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Research Paper

Buy me a river: Use of multi-attribute non-linear utility functions to address overcompensation in agricultural water buyback

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ABSTRACT

The realization of buyback welfare enhancing opportunities is conditioned to the ability of government agencies to place bids consistent with the shadow price of irrigators. However, methods used to inform buyback programmes to date either rely on *ex-post* trading data that is not readily available in most regions worldwide; or compensate projected foregone income, and thus ignore the effects that buyback may have on other relevant attributes determining utility. This paper uses revealed preference methods to elicit the parameters of a multi-attribute objective function that mimics the observed behavior of irrigators in the overexploited Segura River Basin in SE Spain. Objective functions are used in a series of simulations in which water allocation is progressively constrained to *ex-ante* reveal the shadow price of water using two alternative compensation measures: i) the foregone income, a proxy of the shadow price typically used in the literature; and ii) the compensating variation that addresses foregone utility. Results show a relevant gap between the two methods For example, restoring the balance in the basin through purchase tenders would demand an investment of million 2400+ EUR (9.6+ EUR m^{-3}) attending to the foregone income method, and million 950+ EUR (3.8+ EUR m^{-3}) (−60.3%) with the foregone utility method.

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1. Introduction

The reacquisition or *buyback* of water is an increasingly accepted approach to restore the balance in overexploited basins, as shown by the significant investments recently committed to water buyback in areas like Australia's Murray-Darling Basin (AUD 3.1 billion for the period 2009–2024), Spain (EUR 829.9 million for the period 2007–2027) and the US, notably California (USD 547 million during 1987–2011, 55% of which after 2003) (DoEE, 2017; Garrido et al., 2013; GRBA, 2008; Hanak and Stryjewski, 2012). Reacquisitions are operated through purchase tenders that compensate irrigators who decide to surrender (part of) their right to withdraw water (Montilla-López et al., 2016). A major concern in water buyback involves information rents and the extent of the compensation (Crase et al., 2012): information asymmetries often lead to agency costs that inflate market prices and hinder the realization of buyback welfare enhancing opportunities. Government agencies (the *principal*) typically set in advance price and budgetary thresholds to control for agency costs (Iftekhar et al., 2013; Wheeler et al., 2013). The accomplishment of water buyback is therefore conditioned to the quality of the information available, which largely determines the ability of the principal to encourage bids consistent with the shadow price of the potential seller and thus limit agency costs.

Mature water markets in Australia, Chile and the US offer a platform to obtain data on prices and amounts traded for a variety of locations and moments, which can be used to predict responses and adjust bids using econometrics (Zuo et al., 2015). Yet, this approach is not applicable where formal water markets do not exist or are still in an early stage and *ex-post* trading data is not readily available.[1] This is the case of most regions worldwide −some of which are in the process of, or already implementing buyback programmes (Delacámara and Gómez, 2015). Informing purchase tenders under limited, incomplete or straightaway inexistent trading data demands an in-depth knowledge of, and information on,

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[1] In these instances, 'prices' do not reflect the interaction between supply and demand in a market environment, rather government charges to (partially) recover regulation, abstraction, transportation and distribution costs (EEA, 2013).

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sellers' motives and behavior, so that their objective function can be obtained to account for the marginal cost of strengthening the water allocation constraint (i.e. the *shadow price*). The Theory of Planned Behavior shows that motives driving behavior can be accurately predicted from a set of assessments based on agent's *beliefs* on the "goodness" or "badness" of an object, which can be in turn normally associated to a particular attribute (Ajzen and Fishbein, 2000). The theory is well supported by empirical evidence (Ajzen, 1991; Gómez-Limón et al., 2016), implying that accurate modelling of agents' decisions requires the inclusion of more than one attribute in a multi-attribute utility function –the idea that underpins the development of Multi-Attribute Utility Theory (Keeney and Raiffa, 1993). Yet, methods used to date rely on single-attribute objective functions that compensate projected foregone income and ignore the effects that buyback may have on other relevant attributes explaining utility, such as risk or management complexity aversion (Heady, 1952; Patrick and Kliebenstein, 1980). Since buyback programmes offer a payment with no risk or management complexity attached to management complexity- and risk-averse farmers, this approach may overcompensate sellers. This paper relies on Mathematical Programming (MP) methods to elicit the parameters of a multi-attribute objective function that is consistent with economic theory and empirical evidence on farmers' motives and behavior to test this hypothesis. Methods can be used to enhance the design and performance of water buyback programmes, particularly in areas where *ex-post* trading data is unavailable.

Literature reports different MP methods to calibrate irrigators' objective function and simulate policy responses, notably Linear Programming (LP), Positive Mathematical Programming (PMP) and Revealed Preference Models (RPM) (Heckelei et al., 2012; Howitt, 1995; Varian, 2012). Non-linear PMP and RPM avoid the unrealistic corner solutions and infinite solutions in LP, and yield smooth calibration results instead (Paris, 2011). PMP is possibly the most popular MP method (Heckelei et al., 2012), and has been used in the past to assess the environmental and economic outcomes of water buyback (Blanco and Viladrich-Grau, 2014; Martínez-Granados and Calatrava, 2014; Qureshi et al., 2014, 2009). However, PMP and LP rely on single-attribute objective functions that appear to be inconsistent with real-life observations and economics research since the 1970s (Bergevoet et al., 2004; Läpple and Kelley, 2013; Lynne, 1995; Poppenborg and Koellner, 2013). This paper relies on the axioms of revealed preference (Houthakker, 1950; Samuelson, 1938) to calibrate a *multi-attribute* utility function that is consistent with observed choices and suitable as a basis for empirical analysis. For a detailed and up-to-date description of the pros and cons of RPM and other MP, readers can refer to Gómez-Limón et al. (2016) and Pérez-Blanco et al. (2015a).

The RPM presented in this research builds on the methods developed in the seminal work by Gutiérrez-Martín and Gómez (2011) and applies them to the case of agricultural water buyback in the overexploited Segura River Basin in SE Spain. Alternative model setups have been used to inform instruments such as water charges (Pérez-Blanco et al., 2016, 2015a), irrigation modernization (Gutiérrez-Martín and Gómez, 2011) and drought insurance (Pérez-Blanco et al., 2015b) in the Segura River Basin and elsewhere, allowing for comparisons across regions and policies. In this version of the model, coding has been updated to normalize attributes and estimate the compensating variation; and to reduce computational requirements in the calibration procedure, which here is based on a projection method (see Section 3.2). Along with the comprehensive and detailed database recently made available by the Segura River Basin Authority (SRBA, 2014), this makes possible to expand the number of agents from 12 to 62, 5x + as compared to previous versions of the model (Pérez-Blanco et al., 2015a), resulting in more disaggregate and homogeneous units. Once calibrated, objective functions are used in a series of simulations in which water allocation is progressively constrained and agents have to adapt through crop portfolio decisions (see Section 3.4). The simulation module captures the changes in income *and utility* resulting from agents' decisions. Buyback prices can be then obtained from two different compensation measures: i) the foregone income, a proxy of the shadow price typically used in the literature (Iftekhar et al., 2013; Martínez-Granados and Calatrava, 2014; Qureshi and Whitten, 2014); and ii) the compensating variation that addresses foregone utility. This allows for comparison between the two compensation methods to test our initial hypothesis of whether conventional estimates based on foregone income overcompensate sellers.

2. Setting the scene: water buyback in Spain and the Segura River Basin

2.1. Water buyback in Spain

Water rights in Spain follow a concessional model: rights expire after a given term (typically 75 years, the upper threshold) and are subject to forfeiture, expropriation and waiving (BOE, 2001, chap. 52, 53, 59). *De iure*, river basin authorities are entitled to limit or even terminate a water concession that has a negative impact on the environment, without any compensation (BOE, 2001, chap. 3, 14, 65). *De facto*, the relevant transaction costs of revoking granted rights (McCann, 2013), and concerns over the negative economic impact this may have on rural areas (Gómez et al., 2013), result in concessions being renewed automatically provided use continues. Against this backdrop, water buyback programmes in Spain aim at restoring environmental flows, overcoming resistance from farmers through financial compensations, and compensating other possible negative feedbacks[2] (EC, 2000; Garrido et al., 2013; GRBA, 2008).

Two milestones define the background for the implementation of water buyback in Spain: *first*, the reform of the Water Law in 1999 (BOE, 1999) introduced exchange centers (*centros de intercambio*), a clearinghouse for users who wish to purchase or sell water; *second*, the Royal Decree 9/2006 made possible for government agencies to use exchange centers to acquire water concessions for environmental or other public interest-related uses (BOE, 2006). Water buyback programmes have been developed since to restore environmental flows in the Upper Júcar River Basin, the Segura River Basin and notably the Upper Guadiana River Basin. In the first two cases, water buyback addressed a seasonal decline in supply and involved *temporary* (annual) water purchases. In the Segura River Basin, two water purchase tenders (2007 and 2008) acquired 2.9 million m^3 each year at an annual cost of EUR 0.5 million. In the Júcar River Basin, a water purchase tender in 2006 acquired 27.3 million m^3 at a cost of EUR 5.5 million, and another in 2007 acquired 50.6 million m^3 at a cost of EUR 12.7 million (Garrido et al., 2013). In the Guadiana River Basin, the Special Plan for the Upper Guadiana (SPUG) addressed groundwater overallocation problems and planned a EUR 810 million investment to target a *permanent* reduction of withdrawals of 200 million m^3 by 2027. On paper, the SPUG relied on water purchase tenders whose prices reflected "the capitalized value of the present and future foregone income" resulting from strengthening the water allocation constraint (*proxy* shadow price) (GRBA, 2008). Nonetheless, uncertainty regarding the actual shadow price of water, and con-

[2] Other possible negative feedbacks from water buyback are typically balanced out through complementary policies including, *inter alia*, subsidies for economic diversification, water efficiency improvements, and new transportation, communication and energy infrastructures (GRBA, 2008; MDBA, 2012).

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