Economic analysis of Water Harvesting Reservoirs with Internal Water Reallocation: a Case Study in Emilia Romagna, Italy

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Abstract: The existence of formal water markets in the European context is limited to the Spanish case, despite its rationale is deeply rooted in the economic literature. In Italy they are widely criticized and they are not supported by the national legislation. However, due to some specificity, a form of water reallocation exists in a number of rainwater harvesting reservoirs in the North of Italy. The aims of the analysis are the description of such an institutional arrangement and the economic assessment of the reallocation mechanism, with a focus on the distribution of its gains among suppliers and buyers of water. The results suggest that the reallocation increases the gross margins of the area, and that the distributions of the gains are in favour of water buyers. The presence of winners and losers of water reallocation mechanisms should be considered when institutional changes are envisioned. Despite its inefficiencies, the institutional arrangement present in the area adds flexibility to a system that is likely to face major changes and challenges in the next decades.
Keywords: water harvesting reservoir; water management; water market; water trading

JEL: Q15; Q25

Introduction

Water markets (WMs) are proposed by the economic literature as an allocation mechanism for the agricultural sector to cope with scarce water conditions, like e.g. in Mediterranean countries (Easter et al., 1999). When water is a scarce resource, WMs ensure that the resource follows the most profitable use, thus leading to an efficient allocation (Schoengold and Zilberman, 2007). In the context of climate change (CC), WMs are likely to become more and more relevant. For instance, Frederick (1997) and Tietenberg (2003) highlight the added value that WMs have in potentially suppporting the agricultural sector to cope with CC, given their inherent flexibility. More than for other resources, water needs an adaptive management that takes into account both the changes in the supply side, and the capacity of the demand to respond to these changes (Tietenberg, 2003). CC sets a rapidly changing environment that potentially affects both the structure of the supply and of the demand of the water resource. On the supply side, CC affects water cycles, by (1) reducing the average water availability, (2) increasing the seasonal and annual rainfall variability. On the demand side, CC triggers modification in the plant responses to such changes, increases the demand of water in case average temperatures rise, affects the overall irrigation plans, and due to the increased uncertainty affects the utility of risk averse farmers. Administrative water allocation, for their inertia, is likely to fail to adapt to such changes, whereas WMs give the possibility to the resources to follow the time-by-time most profitable use.

Although WM rationale is deeply rooted in the economic theory, WMs are rarely institutionalized given the peculiar character of the resource at stake. In Europe the most famous example are the Spanish WMs, that has been established in 1999, and that have been widely investigated from an economic point of view (e.g. Calatrava and Garrido, 2005). However, WMs are -slowly- entering the European political agenda. The EU Commissions suggests WMs as a policy potentially locally helpful and vaguely call for a formulation of implementation guidelines (COM/2012/0673 final).

In Italy, the national legislation does not support the exchange of water among private users, on the basis that water is publicly owned. WMs/water trading are widely oppose with ideological arguments mixed with worries concerning equity issues. In 2011 a national referendum on the introduction of private capitals in the ownership of the urban water facilities involved a great societal commitment and emotions that further worsen the possibility of having scientific and neutral discussions on water management, especially with regards to the possibility of water trading mechanisms.

However, a form of water reallocation is in place in the hilly district of the Consorzio Romagna Occidentale, a local irrigation board in Emilia-Romagna. More specifically, the area is characterized by the widespread presence of water harvesting reservoirs where water reallocation among farmers is allowed. Given the artificiality of the resource, and the partially private nature of the investments, the individual share of the investment in the reservoir construction is linked to the individual water rights (quotas) that are annually managed internally and are allowed to be transferred.

Moreover, few studies exist on the potential impact of WMs in Italy, for instance Pujol et al. (2006) investigated the effects of the institutionalization of WM, with a specific focus on the implications of different typologies of transaction costs. No scientific literature addresses the issue of the distribution of the gains related to the potential establishment of WMs in Italy. There is no existing literature that analyses the institutional design present in the area here investigated.

Against this background, the objectives of the paper are: 1) The descriptive analysis of the institutional design of the water reallocation within the Consorzio Romagna Occidentale; 2) The economic assessment of the water reallocation mechanism, with a focus on the distribution of its gains.

The descriptive analysis is based on non-structured interviews with relevant stakeholders in the area under analysis, mostly officials of the Consorzio Romagna Occidentale and farmers working in the area. The economics assessment is performed by mean of a mathematical programming model, formulated in GAMS. We analyze the performance of the institutional set-up under the rainfall events simulated for the next fifty years, according to a downscale in the area under analysis of the global climatic scenarios.

. In addition, while in general the institutionalization of WM increases the welfare considering the group of traders as a whole and the price mechanism should allow to have all of the participants better off, relative losers and winners might emerge (Brill et al., 1997). As this may be a key issue in understanding incentive to water trade establishment, we analyze specifically winners and losers from the case study water trade.

Case Study Area

Rural - Hydrological Development

The case study area is a 120,000 hectares hilly district in the province of Ravenna (Italy), where the Consorzio Emilia-Romagna Occidentale, a local Water User Association, manages the hydrology and the irrigation infrastructures. Horticulture characterizes the agricultural sector, whose main cultivations are highly water demanding (e.g. kiwi, apricot) or sensible to water shocks (grape, and marginally olive). Hence the agriculture in the area is strongly dependent on a reliable water supply. Since the end of the 70s, 16 rainwater-harvesting reservoirs have been built and 5 are planned. Farms are connected to the basins by pressurized water pipes. The number of farms connected for each basin is highly variable, ranging from few units for the oldest to some tens farms for the newest ones.

Recently the development of the reservoirs has been financially supported by the Regional Rural Development plan by the Axes 1, measure 125, "Infrastructure related to the development of agriculture and forestry" up to 70% of the cost. Such a measure is explicitly linked to the (EC) 74/2009. The Rural Development Plan constraints the financial support to project that involve a minimum of 10 farmers that are compelled to create a "Voluntary Irrigation Board" (VIB), a formal institutional actor that will be the legal agent in the whole bureaucratic process, and the reference institution for the subsequent reservoir management.

Yearly water allocation management

Within each reservoir, both the initial water quota allocation, and the seasonal management are partially based on a market mechanism.

For each farm, the initial water endowment is determined by the individual investment choices. Farmers decide the investment level for the construction of the reservoir by purchasing investment quotas, which are explicitly translated into water quotas, namely, the amount of water that each farm is entitled. The maximum amount of quotas is however constrained by 1) the crop plan linked to the quotas and for which water needs are computed basing on technical average coefficients 2) the presence of individual rainwater harvesting infrastructures. Normally, at the full reservoir capacity, each quota gives the right to use 1000 m^3, in particularly dry years, that amount might be reduced proportionally to the total availability. In wet years, the nominal value of the quotas is practically not binding, but water consumptions higher then the water officially entitled is purchased at greater price.

A form of seasonal water right transfer gives flexibility to the seasonal allocation mechanism. The exchange of quotas is based on an indirect transaction arrangement, with the VIB functioning as a sort of water bank, collecting the renounces of water quota use, and the demands for higher consumption. Farmers who renounce to use the entitled quotas face only the fixed costs related to the quotas that have been maintained. The seasonal acquisition of additional water quotas can be achieved at higher costs for the amount that exceeds the regular assignment.

If such a reallocation system is not officially a "water market", it certainly represents a deviation from the normal, centrally planned, management, toward a more flexible, market-based approach. The institutional set-up that manages the yearly reallocation has no clear counterpart in the water economics literature. We might interpret the VIB management as a sort of "passive water market" put into practice. Brill et al. (1997) call "passive water market" a central organization that manages the water trades by fixing a price in such a way to clear the market. In practice, the assessment of the equilibrium price might be a challenging task. In our case study the price is differentiated among buyers and suppliers and it is based on the fixed cost that the VIB faces.

Economic analysis of the yearly reallocation mechanism

Model simulation and description of scenarios

The general structure of the empirical model follows. We carry out a sensitivity analysis on the total amount of water that is available at the reservoir level, which might change due to the climatic conditions. Recall that each quota nominally corresponds to 1000 m3 of water, while in case of reduced water availability it determines the proportion of water that each farmer is entitled.

We introduce three scenarios in order to assess the gains and their distributions in different typologies of reallocation mechanisms:

1. "No Trade" scenario (NT, hereinafter), where farms are not allowed to trade the quotas.
2. The scenario "Voluntary Irrigation Board" (VIB, hereinafter) represents the actual institutional arrangement, in which farms are allowed to internally reallocate the quotas at the fixed price set by the VIB.
3. "Free Trade" scenario (FT, hereinafter), where the quota price is determined endogenously.

The following part applies in all the three scenarios. The model maximizes the sum of the gross margins for the area:

$$\max GM = \sum_{k=1}^{n} \left(gm_k x_k - c_k \right) \tag{1}$$

where gm_k is the gross margin for each farm k, x_k is the land available for each farm, and c_k are the individual costs. The maximization problem is subject to a number of institutional and technical constraints. The gross margins per hectare depends on the share of irrigated land, according to a quadratic gross margin function (Viaggi et al., 2010):

$$gm_k = \alpha_k \left(\frac{w_k}{x_k}\right)^2 + \beta_k \left(\frac{w_k}{x_k}\right) + \delta_k \quad (2)$$

where α_k, β_k and δ_k are the relevant farm coefficients, and w_k is the amount of water (=irrigated land) for each farm.

In the NT scenario, the amount of water is constrained by the number of quota (q_k), and by the total water availability of the reservoir.

$$w_k \leq \omega_z q_k \quad (3)$$

with $0 \leq \omega \leq 1$ where ω_z represents a coefficient that adjusts the individual quota to the actual seasonal storage of the rainwater harvesting reservoirs on which we perform the sensitivity analysis previously described. The cost is subdivided in quota related costs (f - related to the management of the rainwater harvesting reservoirs) and variable costs dependent on the amount of water that is actually utilized (v).

$$c_k = fq_k + vw_k \quad (4)$$

The “VIB” scenario describes the actual situation, where the reallocation is partially controlled by fixing the water quota price on a share of the quota related costs. We follow a 2-step procedure to find the quota allocation equilibrium, since the quota price is not allowed to change to clear the market,. In the first step we compute separately the amount of quota that each farm would sell/buy at the fixed prices $\bar{p}$. For each farm, the amount of water that is used is determined by:

$$w_k \leq \omega_z q_k - s_k \quad (5a)$$

$$w_k \leq \omega_z q_k + b_k \quad (5b)$$

where s_k and b_k are respectively the number of quota sold and bought by farm k. Hence we assess if the supply or the demand side is binding.

The costs are given by

$$c_k = q_k f + vw_k - \bar{p}^s s_k + \bar{p}^b b_k \quad (6)$$

In the second step we recomputed the gross margins changing equation (5) into:

$$w_k \leq \omega_z q_k - s_k + b_k \quad (7)$$

and constraining the amount exchanged to the supply/demand bound fixed by the first step.

The “FT” scenario is differentiated by the “VIB” scenario by simply allowing the water quota price to be freely chosen endogenously by the market. So the amount of quotas utilized by each farm is given by:

$$w_k \leq q_k - s_k + b_k \quad (8)$$

and the costs are determined by:

$$c_k = q_k f + v w_k - p^* s_k + p^* b_k \quad (9)$$

where p^* is the equilibrium price.

Data description

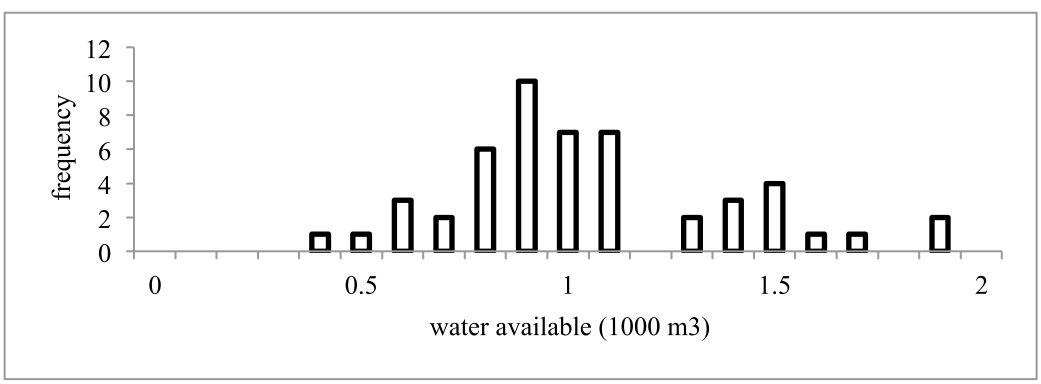
We applied the model to one of the rainwater harvesting reservoir present in the area that we choose for the availability of data regarding the number of farms connected, the initial individual quota endowment, and the quota reallocation for the year 2011.

The reservoir, "Paglia-Brisighella", is located in the hilly area of the Ravenna province. 60 farms are connected to the reservoir, for a total of 510 quotas (510,000 m^3). In 2011, there were transfers of $\approx$ 40 quotas (8% of the total water available) that involved 34 agents.

The data used for the simulation combine secondary data that are adjusted to fit the conditions of the case study, and to simulate the heterogeneity necessary to observe the affect of the water reallocation mechanisms. We used the water profit function estimated in Viaggi et al. (2010) for a similar areas (mostly characterized by fruit tree production) as a starting point to estimate the gross margin coefficients that we employ in the model simulation. Data regarding farmland size was not available; we then estimated it according to farm characteristics of the case study area.

We test the different institutional arrangements with climatic data generated by a weather generator employed to downscale the IPCC climatic scenarios in the area under analysis. The generated rainfall data for the next 50 years are aggregated for the summer months. We assume the average value represents the full capacity of the reservoirs ($\omega_z = 1$), and the other data are scaled in terms of share of the average value. The climate data were provided by the Agenzia Regionale per la Protezione Ambientale - Emilia-Romagna (ARPA).

Graph 1 Distribution of the simulated water availability for the next 50 years (mean = 1; median = 0.9; standard deviation = 0.3).

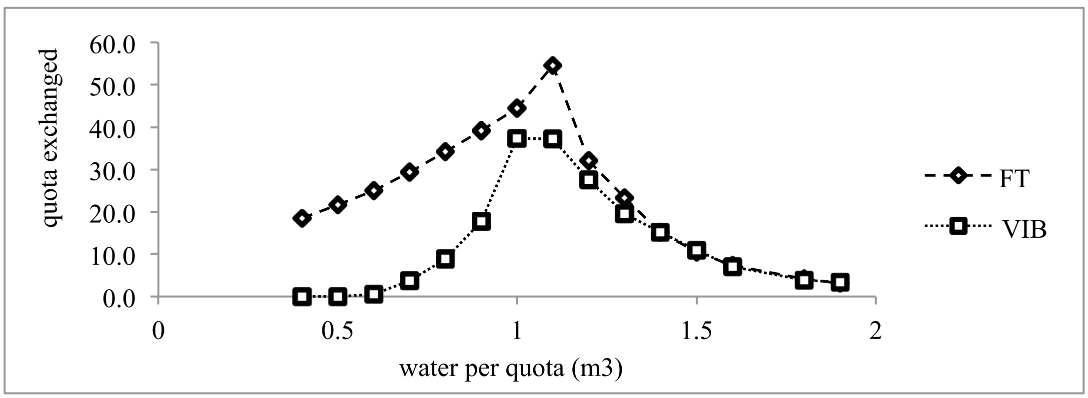


Results and discussion

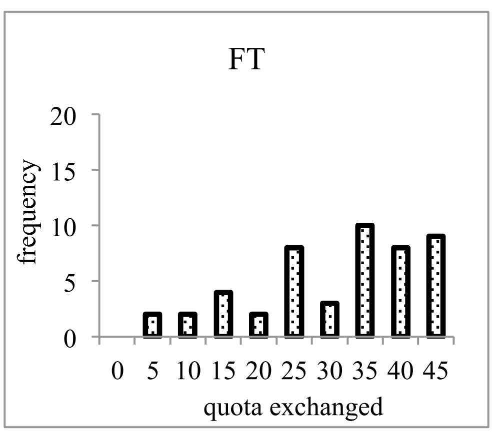
Results Water Trade Flows

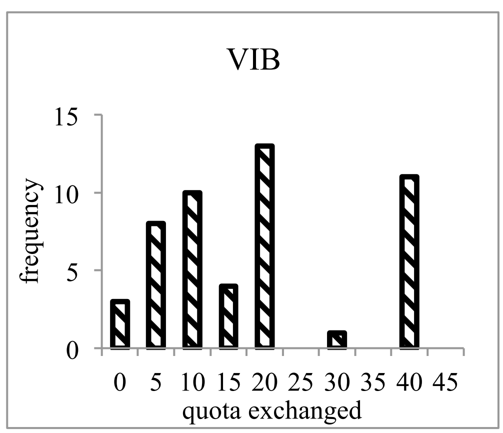
As we observe in the Graph 2 and Graph 3, the amount of water exchanged is always higher in the FT than in the VIB scenario for values ranging until 1000 m^3 per quota, and then the differences between the scenarios are irrelevant. In case of a reduction in the total amount of water of 50% and below, the VIB scenario does not create incentives for reallocation, water flows are depressed to 0, while, as shown in the free trade scenario, there would be still scope for an efficient reallocation of the quotas.

Graph 2 Quota exchanged per water availability in the two reallocation scenarios



Graph 3 Distribution of the quota exchanged in the two reallocation scenarios (FT: mean 30.9, median 34.2, standard deviation 13.0; VIB: mean 16.4, median 13.1, standard deviation 12.9





Results Gross Margins

As expected, both reallocation scenarios are beneficial for the area, and the added value of both mechanisms increases with the total amount of water, for then decreasing after greater values of water availability (Graph 4). The FT scenario leads to the highest payoff for any level of water availability. The greatest difference between the FT scenario and the VIB scenario lies before the average water availability (1000 m^3 per quota) and then decreases.

Graph 4 Differences in the gross margin of the area (euro/ha) between the reallocation scenarios and the NT scenario per water availability

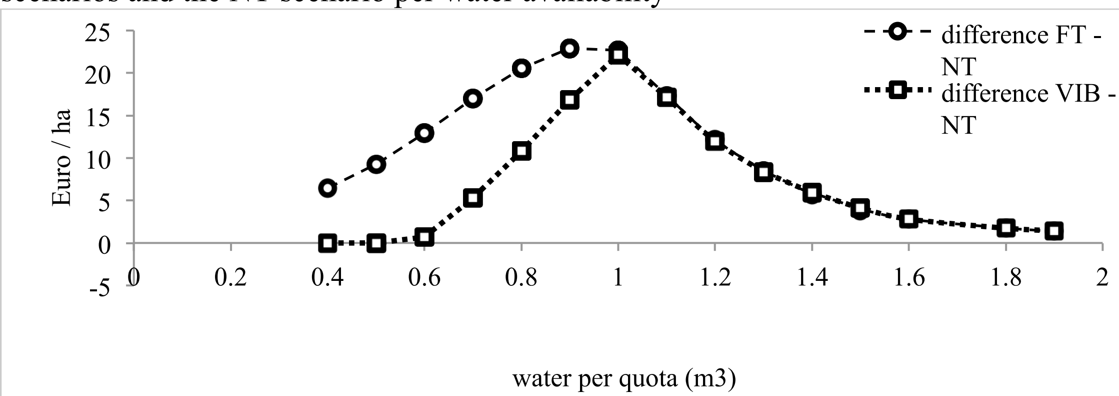


Table 1 Statistical description of the distribution of the aggregated gross margins in the area (euro/ha) in the three scenarios

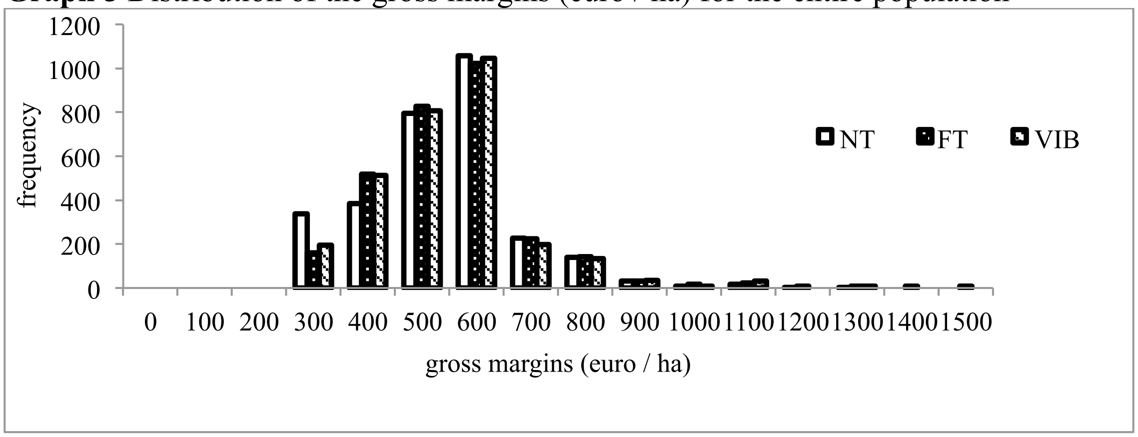
	NT	FT	VIB
mean	539.0	554.8	550.1
Median	550.8	573.7	567.6
Standard Deviation	56.1	56.6	59.8

The distribution of the disaggregated gross margins (euro / ha) for the whole population follow the same patter, the FT leads to the highest gross margin levels (Table 2, Graph 5).

Table 2 Statistical description of the distribution of the disaggregated gross margins per farm (euro/ha) in the three scenarios.

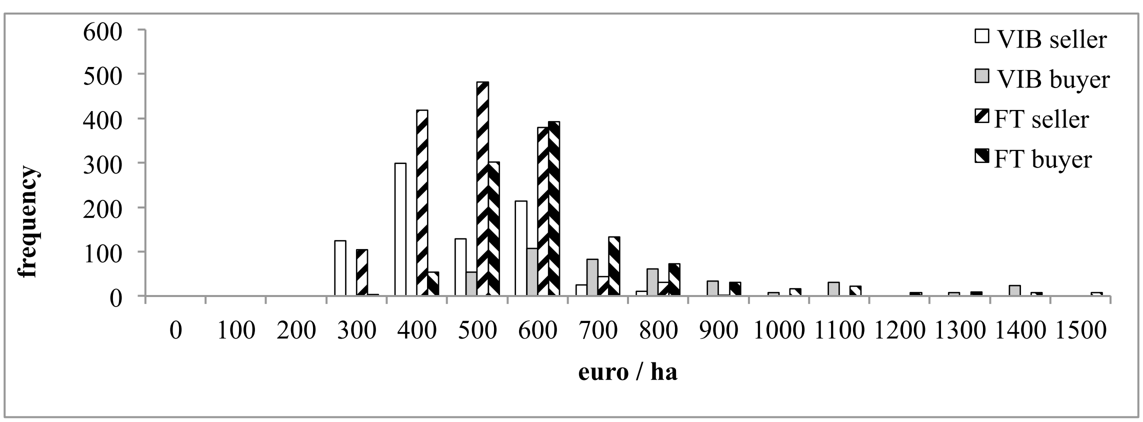
	NT	FT	VIB
Mean	484.6	502.6	496.7
Median	496.9	498.0	499.3
Standard Deviation	135.6	154.9	163.5

Graph 5 Distribution of the gross margins (euro / ha) for the entire population



By differentiating the gross margins for the quota buyers and the quota sellers in the two scenarios, we can observe how the distance between the average productivity of buyers and sellers sharply decrease if we pass from the VIB scenario to the FT scenario (Graph 6 and Table 3).

Graph 6 Distribution of the gross margins disaggregated per farm for the entire population (euro / ha), differentiated per sellers and buyers.



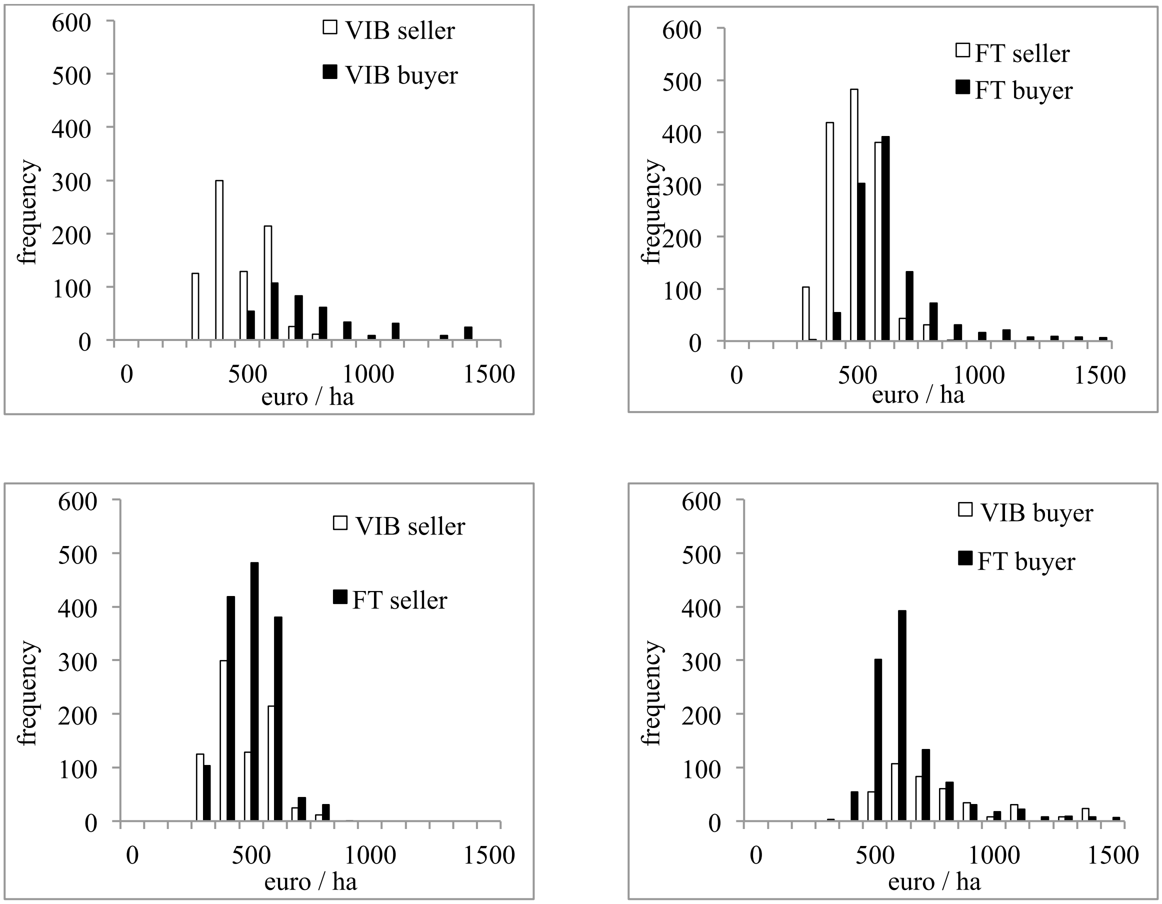


Table 3 Statistical description of the distribution of the gross margins (euro/ha) differentiated per buyers and sellers in the three scenarios.

	FT buyers	FT seller	VIB buyers	VIB sellers
Mean	583.8	442.3	729.2	402.1
Median	528.6	447.4	674.6	380.5
Standard deviation	187.1	99.1	235.9	115.5

Winners and Losers

To understand how the two reallocation scenarios affect the distribution of winners and losers of the same mechanisms we assess 1) how the benefits generated by the allocation mechanisms are shared between suppliers and buyers of the quotas; 2) what is the difference in the return to the quota exchanged between suppliers and sellers of the quota.

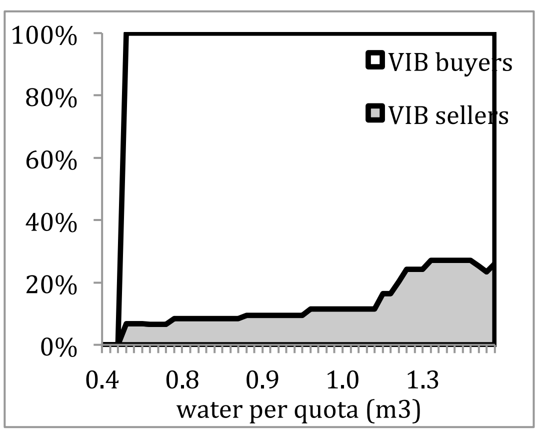
In Table 4 we can observe how the two reallocation mechanisms affect differently the gains they generate. While the average increase in the gross margins is mildly different among buyers and sellers in the FT scenario, in the VIB scenario there is large difference in the average percentage increase in the gross margins.

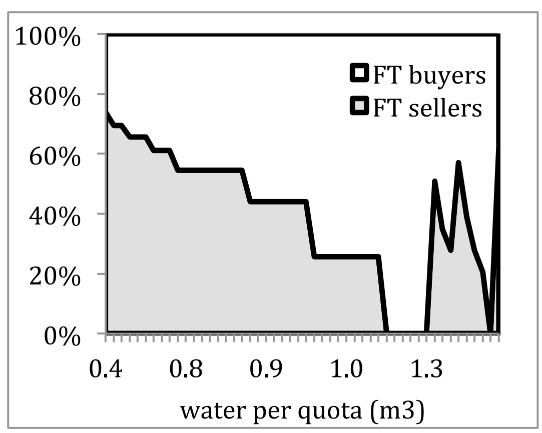
Table 4. Statistical description of the added value of the reallocation mechanisms (% increase in the gross margins with respect to the NT scenario).

	FT buyers	FT Sellers	VIB buyers	VIB sellers
Mean	4%	5%	10%	2%
Median	1%	1%	4%	1%

This is also confirmed by graph 7, that depicts the distribution of the gains between buyers and sellers in the two reallocation scenarios, per water availability.

Graph 7 Distribution of the benefits generated by the reallocation mechanisms, per water availability. For values of water availability below 0.5, the VIB is not activated, so the benefits are 0.





Finally we can observe again the same pattern by analyzing the return on the quota transferred, that clearly shows how in the VIB scenario there is a much higher difference between the buyers and sellers return on the quota with respect to the FT scenario.

Table 5. Return to quota exchanged (euro).

	FT buyers	FT Sellers	VIB buyers	VIB sellers
Mean	19.3	16.5	61.8	8.9
Median	8.6	7.2	36.6	8.1

Discussion

The results show that the reallocation mechanism that is in place certainly improves the overall welfare of the group of farmers connected to the reservoir, with respect to the NT scenario. However, the FT would further improve the welfare, by allowing prices to clear demand and supply of the water quota. Both the FT volumes, and the FT increase in the overall welfare of the area are very similar to the results obtained by Pujol et al (2007) in their analysis on the potential effect of the introduction of WMs in the south of Italy. The relatively low increases in the gross margins caused by the reallocation mechanisms are probably due to the specification in the model of a medium time horizon. Such a temporal dimension do not consider the risks of crop failure and the related investment loss that might occur in case of water shortages, thus certainly underestimating the real benefits of flexible water allocation mechanisms.

The analysis of the distribution of the reallocation shows that the different institutions are not neutral in sharing the benefits they create. The actual management, the VIB scenario, improves relatively more the welfare of the water buyers than that of the sellers, with respect to the NT scenario. In contrast, in the FT much of the gains are shared among suppliers. These results are not easily comparable with those by Brill et al (1997) that compares a seniority rules with the passive market, and that shows that water buyers might lose, and water sellers certainly win, by passing from a seniority rule to the passive market. Two are the main differences between our case and Brill at al.'s one: the initial allocation is based on a market mechanism, and the price is differentiated for buyers and suppliers. However, in both studies the allocation mechanism affects the distribution of the gains, an element that must be considered in case an institutional change is envisioned.

The availability of data severely constrained the analysis. For instance, we could not substantially assess the identity of the water quota sellers and buyers, another element that is likely to affect any potential institutional change. The limits on the data did not prevent from finding results consistent with more detailed studies, and to find a clear pattern in the distribution of the gains.

Conclusions

In this paper we described the institutional design that govern the reallocation of water quota within a number of rainwater harvesting reservoirs in Emilia-Romagna. Moreover we provided an economic assessment of the reallocation mechanism that is in place, which we compared with a situation where no reallocation is allowed, and with a free trade arrangement. While all reallocation mechanism increase the welfare of the area, different relative losers and winners might emerge from different reallocation managements. These elements must be considered in case institutional changes are envisioned, in order to provide sufficient incentives to all participants.

The reallocation mechanism that is in place within the rainwater harvesting reservoir represents somehow a movement toward a market-based approach for the water allocation in a context highly dominated by central management. This possibility is due to the fact the internal reallocation within what is basically a private institution allows to overcame the legal barriers to trade. On the other hand, this example also shows that institutionally established “pricing” systems may help in preventing opposition to free trade of water (though at a cost in terms of efficiency)

To conclude, in spite of the legitimate skepticism of public opinion against water markets in the context of water management, it remains crucial to assess the potential of these mechanisms. This is due in particular to their ability to add flexibility to the system, a characteristic that is likely to become more and more important in the context of climate change. This paper however also corroborates the need of carrying out such evaluation in the context of precise institutional settings.

Acknowledgments

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