Evaluating Economic Policy Instruments for Sustainable Water Management in Europe

WP 4.4 Output 2

Preliminary Analysis to mode water trading in the Pinios River Basin

Deliverable no.:

September 2013

Grant Agreement no. 265212

FP7 Environment (Including Climate Change)

Deliverable Title	
Filename	
Authors	Diego Bodini, Michele Vollaro, Davide Viaggi (UNIBO)
Date	01.09.2013

Prepared under contract from the European Commission
Grant Agreement no. 265213
FP7 Environment (including Climate Change)

Start of the project:	01/01/2011
Duration:	36 months
Project coordinator organisation:	FEEM

Deliverable title:
Deliverable no. :

Due date of deliverable:	September 2013
Actual submission date:	September 2013

Dissemination level

X	PU	Public
	PP	Restricted to other programme participants (including the Commission Services)
	RE	Restricted to a group specified by the consortium (including the Commission Services)
	CO	Confidential, only for members of the consortium (including the Commission Services)

Deliverable status version control

Version	Data	Author
1.0	September 2013	Diego Bodini, Michele Vollaro, Davide Viaggi (UNIBO)

Table of contents

1. **Introduction and objectives** 4
2. **Methodology and data** 4
3. **Results** 8
4. **Discussion and further work** 11
1. **References** 12

1. Introduction and objectives

In the context of EPIWATER project WP4 a case study concerns hydro-economic modelling applied to the region of Pinios (Greece). Attached to the hydrological modelling, the option will be tested to simulate water market in the area.

The objective of this note is to provide a first exploratory analysis of water market potential in the area, based on mathematical programming models simulating water trade among sub area of the whole region investigated.

The document is organized in three parts in addition to this one. In section 2 we illustrate the methodology; in section 3 the results and in section 4 we discuss further developments of the work.

2. Methodology and data

The water markets can be modeled using mathematical programming techniques. The basic idea is that the market among different agents can be simulated by representing the profitability of water for different agents and comparing a constrained situation (when water trade is not allowed) with a market situation, in which trade is allowed. Agents entering the market can be individual farms or different areas.

The profitability of water use may be represented directly through water use profitability functions or through land allocation models based on linear programming or positive mathematical programming. The latter is particularly well suited for territorial areas rather than individual farms, when information available do not allow a detail technical representation of constraints and decision mechanisms.

It is recognised by the literature that market models suffer from major simplifications compared with real world water markets. Usually in models water exchanges are overestimated, while profitability may be higher or lower than in real world, depending on the accurate knowledge of water profitability in each farm.

Some of the issues hindering water trade in real life are connected with acceptance of market, actual transaction costs, or longer term considerations. These issues can partly be incorporated in models, for example explicitly including transaction costs (Pujol et al., 2006).

Simple models such as those used here can be seen as sensitivity analysis of potential economic improvements due to trade.

The information basis for this study is not very detailed. For example economic information is not differentiated by area or farm. The farm structure internal to each area is not known in detail and there is no availability of management information that area usually used in farm-level bioeconomic models to represent agronomic or managerial constraints, nor to consider market or chain constraints.

For these reasons, in this paper we have used a rather simplified approach, using two main modeling strategies:

- The first is based on the use of water profit functions of water use in each study area;
- The second is based on a simple PMP modeling of the crops in each area.

In the first case, profitability functions for water have been built based on estimated water use by crops and related profitability per unit of water used in each crop. The estimation of the profitability of water is based on the differential per hectare between each irrigated crop and the cultivation of wheat, which is the reference rainfed crops. This profitability has been divided by the amount of water used by each crop (based on hydrological modeling of the area). Assuming that farmers, in case of water restrictions would give up irrigation in the crops in which it is less profitable, it is possible to identify a gradient of marginal value of water that has been then interpolated.

The derived functions are illustrated in Figure 1.

Figure 1 – Profitability functions of water use (Y in euro/m3, x in million m3 per sub-area)

Ir1	L_Ionas	y = -0,0092x2 + 0,0887x
Ir2	L_Voula	y = -0,0152x2 + 0,095x
Ir3	L_B.Koziakas	y = -0,0171x2 + 0,0948x
Ir4	L_Gavros	y = -0,0568x2 + 0,0915x
Ir5	L_D.Koiti	y = -0,0027x2 + 0,0886x
Ir6	L_Theopetra	y = -0,0235x2 + 0,094x
Ir7	L_K.Lithaios	y = -0,0007x2 + 0,1078x
Ir8	L_Kleinovitikos	y = -0,0095x2 + 0,0855x
Ir9	L_Lithaios	y = -0,0017x2 + 0,0838x
Ir10	L_MegaRema1	y = -0,0007x2 + 0,1151x
Ir11	L_MegaRema2	y = -0,0004x2 + 0,094x
Ir12	L_Malakassiotikos	y = -8E-05x2 + 0,0001x
Ir13	L_Mouzaki	y = -0,0511x2 + 0,0952x
Ir14	L_Neoxoritis2	y = -0,0148x2 + 0,0802x
Ir15	L_Neoxoritis3	y = -0,0021x2 + 0,0845x
Ir16	L_N.Koziakas	y = -0,0055x2 + 0,0851x
Ir17	L_Pamissos-MesdaniPiniou	y = -0,0009x2 + 0,1006x
Ir18	L_Pinios-AliEfenti	y = -0,0016x2 + 0,11x
Ir19	L_Portaikou-Piniou	y = -0,0008x2 + 0,0943x
Ir20	L_Pyli	y = -0,1524x2 + 0,1062x
Ir21	L_Sarakina	y = -0,2097x2 + 0,9513x

In the second modeling exercises, we have used Positive mathematical programming (PMP). PMP models arise from a long process, started by Heady (1964; 1978) and further explored by Howitt (1995) and Paris and Howitt (1998), with the aim of adding sufficient flexibility to non-linear optimization problem by reducing the limitation of the calibration constraints in the traditional linear programming models. Indeed, the term "positive" into PMP models implies that the models are built by including "observed behaviors" in the specification stage, so to avoid the relative calibration constraints (Heckelei et al., 2012). For such reason, PMP considers the observed situation as the optimum one, so the model will reproduce exactly the observed situation, through all the relationships that leads to the observed optimal condition.

The main objective of PMP models is to reproduce exactly the observed production process and then simulate the optimizing behavior of farmers according to the variation of the different parameters and constraints. Due to the fact that the models explain the producers response to external changes, policy makers consider PMP an interesting real analytical tool for the evaluation of different policies, through the construction of models able to provide economic, production and financial information at regional or sub-regional level. The PMP methodology can be identified by three different categories of PMP models:

- bio-economic farm models, which are able to handle joint production of agricultural outputs and environmental goods, by linking economic and biophysical models (Janssen et al, 2007);
- exogenous price models for aggregate agents, which account for farm type groups and regional models by the means of farm type information as input used to represent the agricultural system;
- price endogenous models for outputs, which apply the typical PMP approach with a spatial equilibrium setup following Takayama and Judge (1971) to incorporate price feedback directly in the model structure (Heckelei et al., 2012).

Further evolution of PMP is represented by Econometric Mathematical Programming Models (EMP) which combine econometrics and mathematical programming in order to improve the practice of multifunctionality. In particular, the main difference of this kind of models, compared to the MP approach, is related to data source and computational tools. EMP models, in fact, are based on statistical estimations of parameters from time series or cross-sectional data and commonly run according to underlying optimisation assumptions (Howitt, 2005). Econometric studies, therefore, look at focusing more on *ex-post* analysis, due to the fact that, on the one hand, a great part of the work of the modeler is concerned with parameter estimations and, on the other hand, such studies are actually used to understand determinants of past behavior.

The PMP exercise has been carried out using the simplest approach based on the derivation of quadratic costs coefficients through a first phase calibration approach. The resulting quadratic function is then used for simulation.

This model has been used to simulate trade among areas given the present set of crop and with an alternative set based on the following assumptions:

New Crops Scenario		Area (in m^2)
Broccoli	5% of maize cultivation to be replaced by broccoli	6.042.331,75
Aloe Vera	15% of cotton cultivation to be replaced by aloe vera	42.559.126,72
Kiwi	10% maize cultivation to be replaced by kiwi	1.208.466,35

3. Results

Figure 2 shows the main results obtained with model based on water profit function.

Figure 2 – Change in profitability due to water trade among zones

	Market	No Market
Total Profit (mio Euro)	26,438	25,881
Water Use (mio m3)	450,323	434,696
Marginal Value (euro/m3)	0,013	

Water markets increase profitability by a relatively small amount (less than 1 milion euro). This result is largely in line with existing studies, but can also have been be squeezed by the adoption of simplified smooth functions, that tend to reduce the difference of profitability among areas.

Figure 3 shows the detail of water use across the different areas. Cases with increased water use in the markets conditions are buyers, while cases with decreased water use are sellers.

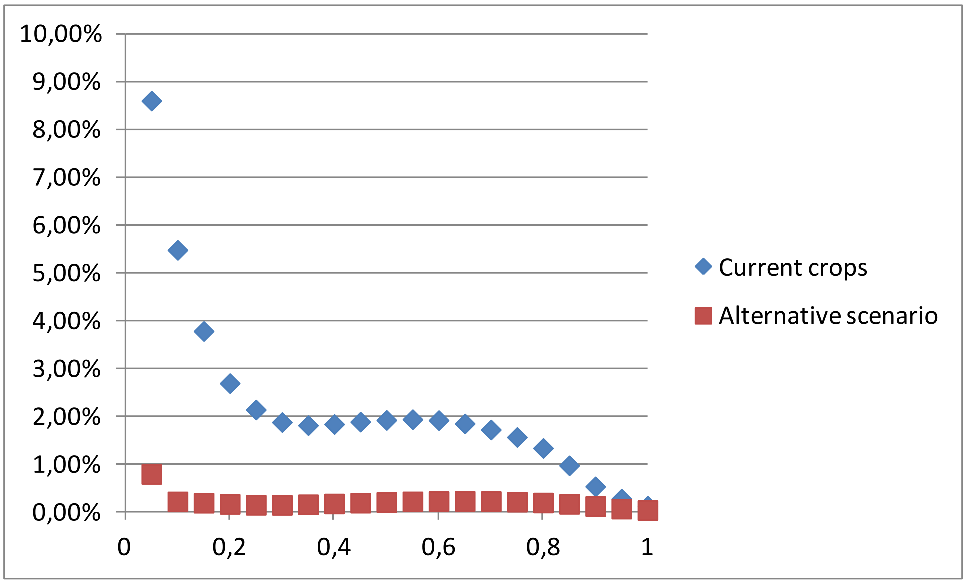
Figure 3 – Change in profitability due to water trade among zones per zone (excluding water price paid)

Area	Market		No Market		
	Profit (mio Euro)	Water Use (mio m3)	Profit (mio Euro)	Water Use (mio m3)	Marginal Value (euro/m3)
Ir1_L_Ionas,	0,209	4,106	0,214	4,821	
Ir2_L_Voula,	0,146	2,692	0,134	2,16	0,029
Ir3_L_BKoziakas,	0,129	2,387	0,131	2,772	
Ir4_L_Gavros,	0,036	0,69	0,035	0,61	0,022
Ir5_L_DKoiti,	0,711	13,971	0,711	13,96	0,013
Ir6_L_Theopetra,	0,092	1,72	0,094	2	
Ir7_L_KLithaios,	4,088	67,603	3,923	58,99	0,025
Ir8_L_Kleinovitikos,	0,188	3,808	0,192	4,5	
Ir9_L_Lithaios,	1,007	20,778	0,877	15,08	0,033
Ir10_L_MegaRema1,	4,67	72,817	4,712	76,93	0,007
Ir11_L_MegaRema2,	5,414	101,055	5,245	91,16	
Ir12_L_Malakassiotikos,	.	.	1,86E-05	0,23	0,000062055
Ir13_L_Mouzaki,	0,043	0,803	0,044	0,932	
Ir14_L_Neoxoritis2,	0,106	2,265	0,093	1,69	0,03
Ir15_L_Neoxoritis3,	0,829	16,987	0,643	10,18	0,042
Ir16_L_NKoziakas,	0,321	6,54	0,329	7,736	
Ir17_L_Pamissos-MesdaniPiniou,	2,763	48,58	2,811	55,889	
Ir18_L_Pinios-AliEfenti,	1,864	30,264	1,836	28,53	0,019
Ir19_L_Portaikou-Piniou,	2,725	50,715	2,759	53,91	0,008
Ir20_L_Pyli,	0,018	0,305	0,019	0,348	
Ir21_L_Sarakina	1,079	2,237	1,079	2,268	

The main results of the PMP simulation are illustrated in

Figure 4.

Figure 4 – Percent increase in profitability due to water market (% of total agricultural gross margin)



The x-axis shows different scenarios of water availability as a share of the current total water availability in the area, assuming that, in the case of water limitation, limitation would be proportionally the same in all sub-areas. The y-axis shows the percent variation of gross margin due to water trade as compared to non-market situation.

The percent increase changes dramatically depending on water availability. Consistently with expectations the gain from trading is very low if water availability is the same as at present, while it increase for higher shortages. In cases of dramatic shortages benefits can be as high as almost 10%.

Interesting enough the trend is not linear, as it depends on the interplay of crop substitution. Also, only for rather low values of water availability the percent increase of gross margin goes above 2%.

The figure also simulates the increase in gross margin with market in case of alternative crops options are introduced, i.e. kiwi, Aloe vera and broccoli. The results are rather different. Basically, the assumption of widespread introduction of these crops squeezes the difference across areas, particularly for very low water availability. This happens both in absolute terms (though this is not very dramatic) and in relative terms. The latter result is particularly low due to the fact that income in both market and non-market increase substantially. This effect in the direction of reducing market benefits, is due to the fact that the alternative crops have lower water requirements and much higher gross margin per hectare compared with alternative crops.

4. Discussion and further work

The above exercise illustrates an attempt of modeling water trade with limited information and using alternative method. Given the degree of detail of the information basis it is not surprising that the results are rather different among methods. In addition, both of them can be hardly compared with reality and rather offer an idea about the direction and size of change. In this respect, the main result is that water trade does not change substantially the profitability of water use in the area. The main implication is that this would likely not be a priority, unless it shows synergies with other policy components (e.g. metering) or unless the ratio between energy costs, water costs and agricultural prices would drive profitability in a different direction.

The most straightforward developments of the work go in the direction of a fine tuning of the models, particularly with a higher differentiation gross margin calculation per farms type, crop and area. More soil type and management- related information would also allow a more detail simulation, likely increasing the value of economic benefits due to the market.

The work would be further complement through interviews collecting actual elements of farm decision-making and attitudes/preferences towards water trade. This could also be formalized in terms of willingness to pay/accept and feed the model consequently.

Finally, the simulation model could be expanded to investigate the interaction between water markets and other instruments such as water fees, energy pricing and water measurement.

1. References

Pujol J., Raggi M. and Viaggi D. (2006): The potential impact of markets for irrigation water in Italy and Spain: a comparison of two study areas, Australian Journal of Agricultural and Resource Economics, 50, pp. 361-380.

Heady, E.O. and Egbert, A.C (1964). "Regional Programming of efficient Agricultural Production Patterns". In Econometrica, pp.374:386, vol.32, n.3.

Heady, E.O. , Meister, A.D. and Chen, C.C. (1978). Quadratic Programming Models Applied to Agricultural Policies. Iowa State University Press. Ames.

Heckelei, T., Britz, W. and Zhang, Y. (2012). Positive Mathematical Programming Approaches – Recent Developments in Literature and Applied Modelling Bio-based and Applied Economics 1(1): 109-124, 2012

Howitt R.E. (2005): Agricultural and environmental policy models: calibration, estimation and optimisation, MIMEO.

Janssen, S. and van Ittersum, M.K. (2007). Assessing farm innovations and responses to policies: A review of bio-economic farm models. Agricultural Systems, 94 (3): 622-636.

Takayama, T. and Judge, G.G. (1971). Spatial and Temporal Price and Allocation Models. Journal of International Economics 3(3): 304-304.