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Effects of irrigation modernization in Spain 1995-2015

Authors

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Abstract

The present study analyzes the empirical evidence of impacts of water saving investments (irrigation modernization) in Spain in the period 1995-2015 resuting in XXX milllion ha modernized with a public subsidy around 50% and an average cost of 6000 EUR/ha. The negative effect of the measure have been an increase of energy consumptio and the water cost. The positive effects have been: increase in productivity of land, labour and water, generallized volumetric billing, substitution of commodity for high value crops, improved working conditions, improved water quality as return flows decrease chemical and salt exported trough retun flows and increased water supply guarantee. Consumption rebound effect has been hetereogeneous as the result of three factors: ex-post limitation to irrigated area expansion, ex.post water allocation cutback and ex-ante existence of deficit irrigation. Finally the positive effects mentioned seems to pay off the invetsment with negative outcome of increased energy and the obligation to maintain an strict policy controlling irrigated are expansion and reducing water rights to avoid a possible rebound effect.

Keywords

water conservation; Jevons paradox; rebound effect; water pricing; water use; water consumption; Spain

Highlights

- The present study analyzes the empirical evidence of impacts of water saving investments in Spain (1995-2015)
- Rebound effects depend on three factors: limitation to irrigated area expansion, water allocation cutback and the pre-existing context of deficit irrigation.
- Increase of energy cost drives higher water cost and implementation of volumetric metering was generallized.
- Positive impacts in water quality (improved return), increase in factor productivity (land, labour, water) and improved working conditions.

1 INTRODUCTION

A majority of arid or semiarid regions of the world have long time entered a 'water mature economy' phase characterised by a constrained water supply and an increasing water demand with rising conflicting uses (Randall 1981). Some regions have gone beyond this phase due to the current 'closed' state of their river basins and/or aquifers. In this regard, the closure of waterbody is met when all resources are allocated (and frequently 'overallocated') as a consequence of human intervention (Molle, Wester et al. 2010). Dramatic examples of overallocation can be seen in developed countries such as the State of California in the USA (Owen 2014) and elsewhere. A wide range of policy measures (and combinations of them) has been suggested to address this problem, such as subsidies to water conservation techniques (WCTs) which has been the most relevant policy applied in Spain during the last ten years. This paper focuses on the analysis of the effects of the irrigation modernization process occured in Spain during the last ten years from a DPSIR approach. Modernization can be understood as a 'response' according to the DPSIR framework (Kristensen 2004) where the drivers of increased population and agricultural development have produced a pressure by over-abstraction of water resources, which has produced a deterioration of the environmental status of water masses (surface-water bodies and aquifers) and impacted both the ecosystem and the human welfare. The public and private responses to this environmental problem has been, among others, the investment in water conservation and saving technologies (also known by WCSTs) promoted by governmental financial subsidies, but also as a private response to decreasing farmers' income in a context of water scarcity (as main driving force). This measure is usually conceived as a socially acceptable policy, what justifies this public support by the potential water savings gained by the modernization of irrigated agriculture. Examples of these public policies can be found in many Western and Central States in the USA, Australia, India, Pakistan, and Spain, what will be the case study analyzed in this study.

Though irrigation modernization must also be understood in a wider sense as a change process that enhances efficiency, flexibility and reliability through the transformation of water delivery and application systems, the consequences in terms of the amount of water used and consumed must also be considered. In the specific case of Spain, the political impulse to this process is undoubtly linked to the effects of the periodic drought periods suffered in the Mediterranean regions of Spain as a result of the global climatic change. The first national program to support irrigation modernization was approved in year 1993, in the middle of the extreme drought that occured in the period 1991-1995, what was followed by various attempts to regulate this measure. Nevertheless, the main political impulse is given during the subsequent large drought period (2005-2008) with the law decree (RD 10/2005) for the '*adoption of urgent measures to fight the damages produced in agricultural sector by the drought*', what included an ambitious national plan (MAPA 2001) with a doble goal. On one side, to reduce water losses in distribution networks, on the other side, to achieve annual water savings of 3.000 Mm^3. This second drought period gave the big momentum to impulse the public engagement with the modernization process of irrigation, based on a public and private financing of the necessary investments to transform/modernize more than 1 million of irrigated hectares, thus the year 2005 will be defined as the year of the real kick-off in the 'modernization process of irrigated areas in Spain'. Since then, the modernization of irrigated systems and the subsequent projected water savings have become key issued in the implementation of the River Basin Management Plans (RBMP) in Spain. Nevertheless, responses also appeared from the private side, as farmers had to adapt to water scarcity and a continued decline in farm incomes (falling 1.1 % annually since the beginning of the 90s, according to

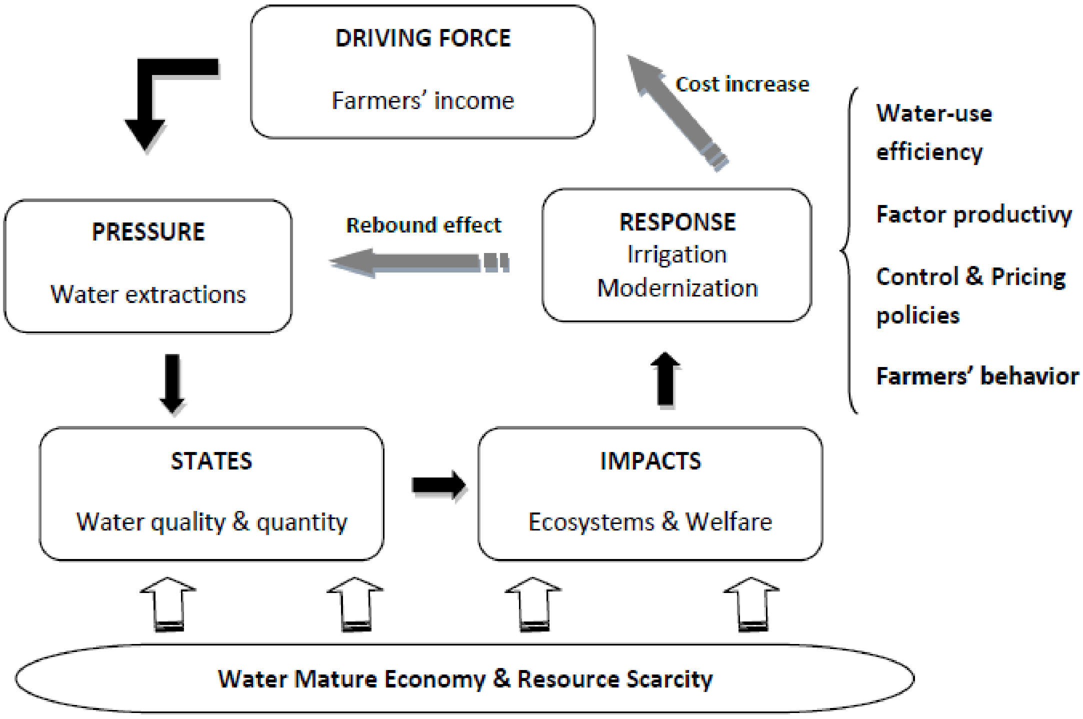
MARM, which attributes this decrease to the increasing cost of inputs and lower commodity prices. These facts affected farmers' decisions (i.e. crop composition, deficit irrigation, and managerial behavior). In this regard, (Berbel, Kolberg et al. 2012) have described the role of water saving measures in the implementation of the Water Framework Directive (WFD) in the Guadalquivir river basin (RB) in southern Spain.

The main political justifications of the public subsidies to irrigation modernization may be summerized by a) the achievement of potential water savings, and b) the increase of resource-use efficiency. Both goals are in line with the consolidated principles of environmental policy, as it is exemplified by the European Union strategy in resource use efficiency (European Commission 2011) and (European Commission 2012). This paper aims to address answers to both policy goals, that is waster savings and resource use efficiency. Thus, the first question requires to address the evidence of water savings after twenty years of massive investment in irrigation modernization, followed by the analysis of the observed evolution of water-use efficiency in this same period. Though the pioneering disciplines studying the effects of modernization have been hydrology (Whittlesey 2003) and agronomy (Playán and Mateos 2006), this paper aims to offer an integrated assessment through an analysis of the socio-economic effects of irrigation modernization as main response to maintain (or increase) farmers' income in a context of water scarcity with the use of a DPSIR framework. We believe that this analysis is crucial to understand the complexities of the outcomes derived from public and private modernization initiatives, including potential undesired/unexpected effects (i.e. rebound effect on irrigation-water extractions).

This paper is organized as follows. Next section briefly reviews existing literature on this subject and presents the scheme of analysis. Section 3 focuses on the increase of water-use efficiency as main response driven by the modernization process of irrigated areas, followed by a fourth section devoted to the analysis of the socio-economic responses. Due to the greater attention received among scholars and policy makers in last years, the possible 'rebound effect' of irrigation modernization is discussed in Section 5. Last section summarizes some concluding remarks.

2 REVIEW OF LITERATURE

In order to globally understand the impact of a policy measure in a system where environmental and economic uses interact with each other, it is appropriate to apply the scheme of analysis proposed by the European Environmental Agency (EEA). The analysis scheme is called DPSIR (from Driving forces / Pressure / State / Impact / Response), as shown in Figure 1. This analytical scheme helps us to understand how the increase of water extractions, as a 'Pressure' derived from the 'Driving force' of maintaining farmers' income through irrigation expansion (or conversion of rainfed to irrigated agriculture), leads to changes in 'State' of water bodies, which are materialized in 'Impacts' and followed by 'Responses'. In this context, the 'Pressure' deteriorates the 'State' of the water body, both regarding quantity and quality conditions, and this generates



an 'Impact' on the environment, as well as on human health. As a main response to these 'Impacts', increase in water-use efficiency has been, undoubtely, the most desired outcome of the irrigation modernization initiatives, both from public and private dimensions. Nevertheless, the concept of "irrigation modernization" refers not only to a higher efficiency in the use of irrigation water (i.e. through the use of WCSTs), but to a wide range of socio-economic changes, such as factor productivity maximization (i.e. thought crop-pattern changes, widespread of deficit irrigation techniques, etc.), public planning and control iniciatives (i.e. volumetric billing and water-pricing policies), as well as changes in the managerial behaviour of private agents (i.e. farmers and WUAs). As it is expected, these wide range of responses generate effects on pressures (i.e. minimising extractions), states (i.e. improving quality and available quantities to guarantee the demand of other users, including the environment) and impacts (i.e. reducing agro-contaminant levels in water bodies), but in this case, public and private responses lead undoubtely to higher costs (i.e. investment amortisation, monitoring costs, etc.), impacting negatively on farmers net income and triggering it as driving force in a potential vicious circle in our DPSIR framework. Furthermore, and as many studies have discussed, irrigation modernization processes may deliver a non-desired outcome in the form of the so-called 'rebound effect', which would behave as an added 'Pressure' (i.e. augmenting extractions), intensifying the potential vicious circle.

The Driver-Pressure-State-Impact-Response (DPSIR) framework was developed by the European Environment Agency in 1999 (EEA 1999). DPSIR is a useful framework for describing the relationship between the causes and effects of environmental problems. DPSIR has been used extensivelly both by EU Commission services and by academic and parcticioners elsewhere. The main shotcomming of the DPSIR framework is the lack of dynamic component (Binder, Hinkel et al. 2013) that is treated throught comparison of the level of indicators throught time.

Figure 1. DPSIR framework.

Within this DPSIR framework, modernization is understood as a 'Response' to the problem of poor quantitative and qualitative status of water bodies, letting us to assess the effect that irrigation modernization has had on the management of the water resource in Spain, both in relation with the improvement of the state of water bodies, as with its socio-economic aspects, by analyzing what we have learned from changes in both pressures and impacts Berbel et al. (2011) make an application of this analytical framework to the cost-effectiveness analysis of quantitative measures in the management of the Guadalquivir Basin, including the modernization process of irrigated agriculture.

Public subsidy of efficient irrigation technologies has been used as a measure to promote water conservation in different parts of the world. Examples can be found in the USA (California) (Medellín-Azuara, Howitt et al. 2012) (Xie 2016), Indian and Pakistan (Batchelor, Reddy et al. 2014), and Tunisia (Kuper, Faysse et al. 2015).

Irrigation modernization has recently become the center of an academic and political debate, where the critical point is the possible existence of a 'rebound effect' of WCTs' investment. This would imply that an increase in efficiency of resource use tends to increase (rather than decrease) the rate of consumption of that resource. This controversial effect has been acknowledged by European policy-makers (European Commission 2012), receiving also a wide attention from the research community (Perry, Steduto et al. 2017), (van der Kooij, Kuper et al. 2017) (Molle 2017) and (Berbel, Gutierrez-Martin et al. 2015), the latest reference analyse the effects of irrigation modernization in a survey of 30.000 ha in Spain (2000-2010)

3 OVERVIEW OF IRRIGATION MODERNIZATION AS POLICY RESPONSE

The nucleus of the political response to water scarcity are subsidies and public invetment in water conserving tecnhnologies increase in the water-use efficiency, as an expected result of the achievement of significant gross savings, measured as a decrease in water abstractions for irrigation, this policy is congruent with EU resource efficiency strategy to (European Commission, 2011). Nevertheless the effect of the measure are complex and try to be illustrated by figure 2.

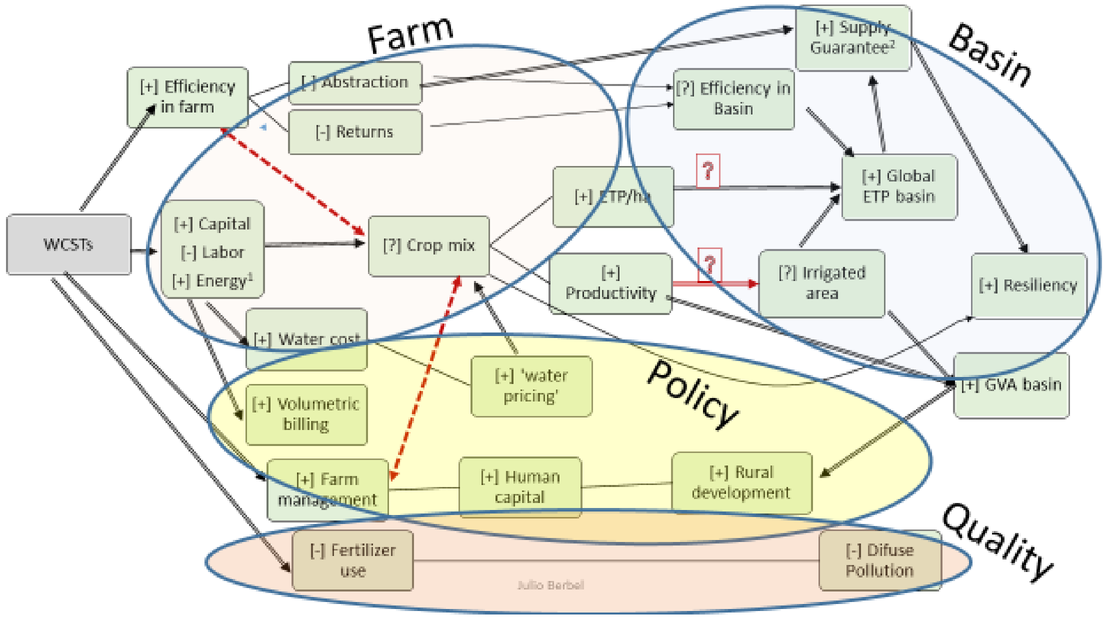


Figure 2: Overview of modernization effects

The Ministry of Agriculture (2016) estimates 1.79 million hectares modernized and withdrawal savings around 1,925 hm^3. This is possible because pressurized irrigation schemes increased by 1,283 thousand ha (of which 96% corresponds to drip irrigation), and areas of surface irrigation have reduced by about 995 thousand ha (net increase 287 ha. Thus, this change process in irrigation systems has led to an increase of water-use efficiency in the modernized irrigation units. In the case of Andalusia, the estimate provided by Corominas and Cuevas (2017) shows an increase from 65% from 2005 to 87% in 2015.

The increase in water-use efficiency implies a reduction of irrigation water abstracted. Table 1 summarizes the estimated water gross savings achieved at a Water User Association (WUA) and regional level (as it is the case of Andalusia and Valencia), upon the comparions of average water consumption values before and after the irrigationmodernization process. Upon this results, average reduction in irrigation water abstraction in Spain maybe around 33%.

Tabla 1: Water use changes at WUA level after modernization process.

Region	Sample	Water use	Source
Guadalquivir RB	36.000 ha	-30 %	Berbel et al (2015)
Western Andalusia	90.000 ha	-25 %	Borrego y Berbel (cap. 14)
Andalusia Region	1.100.000 ha	-33 %	Corominas y Cuevas (cap. 11)
Valencia Region	60 CCRR	-40 / -60 %	Garcia-Mollá et al (cap. 16)
Jucar RB (Acequia Real Júcar)	35.000 ha	-45 %	Estrela (cap. 15)
Tagus RB (Canal Estremera)	2.903 ha	-39 %	del Campo (cap. 5)

Source: Berbel & Gutiérrez-Martín (2017).

Nevertheless, a reduction in pressure (water use) does not imply directly a reduction of water consumption measured by Evapotranspitarion (ETP), but we will come back to this point later. Next section describe the main findings of our research regarding key indicators.

Following the DPSIR framework, the response to water scarcity has been public (subsidies to WTCs) and private (investment in high technology irrigation) and this has reduced water abstraction (pressure) as a consequence of resource use efficiency gains. But irrigation system goes beyond the quantitaive use of the resource and involve other pressures and status in the system. Table 2 shows a summary of main indicators idenetified in our review of published results and own surveys.

Tabla 2: Summary of effects of irrigation modernization (pressure-status indicators)

	Pressure	Status	Impact or comments
[1]	Water saving abstraction	Average decrease 33% in regulated water. No change in GW resources	See table 1.
[2]	Water rights entitlement	Entitlement is the limit for annual farmer abstractions.	General normative settles that water rights must be reduced by 25%. This reduces legal maximum abstraction
[3]	Crop intensification	Reduction in commodities, increase trees and vegetables	
[4]	Increase in irrigable area	No allowed in water scarce basins (South and East)	Some exceptions in Ebro and Duero[1].
[5]	Water consumption (ET) per ha	Deficit irrigation -> Increase Full irrigation -> Stable	Depending on pre-existing state
[6]	Basin global water consumption (ET)	Function of [4] y [5]	• Global water consumption (ET) stable if: a) no irrigated area allowed and b) water rights (entitlement) reduction. • ET increase if both conditions do not hold.
[7]	Fertilizer applied per ha	Reduced pressure by 25% in general (Fertirrigation, frequent application)	Hydrological Plan Jucar acknowledges that fertilizer pressure (applied volume) reduced by 10% in the basin
[8]	Returns flow	Reduction by 80% in volume, salts, and chemicals	Ebro hydrological plan estimates basin reduction of 30% nutrients and 8% salts and chemicals
[9]	Increase of value added by agriculture	Intensification (variable according specific climatic and socioeconomic characteristics)	Estimation of increase 7% GVA per ha, but long term dynamic effects.
[10]	Volumetric billing	Generalized, compulsory (100%)	1.8 million ha with volumetric billing. Water pricing as an instrument to control demand
[11a]	Water cost (surface)	Average increase by 150% (variable)	Energy (+600%), other cost (+200%)
[11b]	Water cost (GW)	Some small savings in energy	No significant change global.
[12]	Changes in work conditions	Technical qualification required. Better job conditions	Increase young farmers (+80% vs. non-modernized areas)
[13]	Increased water storage	Water supply guarantee increases	Guadalquivir RB (Hydrological Pan 2010) estimated supply guarantee probability failure 33% vs 18% after modernization

Source: Own elaboration from Berbel y Gutierrez, (2017)

[1] Modernization without subsidies may increase area but must reduce global water rights entitlement (scarce application)

The DPSIR scheme implies that status is transformed to impact in environment and society, in this case main systems affected are soil, water mass, biodiversity and rural population. Table 2 has shown evidence related to indicators of pressures and status but we have not been able to translate Pressures into Status and this into Impacts.

Regarding climate change adaptation that is supposed to increase climate variability, modernization may have positive impacts as: (a) increase in water-supply guarantee (water remain stored in the aquifer or watershed for the coming years); (b) increase in the environmental flow when the water-savings are used for this objective; and (c) improvement of resiliency and adaptation of the system to climate change and severe drought periods (as it frequently occurs in Mediterranean regions of Spain). As remarked, a positive effect comes from the increase in water-supply guarantee, but in order to make a good estimation of this effect, an accurate hydrological model of the basin or aquifer is required. Though there is scarce literature analysing this point, we may mention Berbel, Martin-Ortega et al. (2011) who estimate that modernization process in Guadalquivir RB improved reliability of water supply. Reliability is defined as the probability of not serving the water quota below 90% of water rights allocation, i.e. before modernization the probability of 'failure' was 33% and after modernization it was reduced to 18% based upon a long term hydrological model of the basin.

According to our DPSIR framework, fertilization acts as a 'pressure' on the system that translates to an impact on the environment as part of the fertilization nutrients are lost and ultimately contaminate water bodies. In this regard, (Estrela 2017) points out that modernization of irrigation schemes has increased efficiency in the fertilization use as WCTs allow to increase fertilization frequency, changing from two or three times per year in traditional systems to more frequent low doses of fertirrigation under modernized irrigation schemes. Moreover, this study collects the results of a simulation model applied to the Júcar RB and estimates a reduction of nitrates excess around 10.5% due to modernization of irrigation systems. Furthermore, crop uptakes improve as fertilization is concentrated in the 'bulb' of the wet zone and is quickly taken by the plant, with less risk of trawling and leaching than in traditional systems. Additional empirical evidence shows that fertilizers applied in 'Acequia Real del Júcar' (Júcar RB, Spain) have reduced by 27% of applied nitrogen per hectare compared to pre-modernization doses.

Combination of a reduced pressure (less fertilizer), increased crop uptake and reduced water returns, lead to a reduction of the impact on water bodies due to diffuse pollution. This issue has been highlighted by (García-Garizábal and Causapé 2010), who evaluated for the case of Canal de las Bardenas (with an irrigated area of 15,500 ha.) that the volume of returns decreased by 88%, from 362 mm to 45 mm per hectare. Thus, they demonstrate that the environmental status of the water mass has improved, as the pollutant load of these returns has significantly decreased around 50%, measured by the reduction of the amount of nitrates and salts discharged in the water body with respect to the pre-modernization phase. (Lopez-Gunn 2017) quotes the positive impact of modernization in water masses in Duero river basin that change status from bad to good status after implementing modernization.

The economic and social effects of modernization are of paramount importance, though differences emerge depending on the climate and socioeconomic constraints of the region where modernization of irrigation is carried out. Following effects may be remarked: (a) an increase of factor productivity (land, labour, water, etc.); (b) the implementation of water volumetric billing and water-pricing policies; and (c) an improvement in farmers' standards of living changes in managerial behaviour of farmers and WUAs.

With respect to the increase of factor productivity, in Southern Spain modernized irrigated areas generally there is no increase in irrigated area and the main economic effect is a change of crop patterns in favour to those of higher value. This phenomenon is clearly observed in the Guadalquivir RB (Southern Spain) where modernization has induced an increase of irrigated citrus and olive trees, while cotton, maize, beets, cereals, and alfalfa have decreased in terms of cultivated area. This change in crop-composition decisions has resulted in an increase of the value of land economic productivity. A survey in Guadalquivir RB detect that farm value increased 6.6% in real terms due to a change in the cultivated crop composition (Castillo 2017). This increase in the production value is still moderate and does not totally reflect the potential increase of production value in the medium term as some of these changes imply substitution of commodities (maize, cotton) for modernized irrigated tree crops (mainly citrus and olive trees with drip irrigation), which needs time to reach full production levels. Thus, we believe that in terms of the increase of factor productivity, the positive effect of irrigation modernization is still undervalued. Nevertheless, it is remarkable that 33% of the surveyed farmers when questioned about the reasons for the crop change, declared the own modernization as the main explanatory reason, being other justifications the foreseeable market and implications of the Common Agricultural Policy (CAP). A second relevant finding in this survey has been the fact that there has been no increase in crop physical output due to irrigation modernization. If physical yields after modernization have not been altered, the variation in the apparent productivity of the water consumed may only be due to crop changes, that is towards crops with a better water-benefit ratio.

This stability of yields is opposed to the results found in the Ebro RB (northestern Spain), where Lecina (2010) detected yield increases, especially in maize, which are explained by the situation of deficit irrigation existing prior to the modernization in the studied area (Lecina 2010) this is enlarge din the next sectiom.

In this same line, Exposito and Berbel (2017) highlitht that the rationale of maximising the productivity of a scarce factor (i.e. water) can be observed in the Guadalquivir RB (southern Spain), where farmers generally opt for DI techniques (Expósito and Berbel, 2016) and high-tech irrigation for high value crops, in order to maximise the productivity of all production factors: water, land, labor and capital. As a result, irrigation water productivity has increased dramatically in the Guadalquivir RB in recent decades and estimated upon the difference between the yields obtained by rain-fed and irrigated agriculture in terms of the gross value added (GVA). According to this study, the average water consumption per hectare has decreased by 20% in the period 2005-2012, to approximately 3400 m3/ha, while the capacity of irrigated agriculture to generate greater GVA levels than rain-fed agriculture has remained largely unchanged (2001 EUR/ha. in 2012 compared to 2055 EUR/ha. in 2005). In our opinion, this would seem to indicate that the observed increase in the irrigation water mean productivity (from 0.49 to 0.60 EUR/m3) in this period can be explained almost exclusively by the higher production efficiency of irrigated farming, which is thus able to generate the same yield levels with lower levels of water consumption.

With regard to the second highlighted effect, that is water cost increase and volumetric pricing, it may seem paradoxical to include the 'increase in water costs' as a positive consequence, mainly as a result of cost increases of energy and amortization of the modernization investments. Obviously it is not, as it implies a lower income of farmers. However, the European Commission has emphasized the need to increase water prices in order to fullfill the full-recovery principle in water services. In several EU documents, starting with Article 9 of the Water Framework Directive and continuing with the report examining the 1st Cycle of Hydrological Planning

(European_Commission 2015), the Commission has emphasized the need of higher price levels of water services, linking this water-pricing policy to the funding received by Member States from the European Union Fam Support.

It seems clear that irrigation modernization enables a paradigm shift by implementing the payment for water consumption through volumetric counters as opposed system to the previous flat rate system per irrigated surface. In order to achieve a sustainable management of the resource, it is very important that volumetric measurement of water consumption is implemented in all modernized areas. This allows volumetric pricing and in itself it is a paradigm shift versus the traditional 'flat rate' model. If we take into account that more than 1.5 million hectares have implemented this volumetric system, the change that modernization guarantees is highly relevant, allowing the farmer to control the use of water, what was not technically possible before.

Thus, volumetric pricing implementation should be considered a relevant contribution of the modernization process in Spain. In this same line, several evidences regarding the price increase that irrigation modernization has implied in differente localizations may be summarized. (Sanchis-Ibor, García-Mollá et al. 2016) estimate a cost increase of irrigation around 80% in the case of the Region of Valencia (eastern Spain), from 515 EUR / ha before modernization, to EUR 927 / ha after it. In this same line, (Borrego-Marín and Berbel 2017) estimate for the case of Andalusia an increase of 128,30%, from 149 EUR/ha to 339 EUR/ha after the modernization process. Nevertheless, Camacho et al. (Chapter 9) point out the existence of moderate increases, ranging from 8% and 118%, depending on the analyzed irrigation community within the Guadalquivir RB. In our opinion, and specifically for the case of Andalusia, this Spanish region may register a greater cost increase due the initial low cost of the resource when all WUAs used surface water for irrigation. Meanwhile in the case of Valencia, the registered increase is proportionally smaller due to the use of groundwater (or mixed waters) by many WUAs, thus starting from a much higher initial cost of the resource.

However, this increase in the price of water can not significantly affect demand in areas where the resource is scarce and valuable, since the marginal value of water is above 1.0 EUR/m^3 (with higher water productivity values) in many modernized areas. Consequently, these cost increases do not necessarily affect demand of irrigation water in those highly modernized areas, specially those with high-value crops and intensive use of deficit irrigation techniques, but reduce farmers' income (Exposito and Berbel, WARM). An interesting case study would be to analyze what may happen in irrigated areas with less productive crops and abundant water.

Socioeconomic changes are probably key issues that have received less attention in the literature. (Castillo 2017) find that crop changes toward higher crop intensity are positively correlated with younger and more entrepreneurial farmers. Moreover, the most interesting fact is that modernization appears as the main explanatory cause of the crop change in 1/3 of the respondents, while the rest of surveyed farmers justify the change on the basis of the European Common Agricultural Policy (CAP) and market conditions. In our opinion, these findings have a double meaning. On the one hand, modernization appears to be the engine of change towards greater added-value crops and precisely, the most enterprising farmers are the main protagonists of that change. This suggests that modernization acts as catalyst of change in the medium term, when the weight of entrepreneurs in irrigated areas becomes more present. On the other hand, the possible increases in water consumption due to crop change should not be attributed solely to modernization, since 2/3 of the respondents reveal that the crop change is mainly motivated by market or CAP conditions.

The quality improvement of water services has been remarked by 1/3 of farmers in order to justify crop change because of modernization. Before modernization implementation, farmers were subject to uncertain irrigation shifts and time-constrained crop campaigns (mainly between May and September). Once an 'on demand' and precision irrigation systems have been introduced, an extended irrigation campaign is possible, supporting woody and horticultural crops in the case of dry periods in spring and autumn seasons. This improvement in the quality of the irrigation water service is therefore one of the causes that help to explain the value added increase in the modernized areas.

Modernization has also impacted on the managerial behaviour of WUAs organizations. In this regard, (Sanchis-Ibor, García-Mollá et al. 2016) have identified mergers and reorganization processes in WUAs as a result of modernization, especially in small WUAs. Though its positive impact in terms of higher competitiveness of these water management institutions will be seen in the medium and long term, the efficiency gains in the management of the resource seem to be relevant. Finally, the greater complexity of the modernized WUAs has led to a management professionalization with the incorporation of technicians (agronomists) and managers that optimize the system in a context characterized by complex equipments and infrastructures, increasing energy costs, and the need to adapt to a changing environment. Again, the consequences of this change will not be perceived until a few years later, but it is clearly a positive factor in the rural development of the modernized irrigated areas.

The modernization of irrigation brings with it a series of improvements for the well-being of farmers beyond the possible increase of rents as a result of a better use of water. Farmers in modernized areas have improved their managerial capabilities through the implementation of automation and remote management of irrigation equipments, as well as a greater capability to create new jobs of higher qualifications. In this same line, (Borrego-Marín and Berbel 2017) based upon surveys conducted to managers of irrigation communities, point out the relevant improvement in the quality of farming jobs and therefore, in their standards of living, that the modernization of irrigated areas has brought with it.

5 THE ISSUE OF 'REBOUND EFFECT' IN SPANISH MODERNIZED IRRIGATED AREAS

The possible existence of a rebound effect, as unexpected outcome and second order 'response' of the policy cycle added pressure in the basin, has attracted the attention of schollars and policy-decision agents in last years. A wider discussion on this topic can be seen in (Berbel and Mateos 2014) and (Berbel, Gutierrez-Martin et al. 2015). This section will focus on the evidence found regarding the modernization of irrigated areas in Spain, as 'rebound effect' o 'Jevons paradox' may be identified as a non-desired collateral effect of the irrigation modernization process.

We have seen in previous section that modernization has increased factor productivity (land, labour, water) either by increasing crop yields (in cases of previous DI status) or by a change of crops towards higher value productions. Also a common feature has been the implementation of volumetric metering of water consumption and the increase of waster prices due to investment amortization and energy costs.

Main differences observed in the case study are found to be related to the previuos situation regarding water supply either in quantity or in the quality of service (i.e. uniformity, reliability, and frequency) that determines the previous existence of deficit irrigation or full suply, and the second feature is the change in water rights after the modernization was implemented (if water allocation rights were reduced or maintained). Table 3 shows a typology of case studies according to both criteria: water supply changes before and after the modernization, and the increase or maintenance of irrigated area.

Table 3. Case studies classification regarding irrigation modernization in Spain.

		Before	
		Deficit irrigation/ Water quota maintained	***Full irrigation/ Water quota reduced***
After	***Irrigated area maintained***	Water use: Small reduction	Water use: Reduction of water abstraction (25% -33%.)
		Water consumption: No change	Water consumption: No change
		Soto-García et al. (2013); Alcón et al. (2017)	*Berbel et al. (2015); García-Garizábal y Causapé (2010); García Mollá et al. (2013)*
	Irrigated area increased	Water use: Small reduction	Water use: Reduction of water abstraction (25% -33%.)
		Water consumption: Increase	Water consumption: No change
		Playán et al. (2010b) *	*Scott et al. (2014)*

(*) Increase of irrigated area within the pre-modernization authorized irrigable area where water supply does not reach.

According to the evidence shown in Table 3, and depending on the irrigation water scheme, four cases may be differentiated:

1. Irrigated areas with undersupplied water allocation (below 3,000 m^3/ha), as it it's the case of southeast Spain (i.e. Segura RB in south-eastern Spain). In this case, the modernization process has not been capable to increase water allocation sufficiently to reach full-irrigation needs (estimations around 5,000 m^3/ha for these systems). These extreme water-scarcity conditions have not allowed an increase of irrigated areas, but water-allocation rights have not been modified after the modernization because they are still well below the irrigation needs (see (Soto-García, Martínez-Alvarez et al. 2013) and (Alcon, García-Bastida et al. 2017).

2. Irrigated areas where water allocation is over irrigation theoretical needs but a deficient distribution network make that some plots are not irrigated or deficit irrigated due to water losses in the network (i.e. northern Spain). (Lecina 2010) details the effects of modernization in a large irrigation scheme in north-eastern Spain (case study of Riegos del Alto Aragon with 100.000 irrigated ha) where there has been an increase of irrigated plots within the existing limits of the irrigation scheme where irrigation water does not arrive as promised by the modernization process. Consequently, there is an increase in water consumption although the water rights are not modified. This case has been used as an argument by WWF and other environmental organizations as an example of rebound effect, but it is a very specific case that cannot be extrapolated to the rest of the country.

3. Sufficiently irrigated areas (water rights around 8.000 m^3/ha) with no deficit irrigable areas and no increase of irrigated lands (South and Eastern Spain). Water use and water rights have been reduced by 25% on average and water consumption has not been modified after

modernization (e.g. (Berbel, Gutierrez-Martin et al. 2015), (García-Garizábal and Causapé 2010, García-Mollá, Sanchis-Ibor et al. 2013)

4. Irrigated areas where some of the water savings have been used to increase irrigated land (Scott, Vicuña et al. 2014) in Ebro basin and some areas in before 2010 Hydrological Plan.

Current Spanish legislation for drip irrigation subsidies clearly mentions that a change to drip must be realized in the existing irrigated areas without expanding the irrigated surface (MARM, 2010)[2]. Nevertheless, a continuous increase of irrigated area (circa 1% annual increase) has occurred in the last two decades. This new irrigated area is generally not related to modernized areas, on the contrary, they are frequently associated to groundwater or reused water resources. This temporal coincidence has driven to some authors to a misleading hypothesis about this cause-effect relationship (e.g. (Corominas 2017), what in our opinion, does not reflect reality as both national legislation and RB hydrological plans explicitly ban the use of water savings to increase irrigated area.

To conclude this section, rebound effect defined as increased water consumption (ET) due to increased water use efficiency may occur when either "hypothetical water savings" are used to expand irrigated area or when previous condition was characterized by high water transport and distribution losses that cause deficit irrigation before the system was modernized. When irrigated area is bounded and water rights are reduced after modernization (general rule in Spain when investment is subsidized), the rebound effect is not relevant.

6 DISCUSSION

Irrigation modernization has been analysed frequently from the agronomic viewpoint and some authors have already pointed towards the increase in energy consumption (Fernández García, Rodríguez Díaz et al. 2014) (Rodríguez-Díaz, Pérez-Urrestarazu et al. 2011), table 2 indicates the increase of 600% in energy cost in modernized schemes.

The analysis of public subsidies to modernization and the recovery of water savings by government, this model has been also used by other counties. Grafton (2016) comments the Australian government-funded water recovery program where in terms of the On-farm Irrigation Efficiency Program funded by the Australian government, it is expected that at least 50% of the savings in the form of water entitlements will be transferred to the Australian government quoting a Government estimates of 7500 AUS$ per 1000 m^3. Table 3 illustrates this point.

Location	(10^3. ha)	Savings [1] (hm^3)	Investment (10^6EUR)	EUR/ha	AEC[2] EUR/m^3	% Subsidy.	Fuente
Australia (MDB)	n/a	2.526	3.828	n/a	0,66	n/a	(Grafton 2016)
Spain	1.790	2.362	4.000	2.235	0,59	56%	(MAGRAMA 2016)
Andalusia	470	986	2.053	4.368	1,15	70%	(Corominas and Cuevas 2017)

Source: Own elaboration; (1) Gross estimated savings; (2) AEC= Annual equivalent cost.

[2] MARM (Ministerio de Medio Ambiente y Medio Rural y Marino). 2010. Versión preliminar de la Estrategia Nacional para la Modernización Sostenible de los Regadíos, Horizonte 2015. Madrid: Ministerio de Medio Ambiente y Medio Rural y Marino

The main difference between Spain and Australia is the fact that the first discount 25% over pre-modernization water rights entitlements with Government retaining all the 'theoretical water savings' meanwhile the Australian government keeps 50% of the estimated water savings. The difference may be justified in the different water rights regime with full and perennial property of water rights in Australia and temporal (25 years) water use authorization in the case of Spain where regulated surface water is public of Water Act 1985.

After the literature review of (Berbel, Gutierrez-Martin et al. 2015) who analyse the evidence published on this theme, the topic has gained attention of academic and public.

From the recent literature, special relevance should be given to the international detailed FAO report by (Perry, Steduto et al. 2017) concludes that "when properly accounted at basin scale, total water consumption by irrigation tends to increase instead of decreasing" and base this affirmation in 14 countries and more than 20 case studies, the authors also recognize that "water application is reduced, pumping costs are reduced; fertilisers and other chemicals are saved and pollution is reduced; labour costs are often lower; and cropping options are wider. But where water is scarce, and especially where aquifers are over drafted and rivers are drying, reducing water consumption in agriculture should be the primary aim of policies and investments." This report support in general terms our findings regarding additional effects of modernization but neglects our conclusions that water consumption may in the best of cases be maintained relatively constant if rules of management (no irrigated area enlargement and water rights reduction) are enforced, a critical question is the institutional framework where the modernization is implemented.

The need for a have a sound institutional framework and water allocation based upon realistic and hydrological knowledge is signalled by (Molle and Tanouti 2017) The Green Morocco Plan not only subsidizes conversion to drip but also the expansion of intensive farming, with an impact on water resources opposite to what is announced. This may be in contradiction with declared policy goals and show decrease future resilience of irrigated agriculture to extreme drought events. This wishful thinking may have undesired (or voluntary) re allocation effects. (van der Kooij, Kuper et al. 2017) affirm 'The introduction of technologies to "save water" upstream may thus entail a re-allocation of water from downstream users to upstream users'.

The above-mentioned publications illustrate the existence rebound effects of irrigation modernization when there is not a reliable institutional framework able to control abstraction and to monitor and impose the two rules that we argue that are critical to avoid increase water depletion, uncontrolled reallocation of resources and downgraded resilience. The rules are simple to define, difficult to implement: a) no expansion of irrigated area and b) reduction of water allocation to allocate the water abstraction reduction for the environment and water supply resiliency when the next drought or the climate change make them priceless precious.

7 CONCLUDING REMARKS

This work has aimed to contribute to the significant progress in understanding the effects of modernization of irrigation schemes on agricultural systems achieved in last decades, both on the natural and socio-economic environments. In our opinion overall effects have been positive in the case of Spain, since the extraction-savings (an average of 33% in the analysed areas) have been relevant and environmental and socio-economic conditions related to water bodies have improved. Specifically, these water savings have been available to watersheds, providing greater guarantee and resilience to climate change and droughts, and ensuring ecological flows and the needed quality improvement of many water bodies. Moreover, the reduction of the impact of salt and nutrient discharges to water bodies, because of a reduction of water returns, has significantly reduced compared to non-modernized areas.

These environmental improvements are already visible in the short term, but modernization will allow further medium- and long-term gains resulting from shifting to higher value crops, the professionalization of farmers and WUAs, and the incorporation of more efficient irrigation techniques (i.e. drip). Although there are still uncertainties about the final effects of irrigation modernization processes, including the potential existence of 'rebound effects' and further research must still be carried out on this issue, we believe that this paper has provided valuable knowledge at assessing irrigation modernization processes, especially in those parts of the world, such as Spain, with extensive regions that face water scarcity as one of their major constraints to social and economic development.

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