3. Attributes that determine the price threshold for producers to fund modernization and contribute to water-saving objectives (level 4) are identified. Additionally, hypotheses are tested to analyze governance aspects (level 3) and integrate them with the other levels.

Results

First Stage: A water tariff value was determined to be four times higher than the current rate, positioned in the inelastic part of the inverse demand curve. This tariff increase does not significantly alter land use nor negatively impact the profitability of businesses, where the Internal Rate of Return (IRR) with technological substitution, which involves investing in water-saving technologies and increased tariff values, ranges approximately between 20% and 100% for different production models (Rosa, RJ 2016).

Second Stage: The willingness of producers to finance modernization was assessed using the Structural Equations Model (SEM). The signs of the causal relationships proposed in the model are correct and align with the hypotheses. For the construct "Investment in modernization to solve scarcity issues," investing in binary irrigation is the most significant indicator, contributing 1.434 ($\lambda11=1.434\lambda11=1.434$), while increasing income ($\lambda12=1.572\lambda12=1.572$) is the primary motivation for producers in "Visualizing benefits of modernization."

Regarding "Willingness to finance to solve scarcity issues," the visualization of modernization benefits ($Y12=0.0122Y12=0.0122$) has an impact coefficient approximately six times greater than investing in modernization to solve scarcity issues ($Y11=0.00221Y11=0.00221$), highlighting the importance of the third stage for building trust. For "Willingness to finance to solve scarcity issues," quadruple financing has a weight of (λ21=0.0197λ21=0.0197) (Rosa, RJ 2016).

Third Stage: This is a propositional stage where an organizational scheme is designed to implement the strategy within the proposed organizational framework, aiming to provide transparency and security to all processes. This reduces the perceived risk for producers, thereby integrating the overall model.

IoT technology enables real-time monitoring of various parameters related to both water supply and demand, such as irrigation systems, water levels, flow rates, gate statuses, usage times, and water quality. Utilizing low-power wide-area networks (LPWAN), numerous sensor nodes can be deployed across different geographic points, transmitting measured values to the IoT platform. This platform provides real-time and historical data series for various variables, which is crucial for system management and operation. It can also automatically generate notifications or alarms for anomalies, allowing early and immediate responses to improve contingency management.

Blockchain technology adds trust among all participants in the irrigation consortium. Blockchain ensures that the information reflecting the use of the irrigation system is validly and immutably recorded and openly available to all participants. Smart contracts can be generated using blockchain, considering water resource availability, each producer's participation in the financing fund, and the management of irrigation quotas or allocations.

Conclusions and Recommendations

The study concludes that water pricing is a valid instrument for funding the technological substitution of irrigation when producers perceive the benefits of such substitution in a context of relative resource scarcity. This can contribute to water-saving objectives or its reallocation if framed within an organizational and institutional scheme oriented towards this goal within the context of comprehensive planning. The use of new technologies provides transparency and security to processes, reducing the perceived risk for producers and facilitating their integration into the system. This creates a virtuous financing mechanism for the modernization and management of irrigation water, helping to achieve the described strategy's objectives.

Bibliography

Amir, I, and F M Fisher. 1999. "Analyzing Agricultural Demand for Water with an Optimizing Model." Agricultural Systems 61: 45–56.

Dinar, Ariel, and Jyothsna Mody. 2004. "Irrigation Water Management Policies: Allocation and Pricing Principles and Implementation Experience." Natural Resources Forum 28(2): 112–22.

Expósito, Alfonso, and Julio Berbel. 2017. "Why Is Water Pricing Ineffective for Deficit Irrigation Schemes ? A Case Study in Southern Spain." Water Resour Manage: 1047–59.

Foguet, Joan Manuel Batista, and Germà Coenders Gallart. 2000. Modelos de Ecuaciones

Estructurales. ed. Hespérides. Madrid. España.

Jeder, Houcine, Mongi Sghaier, Kamel Louhichi, and Pytrik Reidsma. 2014. “Bio-Economic Modelling to Assess the Impact of Water Pricing Policies at the Farm Level in the Oum Zessar Watershed , Southern Tunisia.” Agricultural Economics Review 15(2).

Rosa, Raúl Jorge. 2016. Tesis doctoral “Gestión del agua regulada por una presa: El precio del agua como instrumento de planificación y financiamiento para la modernización de los sistemas de irrigación”. Universidad Politécnica de Valencia (España). https://www.fundacionaquae.org/autor/raul-jorge-rosa/

Williamson, Oliver E. 2000. “The New Institutional Economics: Taking Stock, Looking Ahead.” Journal of Economic Literature 38(September): 595–613.