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Price induced water irrigation: Unraveling conflicts and synergies between European agricultural and water policies

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Abstract

The 2003 CAP reform considerably affects cropping patterns in European agriculture. At the same time the imperatives of the forthcoming Water Framework Directive (WFD) is expected to modify irrigation decisions especially in Southern Europe where irrigated agriculture utilizes about 70-80% of total water. This paper examines the combined effect of CAP reform and the application of likely volumetric water pricing on water demand by taking into account three drivers of change, namely extensive margin changes, intensive margin changes and irrigation technology shift. For low rates of water prices, CAP reform contradicts the WFD objectives since it leads to cropping patterns that consume more water resources. On the contrary, as water prices increase, decoupling and water pricing display a synergistic effect on water conservation. Finally, decoupling substantially increases the efficiency of water pricing in terms of water conservation. As a result, the post CAP reform regime clearly dominates the prior CAP reform regime when an index of value for money water conservation is examined.

Keywords: irrigation, bio-economic modeling, mathematical programming, policy analysis, price endogenous model, water demand, CAP reform, WFD.

JEL codes: C61, Q18, Q21, Q25

1. Introduction

The impact of agriculture on the environment is considerable and complex, comprising both positive and negative effects which take place at local, regional, national and global levels. A typical example of a negative effect is the pressure that irrigated agriculture imposes on water quality and quantity.

Concerning water quality in particular, the EU Member States have come to realise first the fact that the costs involved in drinking water treatment for nitrates excess, as well as the eutrophication damages, will increase in the near future and second that the investments allocated to urban wastewater treatment will be insufficient if a parallel effort is not devoted to an effective reduction of agricultural nutrients losses.

Likewise, in terms of water quantity, irrigated agriculture utilizes about 30% of total water consumption at the European scale, while this proportion is considerably higher as far as Southern Europe is concerned, where agriculture consumes about 70-80% (Massarutto, 2003). Consequently, any water conservation policy has to take into consideration the extent of water demand from agriculture.

The recent changes in two crucial policy areas related to agriculture, namely the Common Agricultural Policy (CAP) reform and the Water Framework Directive (WFD), present opportunities to combine the efforts in order to alleviate the pressures on EU water originated by agriculture. First, the latest CAP reform, agreed in June 2003, can play an important role in water protection since decoupling may reduce the intensity of input used and hence may enhance water conservation. Second, various requirements of the WFD, such as the principle of full cost recovery and the resulting water pricing, may alter the cropping pattern in an area through a series of extensive and intensive margin changes brought about by likely higher water prices.

The paper focuses on the impacts of water pricing on water conservation. Higher water prices may have an incentive role towards more efficient water management. At the same time the new CAP, through decoupling, may alter the intensity of water use.

This paper aims to empirically examine the range of synergistic possibilities between WFD and decoupling. The structure of the paper is as follows. The next section describes water and agricultural policy. Model specification is given in section 3 and the case study follows in section 4. The results and discussion are presented in section 5 while conclusions finish the paper.

2. Policy Regimes Changes and their Relation to Agriculture

2.1 The Water Framework Directive

The aim of the WFD is to achieve a good quality status for all European waters by 2015. The assessment of water quality is based on chemical, biological and hydrological criteria. The WFD establishes an integrated approach to water management based on river basins, while the "River Basin Management Plan" (RBMP) should be adopted by 2009 and must be updated every six years.

Several provisions in the WFD relate to water pricing. Water pricing should be considered as a potentially cost-effective measure (according to Article 11) for the implementation of WFD objectives. More specific provisions can also be found in Article 9 of WFD, where the concepts of incentive pricing, cost recovery and the polluter pays principle are addressed. In the River Basin Management Plans, Member States should report on the planned steps towards implementing incentive based water pricing policies and the recovery of the costs of water services. These costs include the financial, environmental and resource costs of water uses and their recovery is planned to be accomplished through a water pricing system adopted in each river basin. As a result, the water pricing under WFD, in accordance with the polluter pays principle in particular, is expected to increase water prices and therefore to provide incentive for a prudent and efficient water use. Moreover, such higher water prices are expected to change agricultural cropping patterns by altering the composition between irrigated and non-irrigated products.

2.2 The Main Features of CAP Reform

The Fischler reform of 2003 made a significant step forward in the direction of decoupling. First, it clearly established the principle of decoupling as a cornerstone of CAP reform with payments independent from the commodities actually produced in any current year. Second, it enhances environmental responsibility and links financial support in compliance with environmental standards (e.g. cross-compliance) and finally, it shifts funding from direct aid to rural development (e.g. modulation). Greece applied CAP reform by choosing to completely decouple all crop/livestock payments with the exception of cotton. A partial decoupling was applied to cotton where a 35% of the financial support devoted to cotton prior to CAP reform is still coupled to cotton area.

The new support scheme replaces area payments, and all the other aids granted to each farm under the different CAP regimes, with a single farm payment, which is based on the amount of CAP direct subsidies received by each farmer in the years 2000-2002. Because of their neutrality in terms of market effects, decoupled payments are viewed as the appropriate policy mechanism in terms of efficiency in redistributing income to farmers (Giannakas and Fulton, 2002). Based on the so far evidence, Bhaskar and Beghin (2009) examine how decoupling influence farmers’ decisions. The authors classify the impacts of decoupled payments into the following categories: (a) altering the risk faced by farmers, either through reducing the level of risk aversion (wealth effects) or through reducing the risk they face (insurance effects); (b) affecting the labour allocation decisions of farm household; (c) altering land prices and rents; (d) affecting the intensity of input use and hence having an environmental effect and (e) influencing entry exit decisions through expectations about future payments.

Decoupling is expected to modify cropping patterns in European agriculture but it is rather difficult to predict the impact of CAP-reform on land management and land uses (Acs et al., 2010; Posthumus and Morris, 2010). The removal of area payments will raise the relative gross margins of crops which were not subject to direct payments before the 2003 Reform (mainly fodder crops), compared with set-aside and arable crops (cereals, oilseeds and protein crops), which were eligible for direct payments under Agenda 2000. This could result in higher fodder supply, leading to lower prices and potentially increasing the supply of livestock (ruminant) products. However, decoupling livestock payments will reduce the gross margins of livestock, potentially reducing livestock capital and consequently resulting in less demand for fodder. This would in turn cause fodder prices to decline, and could thus shift the supply function of arable crops to the right (Balkhausen et al., 2008). As a result, the effect of decoupling on the crop pattern is highly specific to the prevailing productive system and hence it is an empirical issue, which is examined in this paper in conjunction with the additional changes induced by WFD.

2.3 Related Literature

To our best knowledge, the interaction between CAP reform and WFD has not yet attracted a particular emphasis in the literature. Goméz-Limón et al. (2002) argue that these two policies must be carefully co-ordinated as they may have opposite impacts in terms of sector competiveness. CAP reform may enhance while WFD is likely to reduce the competiveness of irrigated farming. On the other hand, both of these two policies are likely to reduce input intensity and hence to alleviate the pressure of irrigated farming on water quality. Heinz (2008) discusses the likely role of co-operative agreements for the joint implementation of WFD and CAP reform in order to alleviate possible conflicts between the involved agents and to ameliorate the design of cost-effective measures to meet the policy requirements.

The issue of achieving a “good quality status” in EU water bodies, as required by WFD, has been examined by Fezzi et al. (2008). The authors do not explicitly consider the nature of interactions between CAP reform and WFD, but given that decoupling is overriding, they examine a number of WFD induced measures to reduce diffuse pollution from agriculture in the UK.

Helming and Reinhard (2009) consider the WFD requirements in terms of water quality and examine the impacts on Dutch agriculture from reducing the polluting nutrients.

Elements of the possible contradiction between CAP and WFD on irrigated areas have been previously examined by Berbel and Goméz-Limón (2000). However, the approach adopted in this paper departs from the previous literature in the sense that explicitly tries to address the issue of how and why the joint implementation of CAP reform and WFD affects the nature of water demand in agriculture. In line with Khanna et al. (2002) the paper examines how water demand is affected by the interaction of three drivers: (a) a negative extensive margin effect; (b) a negative intensive margin effect and (c) a technology switching effect. The implementation of WFD is examined by considering a volumetric water pricing. Due to the fact that a full cost account of the water services is not available for our case study, a reasonable set of water rates is examined. In addition, CAP reform is addressed primarily through the impacts of decoupling on the relative crop profitability. The joint implementation of CAP reform and WFD is examined using a bottom-up approach where decisions take place at a farm-level in which farmers aim at maximising gross margin subject to constraints. Thus, policy analysis is examined within a mathematical programming framework specified in the following section.

3 Mathematical Programming for Policy Analysis

Mathematical programming provides a tool to evaluate simultaneous policy interventions in a system, such as arable agriculture, taking into account interrelationships such as resource and agronomic constraints as well as synergies and competition among activities. Optimization models that maximise a welfare measure by selecting planning strategies among feasible activity plans have been extensively used in agricultural sector modelling (Hazell and Norton, 1986). Such models may suggest an efficient allocation of productive activities on the basis, inter alia, that farmers are rational, i.e. they maximise profits. When the baseline optimal crop mix coincides with the observed situation , then the model is expected to forecast future changes and to reveal the impacts of different agricultural policy scenarios on production, resource allocation and farm income, and finally to assess policy efficiency.

3.1 The Structure of the Model

The regional optimisation model which maximises social surplus, defined as the sum of producers' and consumers' surpluses, is given by Eq. (1):

$$\max\left\{\begin{array}{l} \underbrace{\sum_i\sum_j\left[\left(p_j+s_j^p\right)q_{ij}+s_j^a-vc_{ij}\right]a_{ij}}_{rain-fed\ \ crops} \\ +\underbrace{\sum_i\sum_k\left[\left(p_k+s_k^p\right)f_k\left(w_{ik}\right)+s_k^a-vc_{ik}\right]a_{ik}}_{iriggated\ \ crops} \\ +\underbrace{\sum_i\left[\left(\gamma-\frac{\beta}{2}\left(\sum_i\theta_i q_{if}a_{if}\right)\right)q_{if}-vc_{if}\right]a_{if}}_{fodder\ \ crop} \end{array}\right\} \qquad (1)$$

Notation: i indicates the decision unit (producer at the individual farm),

j indicates the rain-fed crops,

k indicates the irrigated crops,

p indicates the crop prices (p_j and p_k prices for rain-fed and irrigated crops respectively).

s^p denotes price subsidy (s_j^p and s_k^p price subsidy for rain-fed and irrigated crops respectively). Note that $s_j^p = s_k^p = 0$ under CAP reform, while $s_j^p \neq s_k^p \neq 0$ for the old CAP.

s^a denotes direct payments (or area payments) (s_j^a and s_k^a area payments for rain-fed and irrigated crops respectively). Note that $s_j^a = s_k^a = 0$ under CAP reform, while $s_j^a \neq s_k^a \neq 0$ for the old CAP.

vc_i stands for the variable costs of the ith producer (vc_{ij}, vc_{ik} and vc_{if} for the rain-fed, irrigated and fodder crops respectively).

a_i indicates the agricultural land of the ith producer (a_{ij}, a_{ik} and a_{if} for the area under rain-fed, irrigated and fodder crops respectively).

$f_k(w_{ik})$ denotes the yield of the irrigated crops and is defined as a function of w_{ik} , that is the amount of water used by producer i for the k crop.

γ stands for the intercept and β for the slope of the inverse demand curve for fodder crops.

θ_i indicates the Farm Accounting Data Network (FADN) weight attached to the ith producer according to its relative representative power of the regional farm types.

The regional optimisation function comprises three components. The first two ones, namely the rain-fed and the irrigated crop components, are formulated on the basis that output prices are exogenous and hence the corresponding demand for these crops are perfectly elastic. On the basis of such an assumption, the policy scenarios examined in the paper do not impose any relevant changes to the corresponding consumer surpluses associated with these crops. Hence we can ignore these consumer surpluses from the objective function since the prime aim of the paper is to assess the welfare effects, i.e. the changes in the social surplus, brought about by policy changes. Consequently, any policy driven changes in the social surplus associated with these rain-fed and irrigated crops are due to changes in the producer surpluses. Note that the concept of producer surplus (primarily a geometric area) and the concept of quasi-rent or gross margin (primarily an economic concept) are equivalent (Just et al., 2004).

Given that one of the main drivers behind water demand changes is the intensive margin changes brought about by the examined policy scenarios, we relax the Leontief assumption of fixed input use regarding the irrigated crops. To this end, we utilise crop-water response functions for the main irrigated crops in the region, such as cotton and maize. These functions were estimated by “curve fitting” with Mathematica® on a set of data drawn from Danalatos (1993). The quadratic function was found to give the best fit which can be written as:

$$f_k(w_k) = a_0 + a_1 w_k - a_2 w_k^2 \tag{2}$$

where a_0, a_1, a_2 are parameters. Quadratic production functions are very often used to characterise the response of crop yield to irrigation (see for example, Tsur and Dinar (1997) and Goetz et al. (2008). Other functional forms are often suggested in the literature, such as the von-Liebig one (1989). It is suffice to say that the choice of the appropriate functional form characterising crop response to nutrients and/or water is still controversial (Berck and Helfand, 1990; Llewelyn and Featherstone, 1997) and hence polynomial forms, such as the estimated ones in this paper, cannot be ruled out (Grimm et al., 1987).

The third component of the objective function belongs to the so-called price endogenous models. In contrast with the standard linear programming formulation where input and output prices are assumed fixed and exogenous, price endogenous models are used in situations where this assumption is flawed or untenable (McCarl and Spreen, 2004).

These problems may involve modelling an industry or sector such that the level of output or purchases of inputs are expected to influence equilibrium prices. This is the case of fodder crops in our case study. The quantity of fodder crops produced, alfalfa in particular, affects the equilibrium price primarily due to the high transportation costs which restricts its consumption locally or to adjacent regions. As a result, and given the limited alternative uses of fodder crops, it is fair to assume that the price (of alfalfa) received by producers is determined by the total amount produced in the region.

In terms of modelling, market demand for alfalfa is endogenous and can be expressed as an inverse demand:

$$p_i = \gamma_i - \beta_i q_i \qquad (3)$$

where p_i is the product price, γ_i is the intercept, β_i is the slope of the demand curve whereas q_i stands for the quantity demanded. The value of these parameters, γ_i and β_i estimated for the examined region were taken from Rozakis et al. (2008). For the domestic demand of alfalfa the integral over the inverse demand gives:

$$\int \gamma_i - \beta_i q_i = \gamma_i \sum_i q_i - \frac{\beta_i}{2} \sum_i q_i^2 \qquad (4)$$

Then, social surplus comprising consumer and producer surpluses is given by the area defined in (4) minus the variable production costs, which in our case can be written as:

$$\sum_i \left[\left(\gamma - \frac{\beta}{2} \left(\sum_i w_i q_{if} a_{if} \right) \right) q_{if} - vc_{if} \right] a_{if} \qquad (5)$$

Presumably, the regional optimisation problem defined in (1) is subject to a number of conventional restrictions concerning resource availability and to a number of ad-hoc flexibility constraints. Following Petsakos et al. (2009), constraints for arable farms in the region are generally defined as:

1) Fixed amount of available resources (for example there are no changes in total agricultural land, water resources and family labour availability).
2) Fixed liquidity at the farm level.
3) Fixed and quasi-fixed capital is given at the farm level.
4) Alfalfa is the only non-annual crop in the regional cropping pattern and the relative rotational constraint is adjusted accordingly.
5) New CAP provision: Cross compliance obligation in order to receive the single payment (crop – rotation with legumes in 20% of the eligible land).
6) New CAP provision: Actual farm land must be greater than or equal to eligible land.

It should be stressed that nonlinear programming models, as the one defined in (1), can considerably improve the performance of regional models in terms of adequate representation of the baseline situation (Bauer and Kasnakoglou, 1990). A similar modelling approach is recently followed by Marques et al. (2005).

4. Case Study

The analysis is based on a sample of 344 farms from the region of Thessaly which were included in the FADN database for the year 2002. The area of the sampled farms was 4483.8 ha. Each of these farms cultivated at least 0.1 hectares of either cotton or sugar beet in the same year. Using the FADN weighting factors this sample represents 22,116 farms in Thessaly, corresponding to 28% of the total number of farms in the region.

Thessaly is located in the central part of mainland Greece as depicted in Map 1 and belongs to the eco-region 6 as classified in terms of the WFD requirements. The main river of eco-region 6 is Pinios (216 Km) while the total area of Thessaly is 10,550 Km^2. Irrigation water demand accounts for 96% of total water consumption. Total water availability is about 3.209 hm^3 and consists of 2.596 hm^3 surface water and 613 hm^3 groundwater (GCGCM-UNEP, 2004). The Thessaly water basin is currently water deficient (NTUA, 2007). The prevailing pricing regime for irrigation water in the region is an area based payment, where the farmers' irrigation fees depend on the size of irrigated land and the specific crops grown. The majority of irrigated land, however, is serviced by private boreholes and therefore no irrigation fees are imposed. The applied irrigation fees, if any, cover only part of the financial costs of water provision and obviously deviate from the WFD requirement, the so-called full cost recovery of water services. As a result, over-exploitation of groundwater is the major environmental problem which may threaten with depletion many aquifers in the region (Mouratiadou and Moran, 2007). Consequently, it is the authors' contention that examining the issue of water conservation, as affected by European agricultural and water policies, is quite topical.

INSERT MAP 1 ABOUT HERE

Farming in Thessaly involves mainly arable crops such as cotton, tobacco, durum wheat and maize, with cotton being the most widely cultivated crop. Table 1 gives the main statistics of the major crops cultivated in the area.

INSERT TABLE 1 ABOUT HERE

The estimates of variable costs per crop and farm mostly rely on the micro-economic data published by the Greek FADN combined with survey data. A well known caveat of the FADN data is that variable costs are reported at a farm level as total without being disaggregated to specific crops. To overcome such a burden a goal programming model was adapted using FADN and survey data to allocate total variable costs to specific crops. The latter was originally proposed by Guindé et al. (2005) while Rozakis et al. (2008) adjusted it for the regional conditions.

Two irrigation technologies were considered in this paper, namely sprinkler gun and drip irrigation. The former constitutes the majority of irrigation systems for cotton and maize in Thessaly, while the latter is less widespread in the region and is mainly used by cotton growers. These two irrigation technologies differ in terms of their efficiency (e), which is defined as the ratio of water quantity drilled (w_r) to the water quantity that is actually consumed by the crop in the field (w_k), $e = w_k / w_r$, where w_k and w_r are measured in m^3 per hectare. According to Mateos (2008) the previous definition of irrigation efficiency reflects a strong engineering approach which sometimes may be misleading. However, more complicated concepts of irrigation efficiency are not easily tractable and clearly beyond the scope of our paper.

Following Anonymous (2002), the regional efficiency of the drip system is estimated at about 80%, while that of the sprinkler system is lower and estimated at about 65%. It is evident that the lower the irrigation efficiency the higher the energy consumption, due to longer irrigation time and the higher the water drilled. In order to assess the likely operating costs associated with these irrigation technologies, it was assumed that each farm utilizes a typical for the region 30 hp oil pump with a pumping capacity (PC) of 40 m^3 of water per hour. The pump operating costs were calculated by the following formula, which is used by local authorities in order to estimate proxy costs of farm operations when financing farm improvement investment plans(Anonymous, 2002):

$$OC_{ir} = 0.2 \times HP \times T_{ir} \times C_{oil} \tag{6}$$

where, OC_{ir} is the pump operating costs (€), HP is the pump horsepower (in hp), T_{ir} is the irrigation time (in hours) and C_{oil} is the cost of oil (€ per lit). The coefficient 0.2 (lit/[hp × hours]) refers to farm operations performed with petrol-based equipment, other than tractors. Local authorities use similar formulas, with different coefficients in order to estimate operating costs of gasoline based equipment, electrical pumps and tractors.

Given the assumption of a common oil pump for all farms and constant oil prices, the only variable in (6) that is determined by the model is the irrigation time, T_{ir}, which is given by $T_{ir} = w_r / PC$. Total irrigation cost (TC_{ir}) is then the sum of pump operating costs, OC_{ir}, and the water expenses, price of water times the quantity of water drilled:

$$TC_{ir} = OC_{ir} + \left(p_w \times w_r \right) \tag{7}$$

The sprinkler gun was the default irrigation technology, while drip irrigation was optional. The adoption of drip irrigation, however, in addition to the irrigation costs defined in (7) requires an extra cost element which is the annual equivalent cost of installing a drip system installation cost, estimated at 280 €/ha, under the assumption of a 5% interest rate (Anonymous, 2002).

The validation process revealed that in many cases the model was able to perfectly reproduce the observed data. However, in about 30% of the farms optimal crop mix is more or less different from the observed one (Rozakis et al., 2008). Despite that, at the aggregate level the model matched the observed crop mix almost perfectly.

5. Results and Discussion

The model described in section 3 was used to examine the possible interactions between decoupling and the likely introduction of water pricing in terms of the WFD. To this end, we considered price ranges often mentioned in the literature. In particular, Iglesias and Blanco (2008) examine the range [0 – 0.06 €/m^3], Manos et al. (2006) the range [0 – 0.15 €/m^3], Bartolini et al. (2007) the range [0 – 0.8 €/m^3], while Gómez-Limón et al. (2002) the range [0.025 – 0.048 €/m^3]. To evaluate the impact of the various water prices on the regional agricultural farm returns as well as the regional water demand we use examine a range of water prices varying between zero and 0.2 €/m^3. This price range was considered for both policy regimes, namely the CAP prior to the 2003 reform and the post CAP reform which introduced decoupling. By doing so, it is possible to trace the likely synergies, if any, between CAP reform and water pricing induced by the WFD. Table 2 presents the share of irrigated and non-irrigate land under various water pricing scenarios prior and post CAP reform.

INSERT TABLE 2 ABOUT HERE

As it was anticipated, the introduction of water pricing favours the expansion of rain-fed crops at the expense of irrigated crops. This is evident looking at (b) and (d) columns in Table 2, which show that water pricing both prior and post CAP reform reduces the share of irrigated land. At the same time, nevertheless, decoupling may favour the expansion of irrigated crops (see columns (a) and (c) in Table 2) as a result of the changes in the resulting gross margins (see Table 1). This impact of decoupling dominates the nature of the extensive margin changes when the water prices fall within the range [0 – 0.06 €]. Only when water prices exceed 0.08 € does water pricing reduce the share of irrigated land and foster cropping patterns that may be consistent with water conservation objectives. On the basis of the last column in Table 2, where the changes in the irrigated land induced by decoupling for the range of water prices examined are given, it can be argued that impact of CAP reform on water conservation is indeterminate per se and has to be assessed in conjunction with water pricing. As for low rates of water prices, in our case study this range being from nil to 0.06 €, CAP reform contradicts the WFD objectives since it leads to cropping patterns that consume more water resources. On the contrary, as water prices increase, decoupling and water pricing display a synergistic effect on water conservation.

Now, we turn our attention on the resulting intensive margin changes. Figure 1, shows the optimum water used for cotton, the major irrigated crop in the area, prior and post CAP reform. The dot line represents the yield response function to various quantities of water used. The triangle symbols indicate the optimum water used prior to CAP reform, while the cycle symbols indicate the respective optimum water used after CAP reform.

INSERT FIGURE 1 ABOUT HERE

It is clear that the intensity of water use is declining since the introduction of the CAP reform. According to Figure 1, CAP reform spreads the optimum irrigation levels – for the price scenarios examined – to a wider range along the yield response function in comparison with the situation prior to CAP reform. In particular, the optimum irrigation levels induced by decoupling fall within the range [92.4 – 420.4], while the respective range prior to CAP reform is [220.2 – 420.4]. Put in another way, the intensive margin changes, brought about by decoupling, reduce on average the water used per unit of land and therefore favour water conservation.

The last driver to consider is the irrigation technology shift. Table 3 shows the shares of drip irrigated land for the main irrigated crops, namely maize and cotton, as well as the share of total drip irrigated land.

INSERT TABLE 3 ABOUT HERE

The situation depicted in Table 3 shows that in the hypothetical case that CAP reform had not been realised water conservation technologies, such as drip irrigation, would have been primarily a concern of the cotton growers. In addition, in such a case the percentage of drip irrigated land is declining as water prices increase presumably due to the decline of irrigated land forced by water pricing.

The situation is even more complicated under decoupling since now drip irrigation is a technology chosen by both maize and cotton farmers but not in a consistent (monotonic) way. The adoption of drip irrigation is considerably higher among maize farmers compared to cotton producers. However, as water prices increase (>0.16 €) drip irrigation ceases to be a viable option for maize but starts to be more attractive for cotton producers. A possible explanation for this situation may be the fact that maize and cotton crops compete for water with alfalfa, the price of which is not given but is endogenous and therefore fluctuates. Then, the resulting competition along with the changes in relative gross margins brought about by water pricing and decoupling may not be consistent at different water price levels. On the top of that, in the post CAP reform irrigated crops face stronger competition from rain-fed crops and the overall impact on irrigation technology may be non-linear. The changes at a crop-level water demand may not be consistent with the changes at a farm-level water demand (Moore et al., 1994). Consequently, depending on the sign and the magnitude of these changes the regional (aggregate) water demand is affected analogously. In other words, examining the adoption of irrigation technology shift at a regional level may mask the farm-level and crop level adjustments. Clearly, this issue deserves further analysis focusing on possible ways of decomposing the regional adjustments into farm-level and crop-level adjustments and carefully account for how extensive and intensive margin changes shape the technology shifts in a multi-crop setting.

However, signs of policy induced changes (by water pricing) in the adoption of water saving irrigation technology may be visible in the last column of Table 3, where with the exception of zero water price it seems that in the post CAP reform case water pricing helps the expansion of the overall drip irrigation, given that the share of drip irrigated land increases as water rates rise.

The combined effects of the extensive margin changes, the intensive margin changes and the technology shifts induced by water pricing for both prior and post CAP reform are given in Figure 2 in which water demand is presented.

INSERT FIGURE 2 ABOUT HERE

Figure 2 illustrates the likely conflict between CAP and WFD, since at low water prices decoupling increases water demand. When water prices fall within the range of [0 – 0.03 €] the extensive margin effects in favour of irrigation expansion dominate, leading to higher consumption of water which negates the objectives of WFD. Such low rates of water prices are currently applied in many parts of Greece (Tasoglou, 2009). Above the threshold of 0.03 €/m^3, decoupling (new CAP) and water pricing (WFD) clearly display synergies toward water conservation. As water prices rise it becomes apparent that decoupling has a positive effect on water conservation as the resulting crop mix brings about lower water demand and hence there is a synergy between the two policies. Arguably, this is the point that deserves attention since it may have important policy implications. Table 4 restates the same information as Figure 2 but this time the emphasis is placed on the issue of water conservation induced by CAP reform and WFD.

INSERT TABLE 4 ABOUT HERE

Columns (1) & (2) in Table 4 display the impact of water pricing prior and post CAP reform, where it is evident that water pricing is more effective under CAP reform in terms of water conservation. This observation implies that price induced water conservation is more successful when it relies on the extensive margin changes induced by decoupling. Such a claim is also obvious by looking at the values of arc (demand) elasticities prior and post CAP reform in Table 4. Under CAP reform, water demand is getting elastic at a lower water price in comparison with the pre-CAP reform. The latter is a clear indication that water pricing, in the post CAP reform case, is more capable to induce water saving adjustments.

In addition, the last column in Table 4 depicts the impact on water consumption for every water price induced by CAP reform. As it is also shown in Figure 2, low rates of water prices lead to an increase of water consumption while the situation is reversed as water prices exceed the threshold of 0.03 €/m^3.

The likely introduction of volumetric water pricing substantially reduces regional farm returns as Table 5 shows.

INSERT TABLE 5 ABOUT HERE

According to Table 5, the impact of water pricing on regional farm returns is inflated by decoupling since total gross margin is reduced more under CAP reform for every water price. In addition, the last column in Table 5 depicts the impact on regional farm returns for every water price induced by CAP reform. It is clear that CAP reform reduces total gross margin considerably, which on average accounts for a 55% decline in farm returns. It should be, however, stressed that although regional agricultural gross margin is lower under new CAP, this does not mean that decoupling is reducing agricultural income. Under the new CAP additional transfers, in the terms of the Single Farm Payment (SFP), have been introduced which compensate farmers for the income loss brought about by decoupling.

Finally, the elasticity of a value for money Index (E_{VMI}) is estimated for the examined range of water prices. Such an index can easily summarise the answer to a rather relevant question: “how much water money can save?”. The E_{VMI} is defined as:

$$E_{VMI} = \left(\Delta W / \Delta GM\right)\left(W_i + W_j / GM_i + GM_j\right) \qquad (8)$$

where ΔW denotes the change in water conservation (value) as a result of an increase in water prices from p_i to p_j, while ΔGM stands for the resulting change in gross margin (money) forgone in order to achieve the above water saving. Equally, W_i, W_j refer to water consumed at water prices p_i and p_j, while GM_i, GM_j stand for the resulting gross margins for the same water prices. The estimated values of the IVM is given in Figure 3.

INSERT FIGURE 3 ABOUT HERE

The interpretation of E_{VMI} is straightforward since it is essentially a variant of the elasticity concept. Put it simply, the E_{VMI} express how much water is conserved by a unit of farm return sacrificed. As, it is shown in Figure 3 the post CAP reform regime is clearly more efficient in terms of water conservation compared with the situation prior the CAP reform. The points deserve attention. First, the highest difference between pre and post CAP reform regimes, in terms of value for money water conservation, is observed at water price 0.06 €/m^3 while the lowest one is observed at water price 0.16 €/m^3. Second, the "efficiency" of water conservation in the post CAP reform regime, as captured by the values of E_{VMI}, displays considerable variation. The latter clearly deserves further attention and more detailed analysis since it has profound policy implications.

6. Conclusions

The paper examines the joint effects of the changes in two crucial policy areas related to agriculture, namely decoupling under new CAP and WFD. Based on the paper's results it can be argued that there are opportunities for combining the efforts of the two policies in order to enhance water conservation. The main findings of the paper are twofold. First, decoupling may lead to higher water consumption under low water prices since it induces the expansion of irrigated crops. Therefore the new CAP conflicts with the WFD.

Second, as water prices increase decoupling favours the non-irrigated crops, leading to substantial savings in water consumption. The latter is driven primary by the incentive pricing of the WFD, which fosters an increase in water efficiency expressed as gross margin per m^3 of water. It was found that combining water prices above 0.03 € /m^3 with decoupling has a positive effect on water conservation since the resulting crop mix brings about lower water demand and hence there is a synergy between the two policies. Arguably, this is the point that deserves attention since it may have important policy implications. The reason is that if this policy synergy is to be anticipated then the initially raised concerns about the likely negative financial impacts of WFD on agricultural income need to be revised.

Finally, the analysis reveals that the post CAP reform regime is clearly more "efficient" in terms of value for money water conservation.

A word of caution is finally needed. As argued by Schaible (1997), producer responsiveness to water pricing reforms is likely to be region specific. The reason is that region specific factors such as water availability, prevailing cropping patterns and the institutional setting (water management agreements), all influence water opportunity costs and hence affect producer behaviour. In other words, how transferable the results of this paper are is an empirical issue which needs to be confirmed.

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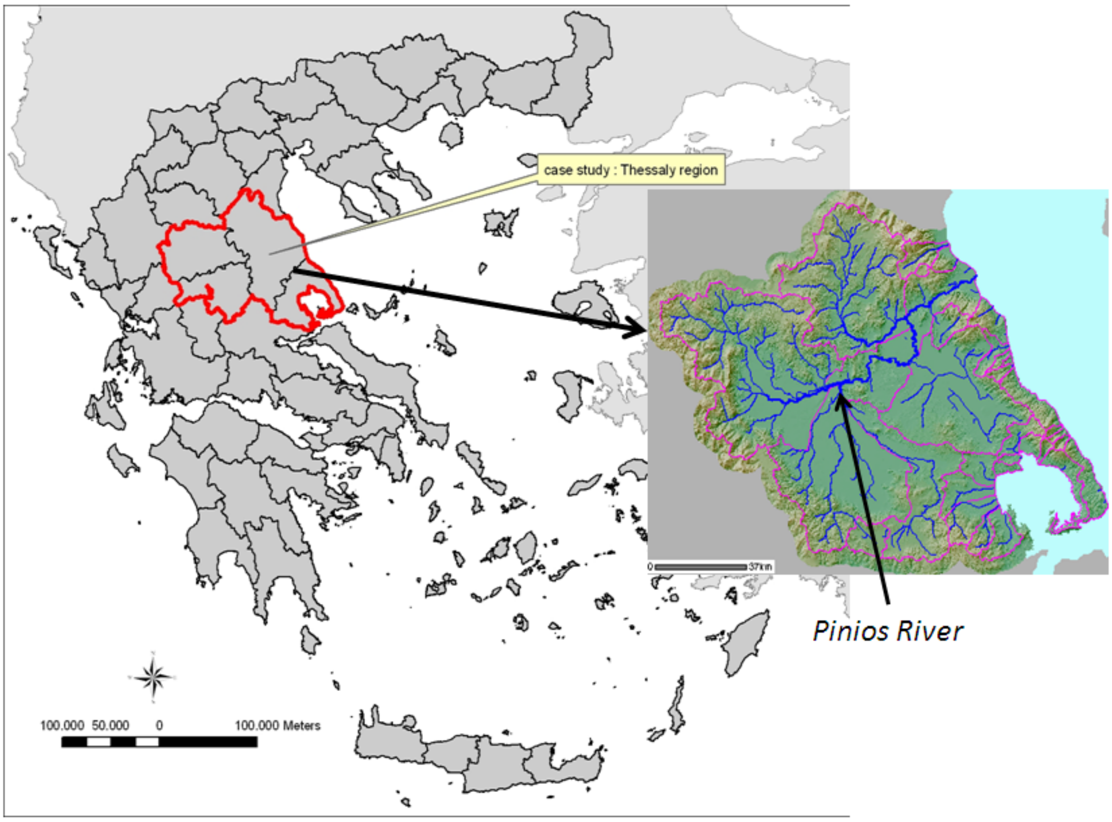

Map 1 Thessaly Water Region and Pinios River Basin

Table 1 Descriptive Statistics of representative farms.

	Number of farms	Area cultivated (ha)	Average yield (kg/ha)	Std. deviation / average yield	Gross Margin CAP2000 (€/ha)	Gross Margin CAP2003 (€/ha)
Cotton	317	2,640.7	3,652.5	17.2%	1,869.5	712.8
D. Wheat	184	1,036.7	3,452.3	29.2%	398.3	256.9
Maize	115	343.1	10,746.2	22.7%	1,210.9	659.5
S. Beet	94	310.2	62,999.2	24.9%	1,119.2	383.3
Alfalfa	62	145.2	11,186.3	38.7%	517.1	*
Tobacco	28	46.5	2,282	35.7%	9,961.4	253.9

* Endogenous

Table 2 The shares of irrigated & rain-fed land under different water prices scenarios prior and post CAP reform

Water Prices	Pre-reform CAP				Post-reform CAP				Change in Irrigated Land %
	Irrigated Land		Rain-fed Land		Irrigated Land		Rain-fed Land		
	ha (a)	%	ha (b)	%	ha (c)	%	ha (d)	%	[(c) – (a)] / (a)
0.00	3,188.8	71.12	1,295.0	28.88	3,309.4	73.66	1,183.4	26.34	3.78
0.02	2,987.8	67.18	1,459.5	32.82	3,216.6	72.01	1,250.1	27.99	7.66
0.04	2,757.2	61.84	1,701.4	38.16	2,932.5	65.79	1,525.1	34.21	6.36
0.06	2,619.6	58.95	1,824.5	41.05	2,623.6	58.16	1,887.4	41.84	0.15
0.08	2,481.9	56.04	1,947.2	43.96	2,459.5	54.95	2,016.4	45.05	-0.90
0.10	2,383.3	53.90	2,038.6	46.10	2,320.5	52.02	2,140.7	47.98	-2.64
0.12	2,293.0	51.94	2,121.4	48.06	2,168.3	48.66	2,287.7	51.34	-5.44
0.14	2,212.7	50.11	2,202.7	49.89	2,030.0	45.59	2,422.7	54.41	-8.26
0.16	2,120.8	48.04	2,293.6	51.96	1,818.3	40.90	2,627.0	59.10	-14.26
0.18	1,999.6	45.29	2,415.3	54.71	1,623.1	36.67	2,803.7	63.33	-18.83
0.20	1,886.2	42.75	2,525.9	57.25	1,518.4	34.37	2,899.9	65.63	-19.50

Fig. 1. Intensity of water used in cotton cultivation prior and post CAP reform

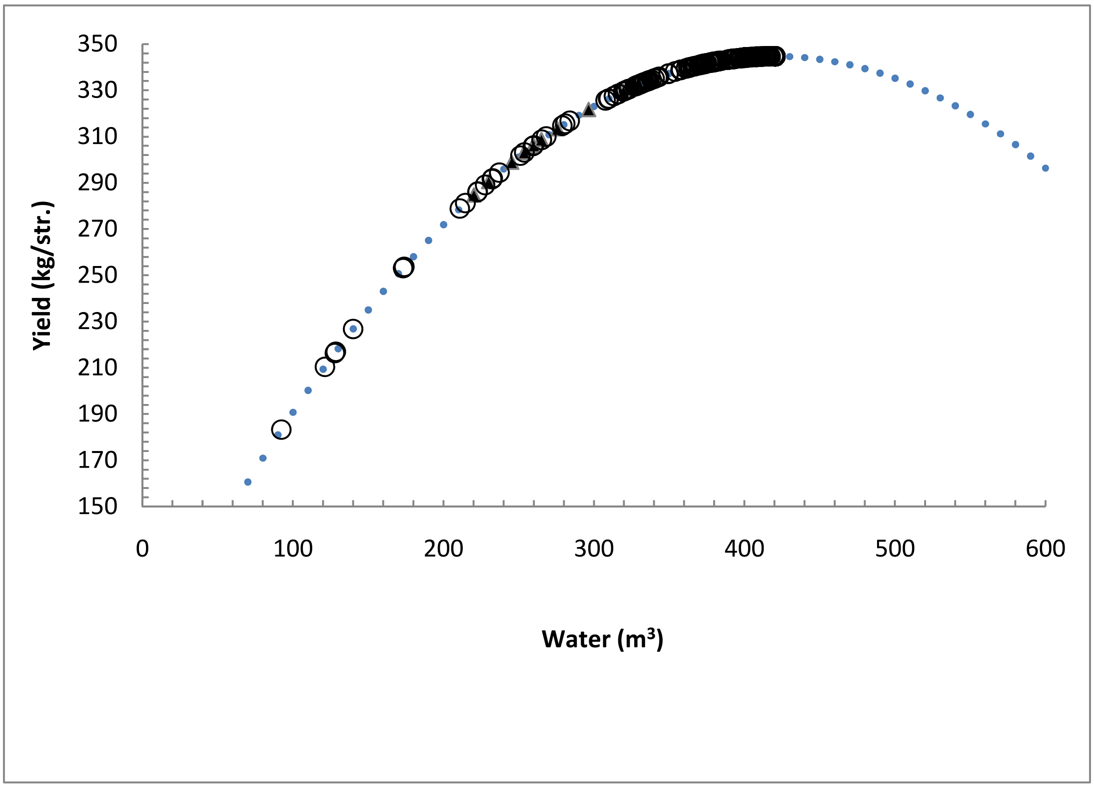

Table 3 The shares of drip irrigated land under different water prices scenarios prior and post CAP reform

Water Prices	Pre-reform CAP			Post-reform CAP		
	Maize	Cotton	Total	Maize	Cotton	Total
0.00	0%	7.17%	5.51%	13.81%	1.23%	1.20%
0.02	0%	6.22%	4.98%	5.55%	0.73%	0.80%
0.04	0%	5.16%	4.31%	2.84%	0.20%	0.84%
0.06	0%	5.05%	4.31%	11.17%	0.23%	0.90%
0.08	0%	4.96%	4.33%	11.62%	0.86%	0.96%
0.10	0%	4.48%	4.00%	11.36%	0.91%	1.28%
0.12	0%	4.41%	3.98%	11.90%	0.95%	2.13%
0.14	0%	3.98%	3.65%	13.21%	0.92%	2.51%
0.16	0%	3.53%	3.27%	0.00%	0.96%	2.70%
0.18	0%	3.57%	3.38%	0.00%	1.01%	3.03%
0.20	0%	3.20%	3.07%	0.00%	1.39%	3.23%

Fig. 2. Water demand prior and post CAP reform

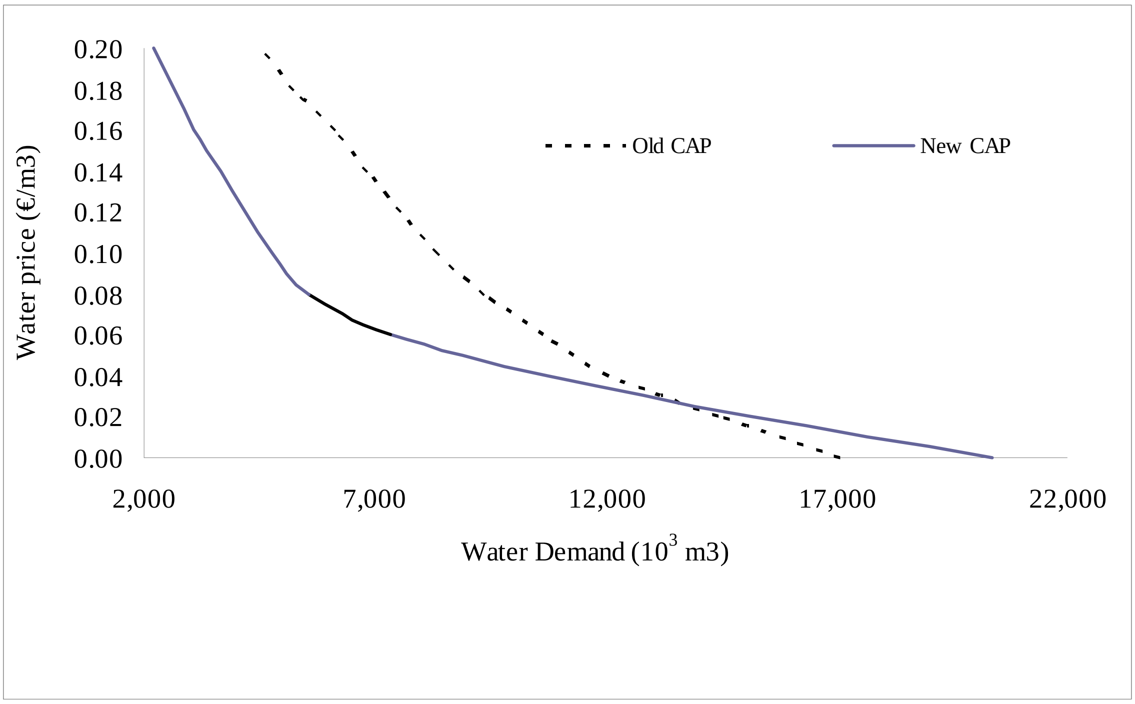

Table 4 Changes in Water Demand under different water prices scenarios prior and post CAP reform

	Pre-reform CAP			Post-reform CAP			Change
Water Price	m^3 (1)	%	arc elasticity	m^3 (2)	%	arc elasticity	[(2) – (1)] / (1)
0.00	17,094.8			20,356.8			19.08%
0.02	14,460.6	-15.41%	-0.167	15,089.4	-25.88%	-0.297	4.35%
0.04	12,102.0	-29.21%	-0.533	10,776.9	-47.06%	-1.000	-10.95%
0.06	10,666.6	-37.60%	-0.630	7,333.3	-63.98%	-1.901	-31.25%
0.08	9,397.4	-45.03%	-0.886	5,569.5	-72.64%	-1.914	-40.73%
0.10	8,377.8	-50.99%	-1.032	4,771.9	-76.56%	-1.388	-43.04%
0.12	7,581.2	-55.65%	-1.098	4,192.4	-79.41%	-1.422	-44.70%
0.14	6,849.9	-59.93%	-1.318	3,675.9	-81.94%	-1.707	-46.34%
0.16	6,161.4	-63.96%	-1.587	3,083.9	-84.85%	-2.627	-49.95%
0.18	5,264.6	-69.20%	-2.669	2,654.5	-86.96%	-2.544	-49.58%
0.20	4,552.1	-73.37%	-2.758	2,214.8	-89.12%	-3.431	-51.35%

Table 5 Changes in regional farm returns under different water prices scenarios prior and post CAP reform

Water Price	Pre-reform CAP		Post-reform CAP		Change
	(1)	%	(2)	%	[(2) – (1)] / (1)
0.00	5,553.0		2,817.9		-49.25%
0.02	4,916.2	-11.47%	2,306.5	-18.15%	-53.08%
0.04	4,393.9	-20.87%	1,946.9	-30.91%	-55.69%
0.06	3,967.1	-28.56%	1,706.5	-39.44%	-56.98%
0.08	3,612.4	-34.95%	1,541.1	-45.31%	-57.34%
0.10	3,317.1	-40.26%	1,416.5	-49.73%	-57.30%
0.12	3,064.6	-44.81%	1,310.9	-53.48%	-57.22%
0.14	2,845.0	-48.77%	1,222.5	-56.62%	-57.03%
0.16	2,655.2	-52.18%	1,146.8	-59.30%	-56.81%
0.18	2,493.8	-55.09%	1,080.4	-61.66%	-56.68%
0.20	2,357.5	-57.55%	1,025.8	-63.60%	-56.48%

Fig. 3. Elasticity of Value for Money Index for Water Conservation