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13/2020

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SEEDS Working Paper 13/2020
July 2020
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Analysis of the impact of a volumetric tariff for irrigation in Northern Italy through the "Inverse DiD" approach.

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Abstract

The impact of water-pricing policy in irrigated agriculture in Emilia Romagna (Italy) is evaluated through the analysis of farmers' water use whereby a flat-rate tariff (2013-2015) is replaced by a two-tier scheme composed of a flat rate plus a volumetric tariff (2016-2018). The policy assessment is performed by an innovative 'Inverse-DiD' approach based on the reverse application of the Difference in Differences method. The results indicate that farmers reacted to volumetric pricing by reducing water use per hectare to 56%. The high responsiveness may be explained by the combined impact of volumetric metering itself and the small price increase from the previous flat rate (zero marginal price) to a moderate volumetric tariff (from 0.025 to 0.044).

Keywords
Difference in Differences, Water pricing, Policy assessment, Irrigation Water Management, Emilia-Romagna.

JEL Q12, Q25

1 Introduction

Economic development increases pressure on resources both quantitatively (by increasing water abstraction) and qualitatively (by diffuse and point pollution). Water scarcity can be defined as the point at which the aggregate impact of all water users affects the quantity or quality of the water supplied to such an extent that it leads to a situation in which the aggregate demand, considering the economic sectors and the environment, cannot be fully satisfied (Wheeler et al., 2015). Water scarcity constitutes one of the main environmental global problems, and will become even more crucial in the near future. Today, around four billion people in the world are affected by water scarcity and water shortages, and, by 2030, the global water deficit is expected to increase with dramatic socio-economic and environmental scenarios (Misra, 2014).

Agricultural activities are one of the main determinants of pressures on water resources and are the principal consumers of water resources: they account for 70% of total water withdrawal around the world (FAO, 2012). Agricultural water use is strictly related to problems with food security, public health, and economic growth (UN, 2015, 2006), and with the direct and indirect production of ecosystem services (Costanza et al., 1997).

One of the main problems in agricultural activity involves over-irrigation (and over-fertilization, which is closely related), due not only to inefficient irrigation systems, but also to farmers' expectations and economic behaviour. Over-irrigation can be defined as the application of water in greater amounts than the crop water requirement (Steduto and Food and Agriculture Organization of the United Nations, 2012). Over-irrigation depends largely on the technology adopted and the information available to the farmer, such as that regarding soil properties, weather, biology, expected yield, and other agronomic and productive aspects. The price of water, however, presents a crucial aspect.

In the European Union, the approval of the Water Framework Directive (WFD) European Commission (2000) established a comprehensive integrated approach towards attaining a good status of all water masses in the EU. The WFD uses economic science (economic analysis, cost-benefit analysis, cost-effectiveness analysis) and economic instruments (water pricing) as their core discipline to reach the environmental goals that constitute the principal objective of the directive. Article 9 promotes cost recovery and water pricing as a guiding principle in the Directive that should be implemented in national legislation (EU Commission, 2000), by indicating pricing policies as suitable instruments to incentivize efficient water use, thereby contributing towards the improvement of environmental conditions (Kejser, 2016). The response to an increase in water pricing depends upon the characteristics of the demand curve, with mixed evidence regarding elasticities, which, in the case of irrigation, depend on crop profitability, environmental conditions, and farmer characteristics (Berbel et al., 2019). An extensive review of residential water elasticity by the European Environmental Agency reported '*in some of the case studies, price does not appear to be a significant determinant of water demand (..) water pricing still remains a key instrument in achieving cost recovery for water services to ensure the maintenance and financing of existing and future water infrastructure'* (European Environment Agency, 2017).

In addition to the elasticity of demand, there is evidence of the impact of metering and of information-sharing in residential water conservation towards reducing water use (Ferraro and Price, 2013) as a behavioural response. Nevertheless, studies regarding the impact of widespread metering of water is sorely lacking according to Wallander (2017): "*The theory on the impact of more metering on water use is not well developed, but if farmers tend to over-apply irrigation water relative to crop water needs, then greater metering could lead to greater water conservation*". In our case study, reliable metering was introduced since the 2013-2015 pre-policy phase, however, the information remained unused for water use by farmers who pay a flat tariff scheme.

In the case of a no-tariff policy for water, farmers can consider water as a non-constraining input and a free commodity. Conversely, if water is priced, it enters into the farmers' cost function, who then have to pay a certain fee for each quantity of water consumed in their productive activity (Hardin, 1968). Demand-side policies, which apply prices to water used for irrigation through volumetric tariffs, can internalize issues regarding public goods by reducing over-irrigation and directing farmers towards the more efficient use of water resources (Cooper et al., 2014; Rogers, 2002; Wheeler et al., 2015).

Economic policy measures operate via incentives, motivation, and voluntary choices rather than via complying with prescriptions as do command and control measures. These policies tend to be reasonably flexible because they can be adapted to various contexts regarding the motivation of individual farmers (Lago et al., 2015) and/or the reduction of problems arising from asymmetric information (Johansson, 2002). The pricing of water assigns a marginal cost to each amount of water consumed thereby transforming water into a binding input in farmers' productive strategies and influencing the selection and allocation of both crops and irrigation technologies (Berbel et al., 2018; Berbel and Gómez-Limón, 2000; Varela-Ortega et al., 1998).

Despite pricing instruments gaining acceptance as a tool towards achieving sustainability in water management, the literature remains divided on the effectiveness of tariff policies. Several scholars claim that water pricing alone cannot lead to improvements in water-use efficiency due to the many additional aspects that should be considered, such as institutions, physical infrastructures, costs, benefits, equity, and transparency (Cooper et al., 2014; Dinar and Mody, 2004; Molle and Berkoff, 2007). Moreover, the most important aspect in influencing farmers' irrigation responses to policies is that of water-demand elasticity to water price whose effect remains unclear from empirical analysis (Scheierling et al., 2006). There is still a gap in the literature on agricultural water management regarding the evaluation of economic measures (especially that of pricing) due to the lack of ex-post evaluations that arises from data limitations (Lago et al., 2015).

This paper strives to attain a double objective: firstly, to test the impact of a policy change from a flat rate to a volumetric two-part tariff; and secondly, to introduce a new method for the assessment of environmental policy through natural experiments. This paper employs data observed in the Central Emilia Irrigation Water District (CEWD) in north eastern Italy and analyses the effect of the application of a volumetric tariff as a policy strategy for the improvement of water use by local farmers. The results enrich the knowledge regarding the farmers' response to the introduction of both metering and an increase in the water tariff on water use.

The paper is structured as follows: in Section 2, a brief introduction to the assessment of water-policy impact is presented; in Section 3, material, methods, and our empirical strategy are described; Section 4 presents the main results, which are then discussed in Section 5; finally, Section 6 offers the concluding remarks.

2 Background on Policy-impact assessment for water resources

2.1 Evaluation of policies for the environment and water resources

Policy-making requires evaluation of program effectiveness. The assessment of policies constitutes a fundamental step towards measuring the results, the overall costs, and the impacts in order to enable both their eventual correction and continuous improvement of the results (Loi et al., 2012). Studies into policy evaluation rely on the evaluation of the real causal effect of a program by considering the differences between the pre- and post-policy situations. The main evaluation problem therein involves the impossible task of assessing the causal effect on the observable unit itself (Angrist and Pischke, 2009).

Ever since the beginning of the last century, statistical and econometric methods have been applied for the creation of practical instruments to be made available to analysts for policies in a wide range of fields such as labour, education, health, and transport (Abadie, 2005; Athey and Imbens, 2006; Bell et al., 1999; Card and Krueger, 1993; Lester, 1946; Rose, 1952; Simon, 1966). The works of Lechner (2010) and Imbens and Wooldridge (2009) provide an interesting contextualization of the evolution of policy-evaluation studies.

All these studies belong to the framework of policy evaluations that use counterfactual analysis, in which the changes in an observable variable, chosen as a measure of a certain aspect influenced by the policy, are compared between two groups of observable units. These groups differ in terms of whether or not they have been subject to the policy (Angrist and Pischke, 2009; Imbens and Wooldridge, 2009). Treatments can be various, such as regulations, taxes, education plans, laws, and the application of a new technology. The aim of the analyst is that of observation, comparison, and measurement (with statistical support) of the average status of the units before and after the assignment of the policy in the two different groups as a result of the causal effect of the policy (Frondel and Schmidt, 2005; Loi et al., 2012).

The ideal method for this type of analysis to be conducted is through the total randomization of the treatment assignment to the units in order to attain unbiased estimations; in many cases, however, this is almost impossible due to the difficulties in carrying out purely designed social experiments (Angrist and Pischke, 2009). Therefore, many empirical applications have taken advantage of different methods to overcome this problem (Imbens and Wooldridge, 2009). One type of these methods is a natural experiment (or quasi-experiment), which mimics the random assignment of a pure experiment using external situations (such as a policy program, a natural event, a new law, or the introduction of new technologies) to assign treatments (Blundell and Dias, 2009). The policy outcome is then assessed as the average difference of the two periods (before and after the policy) between treated and untreated units under specific assumptions while controlling for all other possible factors, known as confounders (Athey and Imbens, 2006; Frondel and Schmidt, 2005).

The Difference in Differences (DiD) approach is one of the natural experiment methods and presents a very flexible tool for policy evaluation. This DiD approach has been applied extensively in the assessment of many socio-economic (labour, education, health, production activities) and development programs (Imbens and Wooldridge, 2009; Lechner, 2010). Recently, DiD has also been used for applications in environmental issues, and has yielded useful answers regarding the effectiveness of environmental programs, such as payments for ecosystem services (Arriagada et al., 2012; Posner et al., 2016), land conservation policies (Ali et al., 2020), health programs against extreme weather events (Benmarhnia et al., 2016), urban greening programs (Branas et al., 2011), and regulations on zones of low air pollution (Gehrsitz, 2017; Malina and Scheffler, 2015). Nevertheless, the literature in this area remains limited compared to applications in other fields.

The DiD approach has also been introduced for the evaluation of agricultural water policies, although applied work on agricultural water issues is still scarce principally due to the limited access to water micro-data in agriculture. Drysdale and Hendricks (2018), Smith et al. (2017), and Smith (2018) studied the effect of water regulations on agriculture related to groundwater management in Kansas and in Colorado, respectively, and found, in both locations, that the introduction of economic incentives is effective for the reduction of agricultural water use. In China, the DiD framework has been used to assess both the causal effect of surface water pollution due to the excessive use of rice pesticides derived from a national program that incentivizes agricultural development (Lai, 2017), and the effect on the subjective quality of life of participatory water management activities (Pan and Guo, 2019). To the best of our knowledge, no other studies related to water resources for agriculture have been carried out using the DiD approach.

2.2 The DiD model

The DiD approach is the most popular instrument in natural experiments methods due to its intuitiveness and ease of application (Angrist and Pischke, 2009). In the DiD method, the average treatment effect on the treated units (ATET) in period *t* is defined as:

$$ATET = \alpha^{ATET} = E[\alpha_i | d_i = 1] = \{E[y_{it} | d_i = 1, X = x_{it}, t = t_1] - E[y_{it} | d_i = 1, X = x_{it}, t = t_0]\} - \{E[y_{it} | d_i = 0, X = x_{it}, t = t_1] - E[y_{it} | d_i = 0, X = x_{it}, t = t_0]\}$$

Equation (1)

where $ATET$ is estimated as the coefficient α^{ATET} , which is the average treatment effect on the treated unit *i* denoted by the variable $d_i = 1$ (otherwise $d_i = 0$), equal to the difference of the expected value of the outcome variable y_{it} in the period after the treatment (*t* =1) and before the treatment (*t*=0), while considering the effect of a set of different observable confounders in the vector X (Angrist and Pischke, 2009; Blundell and Dias, 2009).

The application of an econometric approach in order to obtain the DiD estimator incorporates t-statistics and enables different characteristics of the observed units to be controlled for in order to assess the statistical significance of $ATET$. Within a regression framework, α^{ATET} is the first difference estimator that is commonly used in panel data econometrics:

$$y_{it1-}\, y_{it0} = \delta + \alpha_{DiD} d_{it} + (\omega_i) + (\tau_{t1} - \tau_{t0}) + (\varepsilon_{it1} - \varepsilon_{it0}) \qquad \text{Equation (2)}$$

in which $(\tau_{t1} - \tau_{t0})$ is the difference between aggregate macro shocks in the two periods, $(\varepsilon_{it1} - \varepsilon_{it0})$ is the difference of idiosyncratic errors in the two periods, ω_i is the individual effect of the unit *i*, and $\alpha_{DiD} d_{it}$ is the DiD estimator (Blundell and Dias, 2009).

In another simpler form, the DiD estimator is represented by:

$$y_{it1-}\, y_{it0} = y_{it} = \delta + \omega_i + \tau_t + \alpha_{DiD} d_{it} * T_t + \beta_{it} X_{it} + \varepsilon_{it} \qquad \text{Equation (3)}$$

where $\alpha_{DiD} d_{it}$ is the coefficient of the interaction term between the treatment indicator dummy d_{it} (which indicates whether the unit *i* is part of the treated group) and the time of treatment T_t, in which *t* is the year of the application of the treatment. Therefore, it is possible to estimate the effect of the policy as ATET by using an econometric approach. Moreover, through the use of longitudinal data, it is possible to control for the individual effect (ω_i) by removing biases due to individual heterogeneity, macro-economic shocks (τ_t), and the controlling for a set of various X_{it} confounding factors that consider individual heterogeneity (Cerulli, 2015; Imbens and Wooldridge, 2009).

By following Frondel and Schmidt (2005), Blundell and Costa Dias (2009), Lechner (2010), and Cerulli (2015) in order to overcome the biases due to non-random selection, and by estimating the difference between the differences in means of the two groups (treated and not treated) and the real policy effect on the total population, the DiD model can make the following assumptions:

- Stable Unit Treatment Value Assumption (SUTVA). One and only one potential outcome is observable for each member of the population; there is just one rule for the assignment of treatment and non-treatment, and there is no interaction between units that can influence the treatment assignment.

- Common support Assumption (COSU). This embodies two sub-assumptions: first, that both treated and untreated units are observable; and second, that for each treated unit there is a comparable untreated unit with similar observed characteristics of confounders *X*.

- Exogeneity of the control variable assumption (EXOG). The confounders *X* are not influenced by the treatment.

- Non-effect of treatment on the pre-treatment population in the pre-treatment period (NEPT). This assumption is imposed in order to avoid distortions due to the anticipatory effect on the variable under study.

- Common Trend Assumption (CT). This assumes that the differences in the expected potential non-treatment outcomes (conditioned to the confounders vector *X*) are unrelated to whether or not the treatment is received, and that both sub-populations experience the same trend in the pre-treatment period. This implies that if the treatment did not occur then the two groups would have experienced the same trend. Therefore, this means that changes occurring in the outcome variable depend solely on the effect of the treatment (such as the effect of the policy).

If the above assumptions are violated, then the estimation of DiD is biased and inconsistent and therefore misleading suggestions regarding the policy effects are released. Lecher (2010), Angrist and Pischke (2009), and Blundell and Costa Dias (2009) provide in-depth explanations of the DiD assumptions.

3 Material and Method

3.1 The case study

Italy is classified as a Mediterranean country, whose high annual rainfall (942mm, which is greater than that in France) is more evenly distributed throughout the year than all the other Mediterranean countries. This natural environment implies a certain abundance in water resources, with hydropower as the dominant use of regulated water in Italy, mainly in the Northern regions. Table 1 compares the Italian irrigated sector with the large EU Mediterranean countries. The ratio of estimated vs. declared irrigation use in Italy can be observed as being close to 2, which implies initially high over-irrigation at least compared with its neighbouring EU countries.

Table 1: Estimated and reported irrigation water demand in selected EU countries

	Irrigated Area[1] (th.ha)	Reported[2] irrigation abstractions (hm^3)	Irrigation demand[2] (hm^3)	Reported irrigation[2] (mm/yr)	Calculated irrigation requirement (mm/yr)[1]	RIS [1,3]
ES	3.700	21.763	35.919	679	1.120	0.61
FR	1.500	4.872	6.349	311	405	0.77
GR	1.159	7.600	12.776	656	1.102	0.60
IT	2.866	38.360	22.381	1.565	913	1.71
Sum	9.225	72.595	77.425	866	923	0.94

Source: (1) Authors' own (2)(Wriedt et al., 2008) (3) Reported irrigation/Calculated

The abundance of water in Italy triggered the creation of the 'Consorzio di Bonifica e Irrigazione' (Reclamation and Irrigation Board), which was initially focused on the drainage of temporarily or annually flooded areas, and water supply distribution was gradually integrated for industries, urban areas, and irrigation. The Consorzio di Bonifica e Irrigazione splits costs between drainage services and irrigation water supply to final users in order to recover its operational and maintenance costs.

Excessive irrigation in a river basin, such as that of the river Po, has a reduced impact in quantitative terms since the excess water returns to the hydrologic systems in the form of return flow, while the impact in qualitative terms is highly relevant since the return flow exports large quantities of nutrients and chemicals. Over-irrigation is generally linked to over-fertilization (since the N and P that are partly lost via return flows should be replaced), which in turn contributes towards diffuse pollution through an increase in the export of nutrients and salt from agricultural soils.

The Italian Government decided to implement a volumetric tariff system for all users as defined by the Decree of the Ministry of Environment no. 39/2015 (Ministero dell'ambiente e della Tutela del Territorio e del Mare, 2015). Previously, tariffs were defined on a per-area basis according to the water needs of irrigated land and crops (for further details see Zucaro et al., 2011).

The case study is located in the Emilia-Romagna Region (ERR), in the northeast of Italy. This region has the largest share of irrigated land, and its water courses have been highly modified for agricultural and drainage purposes since the 17th century (Pérez-Blanco et al., 2016). The agriculture in the ERR constitutes an important dynamic sector at both national and European level, the value-added was 3.4 10^9 E (year 2017) with irrigation playing a major role (ERR, 2019a; Fanfani and Pieri, 2018).

In recent decades, the ERR has been experiencing major increasing pressures on water resources due to extreme drought seasons, reduced precipitation, and increasing temperatures, which led to a declaration of the state of emergency for the years 2003, 2006, 2007 and 2015 (Pérez-Blanco et al., 2016; Vezzoli et al., 2015). The ERR government has been at the forefront of the implementation of the WFD at regional level with a series of regulations and economic instruments in order to reduce pressures on bodies of water by incentivizing technological irrigation efficiency and the reduction of water losses and waste. Numerous regional policies have been affected by the introduction of pricing instruments for irrigation guided by the Cost Recovery Principle (El Chami et al., 2011).

We studied the case of the Central Emilia Irrigation Water District (CEWD, in Italian *Consorzio di Bonifica dell'Emilia Centrale*) in the provinces of Reggio-Emilia and Modena in the Italian Emilia-Romagna region, which is the most important agricultural area in the region. The area is famous for being the district of Parmigiano-Reggiano cheese, Balsamic Modena Vinegar, Lambrusco wine, and of other agro-food products with the Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI), such as watermelon, cherries, and pears (ERR, 2019b) with a share of 14.5% of the regional total agricultural added value (ERR, 2019a).

The CEWD is in charge of the management and distribution of surface water with a specific focus on the protection of bodies of water, defence against floods, and the distribution of water for agricultural and environmental purposes in compliance with the WFD (CEWD, 2017). The CEWD has a complex infrastructural network of 3,500 km of canals covering 120,000 ha and serving an agricultural area of 24,000 ha that encompasses three river basins: Po (average withdrawal 142,7hm^3), Secchia (average withdrawal 29,2 hm^3), and Enza (average withdrawal 10,4 hm^3) (CEWD, 2015).

Farmers annually provide their crop plans and their irrigation systems to the CEWD and indicate the size of the irrigated area at plot level. Irrigation water demand from each user is made directly by phone. The amount of water to be delivered is calculated directly by the CEWD, which considers the canal flow rate, the capacity of the water structure, and the duration of delivery. To this end, the CEWD takes into account the irrigation technology used by the farmers and their crop water needs in order to lessen the information requirements from the farmer, since there is only a partial presence of a direct metric pressurized water structure with prevalence of open canal systems. Therefore, farmers cannot ask directly for an amount of water, which is calculated by the CEWD based on the crop/technology scheme, but they can request water whenever their needs arise. At the end of the irrigation scheme, farmers receive a report of their irrigation activities and the relative costs to be paid before the next season in order to continue to receive the irrigation services (CEWD, 2017).

The CEWD is a public entity established in 2009 by the fusion of two previous Irrigation Water Districts (IWD) present in the area (the *Consorzio di Bonifica Parmigiana Moglia Secchia* and *Bentivoglio-Enza*). In the years immediately after the creation of the CEWD

(2009-2015), water users had inherited their previous tariff schemes from the former IWDs. A minority of users coming from the *Consorzio di Bonifica Parmigiana Moglia Secchia* in which flat-rate tariffs were applied continued to pay only an annual fee for general services and not for the amount of consumed water. However, users from *Consorzio Bentivoglio-Enza* already had a two-tier tariff scheme whose volumetric price lay between 0.024€/m^3 and 0.025€/m^3.

In 2016, in accordance with its own sustainability aims, the CEWD implemented a new pricing plan based on a two-tier tariff scheme in order to both reduce over-irrigation and to gather financial resources to recover operational and maintenance costs as stated by the WFD. The two-tier tariff scheme is composed of a fixed fee to cover the general service of the CEWD together with a volumetric part. The latter involves the basic price of 0.025 EUR per m^3 (increased to 0.027 EUR per m^3 in 2017) multiplied by an individual multiplier which considers: the existence of rivalry regarding the water resources (for Secchia and Enza water basin which are water scarce in the dry season); the recovery of operational and maintenance costs per area in which water withdrawal is more energy intensive, out-of-season provision services; and the water intensity of the crop.

A preliminary analysis of the use of irrigation water before (2013-2015) and after implementation of the policy (2016-2018) shows an average per hectare reduction of approximately 56% which indicates high effectiveness as can be observed later in the article.

3.2 Empirical strategy

Our analysis focuses on the effectiveness of the new imposition of water pricing on the behaviour regarding water use of irrigators passing from a flat-rate tariff to a volumetric scheme. This situation occurred in the CEWD as a natural experiment in which, from 2013 to 2015, two separate tariff schemes (flat-rate and volumetric) were applied, whereas from 2016 to 2018, all the users were on the same tariff scheme (volumetric).

The intuition under this analysis is that farmers were facing different types of decision patterns regarding their water consumption depending on their perception of water costs. Farmers who were already on the volumetric tariff should have previously incorporated water costs into their cost functions by considering water as a scarce factor and managing it in accordance with its marginal cost and its marginal benefit. Conversely, farmers who initially faced flat-rate tariff plans considered water as an unlimited input and used it as a free public commodity; this implied an almost zero marginal water cost, which encouraged them to over-irrigate. We can therefore test whether the application of a water-pricing scheme to farmers who previously had a flat-rate tariff scheme can be an effective policy in encouraging a reduction in water use.

Our case study is a natural experiment in which the effect of the volumetric policy on the farmers who had a flat-rate tariff before 2016 can be tested as a treated group using farmers who had had a volumetric tariff since 2013 as the control group. In classic DiD applications, analysts compare two groups of units that are similar in the pre-treatment period and become different in the post-treatment (policy implementation) period. (Angrist and Pischke, 2009; Frondel and Schmidt, 2005).

The empirical problem in this specific case study is that data is available in the converse form of the classic application used for DiD (Cerulli, 2015). Before policy implementation, there were two different groups: one which maintain flat rate until 2016; and another group already paying by volume as early as 2013. Conversely, in the post-policy application periods, there are two homogeneous groups of farmers who are both under the same water-pricing scheme.

Our main interest is focused on the average effect in water demand of those farms which experienced a change in their billing policy. Therefore, those farms which do not receive the policy in the pre-treatment period are considered as treated farms, contrary to the normal application of the DiD method. We called this approach “inverse DiD”.

One can imagine a classic natural experiment as a medical experiment, in which the effectiveness of a drug application is measured as the difference in the average health status between the two sub-groups of patients: those who receive the drug (the treatment) and those who receive the placebo. In this same context, the “inverse DiD” can be considered as a medical experiment, in which, at the beginning of the experiment, both groups of patients receive the same drug, then that drug is removed from only one group and the measure of the drug effect is measured as the difference in the average health status of the two groups of patients.

We apply this idea going backwards in time, starting with the analysis from 2018, the year in which all the farms received the water-pricing policy, to 2013, the year in which the farms had different tariff schemes. Our treatment status is that of being subject to a volumetric tariff scheme. The aim of the analysis is to measure the effect of removing the treatment (the pricing policy) from our units of interest in the second stage of the experiment, and to measure the average effect on farmers’ water demand.

3.3 Data description

The data used in this study is composed of a sample of water demand data in the CEWD for the provinces of Reggio-Emilia and Modena. Water demands are recorded in the CEWD dataset immediately following the irrigator’s requests, which are made by phone. The database employed includes all the information at plot level for: the total amount of water delivered, crop cultivated, irrigated area, water basin, municipality, and irrigation technology used. The CEWD indirectly calculates the amount of water delivered in m^3 as the multiplication of the duration of opening the channel, the flow of water, and the capacity of the channel.

The data used in this analysis is aggregated yearly and at plot level. No data on yields or productivity is available. Climatic data of seasonal accumulated precipitation and seasonal average minimum temperature at municipal level is merged into the principal dataset. Climatic data is from the ERA-Interim dataset of the European Centre for Medium-Range Weather Forecasts (ECMWF, 2019) at 25 km^2 grid level.

The farm plot is assumed as our statistical unit. This can reduce major problems that would otherwise arise due to the underestimation of water-demand elasticity caused by data aggregation (Bontemps and Couture, 2002). A balanced panel of 8,779 observations for the period 2013-2018 (1,463 units per year for 6 years) is used in order to control for the same statistical units during the whole timeframe. In each farm plot, only one unchanged irrigation technique during the time frame has been used, whereas in each plot, crops can differ over the years due to crop rotations (but not different crops within the same year). Farmers cultivate different crops and use different types of irrigation technologies classified in three groups: furrow, sprinkler, and drip systems (Table 2). The farm plots within the dataset are divided into the treated and control (untreated) groups. Hence, there are:

- 289 treated farm plots (1,734 observations over 6 years: 19.75% of the total) which had a flat-rate tariff from 2013 to 2015.
- 1,174 farm plots (7,045 observations over 6 years: 80.25% of the total) which have already been subject to a two-part volumetric tariff plan since 2013.

Table 1. Number of observations per type of irrigation technology and crop for Treated and Untreated farms.

	Untreated				Treated			
Crops	Drip	Furrow	Sprinkler	Total	Drip	Furrow	Sprinkler	Total
Alfalfa	0	14	178	192	0	0	58	58
Forage	0	0	21	21	0	0	3	3
Fruit	30	0	3	33	6	0	0	6
Maize	6	1	226	233	0	1	70	71
Meadows	0	1,773	5	1,778	0	1,492	0	1,492
Orchards	495	96	899	1,490	0	6	0	6
Other Arable Crops	0	1	29	30	0	0	2	2
Silviculture	0	30	0	30	0	6	0	6
Tomato	0	0	17	17	0	0	5	5
Vegetables	6	12	60	78	18	0	12	30
Vineyards	501	984	1,658	3,143	0	31	24	55
Total	1,038	2,911	3,096	7,045	24	1,536	174	1,734

Source: Own elaborations.

The statistical units considered in the sample represent 28% of the total CEWD farm plots served between 2013 and 2018 (the total number of plots served is 31,174). Most of the treated farmers produce Meadows, which are crucial for the production of Parmesan Cheese: a high-value product originally from the area of study. In the untreated group, Meadows, Vineyards, and Orchards are the main cultivated crops.

From simple data analysis, there is an evident reduction of water demand for treated units in the years immediately following the application of the cost-recovery tariff scheme, and an evident decrease in the difference between the two groups (Table 3).

Table 2. Average of the yearly water demand (total sample) and differences between Treated and Untreated units over the years.

Year	Treated	Untreated	Difference
2013	18,473	7,595	10,878
2014	15,270	4,374	10,896

2015	18,041	6,581	11,459
2016	10,696	6,204	4,491
2017	11,997	8,502	3,495
2018	6,687	4,819	1,867

Source: Own

3.4 Description of the method of analysis "The Inverse DiD"

A revised version of the DiD method was applied in order to econometrically analyse the evidence in water-demand reduction obtained with data analysis of simple descriptive statistics (Table 3). The treatment was assigned by considering those farms that did not receive a volumetric tariff in the pre-treatment period (2013-2015) as the treated sample, and the farms that already had a volumetric tariff from 2013 onwards as the (untreated) control group. Our variable of interest is the interaction between the treated group with the period of the pre-treatment (2013-2015).

Fixed-effect econometric models have been employed to test the effectiveness of the policy on the amount of water demanded at plot level. Yearly water demanded at plot level is considered as the dependent variable both in absolute terms and per hectare of irrigated land. This approach integrates the structural differences between farms that could influence the total water demand depending on the farm size, in order to avoid misleading interpretations. Several variables have been incorporated to make allowance for other influencing factors, such as climatic aspects at seasonal level (accumulated precipitations and average minimum temperature), location, type of crop, irrigation technology, and plot size. A trend variable has also been inserted into the models in order to control for structural patterns in the data. Furthermore, lagged and lead variables of order one year have been employed to incorporate anticipatory and forward effects (Angrist and Pischke, 2009; Cerulli, 2015).

The econometric analysis was repeated, but this time considering the different irrigation technology within the sample (Furrow, Drip, Sprinkler) in order to analyse whether there are any differences in policy effect between different irrigation systems. Our baseline econometric model is:

$$y_{it} = \delta + \omega_i + \tau_t + \alpha_{it} Flat_{it} * PrePolicy_{it} + \beta_{it} X_{it} + \varepsilon_{it} \quad (4)$$

where: y_{it} is the volume of water demanded by the farmer for plot *i* in time *t*; ω_i is the individual fixed effect; τ_t is the year's fixed effect, which captures macroeconomic and exogenous shock factors; α_{it} is the coefficient of the inverse DiD estimator, (our variable of interest) composed of (a) the interaction term of $Flat_{it}$, which is a dummy variable indicating whether the unit is treated (equal to 1 if it had a flat-rate tariff before 2016), and of (b) $PrePolicy_{it}$, which is a dummy variable indicating a pre-policy period (equal to 1 for periods before 2016); β_{it} is a vector of a set of coefficients of the X_{it} confounders. X_{it}includes: 1) the size of the plot in ha, 2) the water basin, 3) the crop type cultivated in the plot, 4) the irrigation system implemented in the plot, and 5) the level of seasonal accumulated precipitation and minimum temperature. The climatic variables are expressed in seasonal terms: winter (January, February and March), spring (April, May and June), summer (July, August and September), and autumn (October, November and December). δ is the intercept and ε_{it} is the idiosyncratic error term assumed to have zero mean and a standard deviation of one (Greene, 2008).

In order to obtain consistent results, all the DiD assumptions were verified (see *Section 2.2*). The assumptions in SUTVA and COSU hold due to the nature of the data. EXOG and NEPT also hold since the treatment assignment is completely exogenous and depends on pre-existing conditions which cannot be influenced by any characteristic of the farms. Self-selection of the treated farms is excluded because the type of farming is not influenced by water costs, which are simply a residual part of production costs. Moreover, migrations of farmers among properties between the areas of treatment and the areas of the counterfactuals are also excluded due to the assumption for the treatment that considers farmers in the area usually follow static production strategies using the same lands for generations. In order to control for this migration, the plot is regarded as a statistical unit. The possibility that farmer change crop patterns as a response to water pricing is controlled by using the types of crop cultivated on the plot as confounders.

Furthermore, in order to take possible anticipatory or lead effects related to the NEPT assumption into account, lags and leads of order one of our variable of interest are also included. We also control for trend in water demand. In equation 5, the specification of the model considers lags, leads, and trend:

$$y_{it} = \delta + \omega_i + \tau_t + \alpha_{it} Flat_{it} * PrePolicy_{it} + \alpha_{it_{-1}} Flat_{it_{-1}} * PrePolicy_{it_{-1}} + \alpha_{it_{+1}} Flat_{it_{+1}} * PrePolicy_{it_{+1}} + \gamma_t * Trend_t + \beta_{it} X_{it} + \varepsilon_{it} \quad (5)$$

where all the coefficients and variables in eq. 5 are the same as those in the base model in eq. 4, with the sole additions of the lag $\alpha_{it_{-1}}$ and the lead $\alpha_{it_{+1}}$ of the interaction term $Flat_{it} * PrePolicy_{it}$, and the coefficient γ_t of the time trend as suggested by Cerulli (2015).

The CT assumption in water demand between the two groups has also been verified by considering the parallel trends in the periods after the application of the policy and using a graphical analysis that considers the two periods of policy application in reversed form (Figure 2) and by checking for CT in the periods after the application of the policy (Blundell and Dias, 2009; Lechner, 2010). We inverted the time of the dataset so that it went backwards in time by considering the first period of analysis as the last year and the last period of analysis as the first year: t1=2018, t2=2017,…,t6=2013. The graphical analysis of values of the means of the two groups show parallel trends for treated and untreated units after the policy application (in t1=2018, t2=2017, t3=2016), but that they have different paths before the policy (in t6=2013, t5=2014, t4=2015). Between the two periods of analysis, there is an evident difference in water consumption of the treated farms in the pre-policy, with higher water use pre-treatment (t4 – t6) than in the post-treatment period (t1 – t3).

The difference in means of the two groups reveals a parallel trend after the implementation of the policy and a relevant structural break can be seen graphically in Figure 2 (t=3-4, years 2016-2015) during the introduction of the policy with different water use patterns. The same graphical verification was carried out using the water demanded per hectare of irrigated land and in terms of the three different irrigation technologies. Similar results were found for the CT assumption (Figure 2, 3, 4, 5 in Appendix). Thus, while the CT assumption holds, the effect of the policy can be considered as the only element influencing the differences in the trends of the two groups.

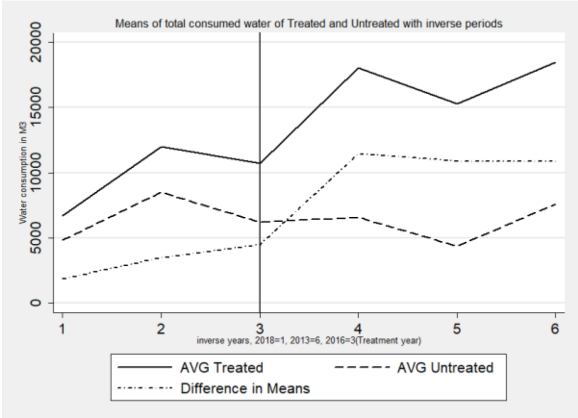

Figure 1. Trends of average values of water use by Treated and Untreated units and difference in means over the inverted period. t=1 is 2018, t=2 is 2017,....t=6 is 2013.

Despite the impressive numbers of DiD applications in the applied economics literature, Bertrand et al. (2004) point out a major weakness of many applied studies using this approach, principally due to serial correlation problems, which imply strongly biased outcomes in many DiD studies (Bertrand et al., 2004). We test for heteroscedasticity and autocorrelation of the data using a White test and a Wooldridge test, respectively, and indicate that the data is both heteroscedastic and serial-correlated (Greene, 2018). In order to manage this situation, clustered standard errors were used at individual level as in the applied works of Malina and Scheffler (2015) and Gehrsitz (2017). Clustering standard errors at plot level were chosen, which have the same effect as Feasible General Least Squares (FGLS) on serial correlation problems, but without limiting the size of the dataset. We used 1,463 clusters, which are sufficiently numerous to cope with serial correlation (rule of thumb: at least 42 clusters) (Bertrand et al., 2004; Hansen, 2007). Our results can, therefore, be considered unbiased, robust, and consistent.

Finally, in order to give greater robustness to our results, a further analysis was performed through the application of matching methods on covariates that use the propensity score matching method with the Kernel method (Cerulli, 2015). Similar units could therefore be compared by considering that confounding characteristics of treated and counterfactuals yield results of a more precise nature, as many other authors suggest (Arriagada et al., 2012; Cerulli, 2015; Frondel and Schmidt, 2005, 2005; Imbens and Wooldridge, 2009). The size of irrigated land, crop cultivated, and irrigation technology were used for the matching.

All the models are extended by additionally considering the three main irrigation systems (furrow, drip, and sprinkler) and by following the same specification of the general models, which consider both total water demand and per hectare of irrigated land. In all models, trend, and the anticipatory and delaying effect of the policy are controlled for with fixed-effect estimation (Cerulli, 2015; Greene, 2018).

4 Results

In all the models, the coefficient of the inverse DiD estimator is highly significant (0.01 significance level) with a positive sign, which indicates that, in the pre-treatment period, water demand for treated farms was consistently higher than the farms with volumetric tariffs. The results remain consistent regardless of whether water demand in absolute terms is considered or per hectare of irrigated land. The specification of the model does not influence the statistical significance of the inverse DiD coefficient. Indeed, the use of lag and lead of the variable of interest and the time trend do not modify the sign nor the magnitude of the coefficient of the inverse DiD estimator. The results of the general econometric models are shown in Table 4.

Table 3. Results of the general econometric models. Columns 1-3 consider total water demand, columns 4-6 consider water demand per ha of irrigated land.

	Total water demand (Water Volume total M^3)			Water demand per hectare of irrigated land (Water Volume total M^3 per ha)		
VARIABLES	(1) Fixed Effect	(2) FE 2 Time Structure	(3) RCS PSM	(1) Fixed Effect	(2) FE 2 Time Structure	(3) RCS PSM
Irrigated Area	960.5***	964.1***				
	(12.47)	(10.10)				
Treated unit	-		138.8	-	-	345.7**
			(0.285)			(2.242)
Inverse DiD	7,488***	6,926***	7,014***	2,948***	2,802***	2,805***
	(15.99)	(11.77)	(14.60)	(14.18)	(10.42)	(14.90)
Inverse DiD Lead(1)		-1,772***			-864.0***	
		(-2.899)			(-3.786)	
Inverse DiD Lag(1)		1,225**			325.2	
		(2.413)			(1.400)	
Time trend		-7,805			-7,244*	
		(-0.768)			(-1.806)	
Constant	173,794***	334,329***	2,360***	79,885***	122,450***	1,709***
	(3.154)	(2.837)	(4.436)	(3.992)	(3.063)	(8.000)
Observations	8,779	5,852	8,286	8,779	5,852	7,290
R-squared	0.336	0.295	0.186	0.290	0.239	0.276
Number of ID_Plots	1,464	1,463		1,464	1,463	
Robust	Yes	Yes	Yes	Yes	Yes	Yes
Cluster SE	Plot	Plot	Plot	Plot	Plot	Plot
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	YES	Yes	No	Yes	Yes	No
Lags and Leads	No	Yes	No	Yes	Yes	No
Trend	No	Yes	No			No
PSM			Crop, Irrig. Area, Irrig. Tech.			Crop, Irrig. Area, Irrig. Tech.
Controls	Irrigated Area, Temperature, Precipitation, Irrigation Technology, Water Basin, Crop.	Irrigated Area, Temperature, Precipitation, Irrigation Technology,	Irrigated Area, Temperature, Precipitation, Irrigation Technology, Water Basin, Crop.	Temperature, Precipitation, Irrigation Technology, Water Basin, Crop.	Temperature, Precipitation, Irrigation Technology, Water Basin, Crop.	Temperature, Precipitation, Irrigation Technology, Water Basin, Crop.

Water Basin, Crop.	

Regarding the total water demand, the lead and the lag effect of the policy are both significant at the 0.01 level for the general model, which indicates that there are no anticipatory effects of the policy, whereas the post-policy effect is evident. The time trend is not significant, which indicates that there is no general pattern of reduction of water use. In the model of water demand per hectare, only the lead variable is significant with a negative sign, which indicates a delaying effect of the policy for treated farms.

Therefore, by also including the anticipatory and delaying effects and the structural trend pattern, the coefficient of the inverse DiD is significant and positive, which indicates that our regression models for total and per hectare water demand are both robust. The results of our analysis consequently suggest that a change in water-use behaviour occurred in the treated farms principally due to the introduction of the water-pricing policy.

The main results for the models when considering each of the different irrigation systems (furrow, drip, and sprinkler) are presented in Table 5. Even in this case, the results confirm that the water-pricing policy was effective on the treated sample with the inverse DiD coefficients positive and statistically significant at 0.01 for all the technologies. The average use of water per hectare (m^3/ha) in the pre-policy period (2013-2015) is higher than that in the period after the application of the policy, which is indicated by the inverse DiD coefficients for furrow (2,476m^3/ha), for sprinkler (2,166m^3/ha), and for drip (2,846m^3/ha) irrigation systems.

The new tariff policy was effective on the treated farms for all the irrigation systems of the CEWD. The analysis of the magnitude of the coefficient by system show that drip system has highest percentage of reduction (vs. sprinkler and furrow irrigation). This is counterintuitive, since drip irrigation efficiency is higher compared to that of furrow and sprinklers and, according to certain authors (Berbel et al., 2018), the elasticity of demand decreases according to efficiency (drip irrigation is less elastic and furrow irrigation is more elastic). One explanation may be that drip irrigation enables higher precision, and hence the farmer may reduce water use subject to the lesser uncertainty of yield reductions compared to that of less efficient (sprinkler and furrow) systems.

Table 4. Results of the irrigation system econometric models. Columns 1-3 consider total water demand, columns 4-6 consider water demand per ha of irrigated land.

	Total water use (Volume m^3)			Total water use (VOoume m^3 per ha)		
VARIABLES	(1) Furrow	(2) Drip	(3) Sprinkler	(1) Furrow	(2) Drip	(3) Sprinkler
Irrigated Area	1,181**	739.8***	959.7***	-	-	-
	(2.481)	(2.715)	(9.379)			
Treated units	-	-	-	-	-	-
Inverse DiD	6,015***	6,595***	6,354***	2,475***	2,846**	2,160***
	(7.409)	(2.664)	(5.182)	(6.979)	(2.198)	(3.711)
Inverse DiD Lead(1)	-1,908**	-9,331	-1,356	-906.9***	-686.7	-515.9
	(-2.550)	(-0.00514)	(-0.968)	(-3.248)	(-0.576)	(-1.367)
Inverse DiD	1,145*	-2,934***	1,601*	397.8	-787.3**	137.2

Lag(1)						
	(1.794)	(-2.607)	(1.803)	(1.363)	(-2.216)	(0.611)
Time trend	5,858	-37,080	-24,012	-2,563	-21,840	-6,161
	(0.331)	(-1.060)	(-1.335)	(-0.351)	(-1.528)	(-1.083)
Constant	300,170*	166,997	28,343	63,868	196,503	22,344
	(1.808)	(0.700)	(0.130)	(1.053)	(1.285)	(0.569)
Observations	2,964	708	2,180	2,964	708	2,180
R-squared	0.269	0.343	0.402	0.241	0.321	0.338
Number of ID_Plots	741	177	545	741	177	545
Robust	Yes	Yes	Yes	Yes	Yes	Yes
Cluster SE	Plot	Plot	Plot	Plot	Plot	Plot
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Ind FE	Yes	Yes	Yes	Yes	Yes	Yes
Lags and Leads	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Irrigated Area, Temperature, Precipitation, Water Basin, Crop.	Irrigated Area, Temperature, Precipitation, Water Basin, Crop.	Irrigated Area, Temperature, Precipitation, Water Basin, Crop.	Temperature, Precipitation, Water Basin, Crop.	Temperature, Precipitation, Water Basin, Crop.	Temperature, Precipitation, Water Basin, Crop.

Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Finally, the effect of the introduction of the volumetric tariff has been analysed within the treated group, while considering the pre-policy and post-policy level of water consumption per hectare of irrigated land for combinations of crops and irrigation technology (Table 6). All combinations of crops and technologies show significant reductions in water demand in the period after implementation of the pricing policy of between -30% and -84% compared to those of the periods before the implementation of the policy.

Table 5: Average irrigation use (m^3/ha)

Crop	System	Before (2013-2015)	After (2016-2018)	Δ	Δ%
Fruit	Drip	3,120	497	-2,623	-84%
Alfalfa	Sprinkler	2,623	927	-1,695	-65%
Vineyards	Sprinkler	3,291	849	-2,442	-74%
	Furrow	4,957	1,902	-3,055	-62%
Vegetables	Sprinkler	2,076	839	-1,237	-60%
	Drip	3,120	1,621	-1,500	-48%
Silviculture	Furrow	6,832	3,518	-3,314	-49%
Maize	Sprinkler	2,874	1,514	-1,360	-47%
Meadows	Furrow	7,690	4,663	-3,028	-39%
Forage	Sprinkler	2,448	1,718	-730	-30%
	Average	*3,903*	*1,805*	*-2,098*	*-56%*

Source: Authors' own based on CEWD data. Note: $1m^3$/ha =0.1mm

All crops show a response to policy change. Table 6 shows that the response to policy is greater in Alfalfa, Vineyards, Fruit (melons), and Vegetables (sugar beet, onion, potato, and mixed horticulture) meanwhile there is a lower response for Forage (millet) and Meadows. This lower responsiveness to price for Meadows and Forage may be explained by the fact that these crops are integrated into the high-value chain of the ERR dairy industry (Parmesan cheese and other products).

5 Discussion

Agriculture, especially in Europe, has been considered traditionally as a strategic sector protected through governmental support (Abu-Zeid, 2001). This has also occurred in the irrigation sector since the cost of water services frequently remain unrecovered (Massarutto, 2003). Without cost recovery or distorting tariff structures such as a flat-rate tariff, farmers can operate structurally with low levels of marginal water costs, below the level of marginal water benefits. This leads to a situation of undervaluing the natural resource in the farmers' production function and in their decisions regarding water allocation schemes (Cooper et al., 2014), where water is considered as a public commodity with problems of over-exploitation and resource misallocation (Hardin, 1968). Therefore, in the absence of suitable incentives aimed at internalizing the full cost of water resources, management methods can become inefficient (Rogers, 2002) with major externalities due to over-withdrawal and over-irrigation (Dinar and Mody, 2004; Wheeler et al., 2015).

Pricing policies for water have been advocated since 1992, with the Dublin declaration in which water was recognized as a social commodity with an intrinsic economic value, and where water pricing was identified as a good measure for the internalization of externalities due to over-irrigation (Dublin Statement, 1992). Transaction costs related to design, implementation of metering infrastructures, and to the costs of control and enforcing the policy constitute possible drawbacks of water-pricing policies (Johansson, 2002). Moreover, there is uncertainty with the outcomes and heterogeneity of the impacts, which are case specific, and difficulties arise in creating best-practices and generalizations (Lago et al., 2015; Molle and Berkoff, 2007).

The findings of our study highlight the effectiveness of the pricing policy applied by the CEWD as an effective tool for encouraging the efficient use of water by farmers in order to sustain water conservation programs. In all the specifications of the models, the coefficients of the innovative application of the inverse DiD are significant and positive, which confirms that the introduction of the policy was effective, with reductions between 2, 948 m^3per ha and 2,802 m^3per ha.

This study confirms the positive effect of metering on the reduction of water consumption behaviours and towards efficient uses of water for agricultural activities (Wallander, 2017). Our study confirms the findings of Smith et al. (2017), Drysdale and Hendricks (2018), and Smith (2018) regarding groundwater, in which they indicate that the introduction of economic incentives consistently reduces water consumption. Their introduction of a tariff reduced the amount of agricultural water extraction by 33% in Colorado (Smith, 2018; Smith et al., 2017) and 26% in Kansas (Drysdale and Hendricks, 2018). In our analysis, a 56% average reduction of water demand due to the policy was found, which is in line with their findings, but slightly higher. Part of the explanation involves the ex-ante context, since groundwater should be pumped so that farmers pay the internal cost of energy, while surface water in the CEWD was almost free before the policy implementation. Furthermore, there are obvious differences between the agricultural systems of US states and those of northern Italy, although in both cases farmers are responsive to economic measures in water demand.

These results highlight a change of paradigm between metering and non-metering water use, and underlines the role of price in farmers' choices. In our case, farmers responded with major reductions in water demand with the introduction of a low price, which indicates that simply passing from a quasi-zero to a non-zero water price can consistently reduce free-rider attitudes, thereby internalizing externalities.

The whole process of water-demand reduction should not be perceived as a simple passage from an initial flat-rate tariff situation or almost-zero marginal cost to one in which marginal costs are present. Even with a flat-rate tariff, irrigation should bear certain costs, such as labour, information, management, and other opportunity costs to the farmer, some explicit and others implicit. Volumetric metering and pricing act as a signal of scarcity to the farmer to induce efficient resource use.

Our approach is original as we developed an in-depth econometric analysis on a large sample of plot level observations including information regarding the irrigation system and crop. The farmers' perception and their behavioural responses to the change of paradigm (metering vs. non-metering) is not totally measurable, due to the difficulties in splitting the total impact of the policy change between the two components: a marginal water-pricing increase and water metering by itself. The elasticity of water use is difficult to measure with our data for this combined effect of metering and marginal price) so that a different methodology should be undertaken to estimate elasticity of water demand.

As mentioned earlier, the context before the policy change involved over-irrigation (see comments regarding Table 1), which from the hydrological point of view implies that excess water is not 'lost ' for the basin since it returns to the system (Berbel and Mateos, 2014) and can be reused downstream, but the quality is deteriorated because it removes nutrients (e.g., N, P, K) in the form of chemicals and salts that are exported from the field, and therefore generates diffuse pollution externalities within the basin and into the sea and coastal ecosystems. The coastal area of the ERR is highly sensitive to anthropic pressures, especially nutrient loads from agriculture. Recently, the run-off of the Po river (Enza and Secchia river are tributaries of the Po) caused a significant growth of algae in the Northern Adriatic Sea and incurred major damage in terms of ecosystem impacts that consequently also affected regional tourism and the fishing sector (Russo et al., 2009). Diffuse pollution from the Po river has been estimated to be responsible for at least of 50% of the eutrophication in the Adriatic sea (de Wit and Bendoricchio, 2001). As farmers reduce water use, they are simultaneously improving water quality and environmental conditions downstream, and therefore exert impacts on water quality. The increase in the efficiency of water use induced by water conservation techniques improves water quality by reducing this significant externality of agricultural activities in the ERR (Berbel, Expósito et al. 2019). Therefore, water-pricing policy is important regarding both the improvement of water quality in a watershed system, and its quantitative impact, even though our research has focused solely on the latter.

On the other hand, an extensive introduction of water conservation technologies could boost progressive changes towards the use of high-value crop production (such as olives, orchards, and horticulture), which in turn can cause "rebound effect" problems (Berbel et al., 2015; Berbel and Mateos, 2014; Perry et al., 2017). Therefore, an overall analysis of the possible effects in the area of the introduction of water-pricing policies should also consider all the possible indirect changes in land use due to changes in farmers' strategies aimed at maximizing their income.

One interesting point arises from the result that shows a higher response (water saving) for drip vs sprinkler and furrow. This is counterintuitive according analytical models of farmer response (Berbel et al., 2018) and the hypothesis to be tested in the future is that higher precision by drip allows frequent application and uniformity in application meanwhile the less accuracy of furrow irrigation and sprinkler induce farmers to over-irrigate in order to reduce the risk of water scarcity and non-uniformity of water that can reduce potential yield; this reasoning requires further study for its confirmation.

The inverse DiD method relies strictly on the classic DiD application, but extends the domain of policy cases in which the application of this econometric tool can be applied. The proposed innovation enables the standard DiD method to be expanded for use in environments other than those required by the original method. We hope that future applications of the reverse DiD method will demonstrate the utility of this innovation.

6 Conclusion

The findings of this study indicate that volumetric water pricing is an effective strategy for inducing water saving in irrigation. The case study of the CEWD shows that volumetric pricing triggers an increase in water-use efficiency even with a low water price (below 0.05 EUR/m^3). Volumetric tariffs render marginal costs of water higher than zero, thereby introducing a non-zero value of water resources into the cost function of the farmers, who therefore start to use the resource as a private commodity instead of a public commodity.

The overall effect of the policy is positive and this has been demonstrated by the huge reduction of water use. However, in our work, a combination of 'metering' and 'small price increase' is introduced almost simultaneously and the individual impact of each instrument cannot be easily differentiated. The transition from a zero marginal cost (common commodity) economy to a priced and measured input has been demonstrated to be highly effective in our case where instances of 'over-irrigation' in the behaviour of farmers was previously evident.

Finally, the 'Inverse-DiD' methodological proposal is an innovative application of a simple and robust method that can be used to test policy innovations.

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