“Designing Water Markets to Manage Coupled Externalities: a Preliminary Analysis”

Sophie LEGRAS
Robert LIFRAN

DR n°2006-11
DESIGNING WATER MARKETS TO MANAGE COUPLED EXTERNALITIES: A PRELIMINARY ANALYSIS

SOPHIE LEGRAS AND ROBERT LIFRAN

Abstract. This paper aims to investigate different water market designs to accommodate coupled externalities in the context of irrigation-induced salinity. It provides a preliminary analysis of three types of market mechanisms, involving diversion rights and recharge rights.

Keywords: water markets, irrigation-induced salinity, Australia, externalities, policy instruments.

[JEL] Q25, Q53

1. Introduction

Facing increasing demand for human uses, water resources are becoming scarcer throughout the world. As a consequence, managing water scarcity has been a burning issue for users and regulators for decades. Among the institutional arrangements proposed to cope with water scarcity, the definition and subsequent trading of water rights is usually recognized as one of the most efficient ways to manage the resource. In several countries, water markets were designed in order to balance water scarcity and economic efficiency. Nevertheless, such markets face complex issues due to the nature of the resource. Allocating water among different users often implies huge changes to the water cycle, and thus generates external effects. For instance, irrigation-induced salinity is an environmental issue which has important impacts in irrigated areas of semi-arid countries, such as India or Australia. It also constitutes...
a particular setting by respect to water management as it combines in a complex manner quantitative and qualitative issues. The aim of this paper is to explore some aspects of this complexity arising from several coupled irrigation-induced externalities, and to compare some economic instruments to overcome this complexity.

The interest for markets for water rights lies in three main points. First, they induce a reallocation of water to higher benefit uses [1]. Second, introducing markets for water rights is a politically soft process. Indeed, the government is not perceived as arbitrarily choosing the winners and losers of the reallocation process [9]. Finally, markets for water have a triple beneficial impact on resource conservation [3]. Immediately after the introduction of the market, users are induced to reduce their water consumption, as water becomes a valuable resource. On the short term, the less efficient users are induced to sell their access rights to those who use it in a more efficient way. On the longer term, users will improve their productivity by investing in water-saving facilities.

There exists in fact few papers developing formal models of water markets [9]. However there exists an abundant literature on site specific aspects of water markets, including simulations based on catchment data, description of the institutional context and of the functioning of local markets and associated problems [10],[8], [2]. If simulations provide optimistic results [2] empirical analyses show more contrasted results. Tan [5] explains that authors who have a significant experience in water markets advocate a strong role for regulation, in order to account for environmental externalities and to impact on the scope and direction of water reallocation. A recent study by Tural et al. [7] provides an analysis of water markets in the southeastern states of Australia. The main observations are that (1) intersectoral trade is very limited; (2) permanent trade is still extremely limited, accounting for 1% of transaction in volume; (3) temporary trade is more frequent and growing. According to Tural et al. [7], permanent trade, even if very restricted, has proven an efficient tool to accompany structural adjustment. Illustrating examples include the conversion of inefficient grazing to highly efficient dairy farms in Northern Victoria. However, the authors also identify several instances of barriers to trade, which may be explained by concerns for the environment. Tural et al. [7] illustrate the need for regulation
to accompany an efficient water market, in order to improve the ability of water markets to manage environmental issues.

In this regard, the current development of water markets for managing water scarcity in Australia may not take sufficiently account of other environmental issues that may arise from their implementation. In order to tackle the consequences of diverting water from natural ecosystem for human use, the necessity to cap the amount of diverted water has been recognized early and the allocation of water made through the use of mixed instruments, such as cap and trade. The aim of capping diversion was to keep a satisfying level of environmental flows. Nevertheless, as irrigation became widely used to improve agricultural production, additional negative environmental effects, such as waterlogging or soil salinization, arose. Moreover, discharge of salty groundwater into the surface river system increased stream salinity downstream and hindered further human uses. If we operate a simplification of the issues at stake, irrigation-induced salinity can be reduced to a single objective to be followed: reducing the recharge to the aquifer. Then a satisfying management of water resources in the southeastern states of Australia should seek to attain two objectives: maintaining instream flows, and reducing the recharge to individual aquifers. However, due to the hydrological linkages existing within catchment areas, environmental flows and irrigation-induced salinity turn out to be coupled externalities.

The specific aim of this paper is to investigate different water market designs to accommodate coupled externalities in the context of irrigation-induced salinity. It provides a preliminary analysis of three types of market mechanisms. Indeed, following Tinbergen’s [6] principle which states that one instrument should correspond to one objective, one could consider that separate instruments should be needed to cope with irrigation-induced salinity. This would translate into a system of two decoupled markets, one for recharge rights at the catchment scale, and one for diversion rights at the basin scale (Case C in the remainder of the paper). However, recharge and diversion are linked, which implies that this separation of instruments might not be efficient. Indeed, Weinberg et al. [10] show that introducing water trade has beneficial impacts on the management of drainage from irrigation districts. If a sole market for water right may not achieve the least cost solution, it induces a
general reduction in water use and related drainage which has beneficial impacts on
the environment. This leads the authors to point out that “water quality benefits
resulting from a water market should be considered a positive externality to market
formation” ([10] p.290). Currently in Australia, water markets deal with diversion
rights only. While some voices arise in order to allow exchanges among users of the
whole surface water system (Case A), some authors express concern and propose to
constrain trade of surface flows within catchments, for social, economic and environ-
mental reasons (Case B).

In order to investigate these different instruments’ designs, we propose in this paper
a very stylized model of irrigation-induced salinity, able to exhibit the main hydro-
logical interactions at stake. While hydrological mechanisms are in essence dynamic,
we keep our analysis static, and assume that a regulator is able to adapt targets to
manage markets according to each site-specific situation. Furthermore, in our study
we assume that social welfare concerns are already integrated when authorities issue
the cap on each market.

Section 2 develops the model under study. Section 3 presents the program of the
regulator, which corresponds to the constrained optimal situation. In section 4 we
address different designs for a system of water markets to manage irrigation-induced
salinity. Section 5 provides some concluding remarks, and the next steps on our
research agenda.

2. Model

Consider $m$ hydrological zones, denoted by $k$, located along a river and ordered
upstream-downstream. To a hydrological zone corresponds a unique watertable,
which recharge management can totally be undertaken on this zone. According to
the type of aquifer under study, the relative size of the zones can vary from sub-
catchment to basin.
In each of these zones, \( n_k \) agents denoted by \( i \in [1..n_k] \) undertake irrigation. Agent \( i \)'s utility function writes as:

\[
B(u_{ik},a_{ik}) = \rho_p f(u_{ik}) - \rho_E u_{ik} - C_a a_{ik} - \varepsilon_k \sum_i p(u_{ik},a_{ik}),
\]

where \( f(u_{ik}) = A + Bu_{ik} - \frac{C}{2} u_{ik}^2 \) is the production function and \( p(u_{ik},a_{ik}) = \alpha_k u_{ik} - \delta a_{ik} \) is the percolation function. \( u_{ik} \) is the quantity of water applied for irrigation, \( a_{ik} \) refers to abatement decisions, \( \varepsilon_k \) is a damage term illustrating the fact that individual agents are affected by the rising of the watertable, caused by the aggregation of individual percolation, \( \alpha_k \) is inversely related to the efficiency of irrigation technology\(^1\), \( \delta \) refers to the efficiency of abatement actions. \( \rho_p, \rho_E \) and \( C_a \) are cost terms. \( \varepsilon_k \) and \( \alpha_k \) are supposed to be catchment-specific.

It is assumed that an aggregate quantity of water \( d_k \) is diverted from the river at one uptake point for each zone \( k \), and that an amount \( rf_k \) of return flows goes back to the river at zone \( k \)'s outset point, such that:

\[
d_k = \sum_i u_{ik} \quad \text{and} \quad rf_k = \sigma_k \sum_i p(u_{ik},a_{ik}).
\]

\( \sigma_k \) is a return-flow parameter specific to each catchment.

Water flows in the river can be described by the following equation:

\[
q_{k+1} = q_k - d_k + rf_k
\]

The assumption underlying these formulations is that only the actions undertaken on point \( k \) have an impact along the segment \([k, k+1]\) of the river (see Figure 1).

3. The “optimal” allocation of water

3.1. Regulator’s objectives. The first objective of the regulator is to guarantee a minimum level of instream flows at each point along the river, in order to satisfy the needs of the environment and of a range of other types of non-consumptive users. We call this the environmental flow constraint:

\[
q_k - d_k \geq Q, \forall k
\]

\(^1\)In this model, we assume that agents do not have the possibility to change their irrigation technology.
The second objective of the regulator is to maintain the level of the water table below a critical point. In each of the zone, the following recharge constraint is enforced:

\[
\sum_i p(u_{ik}, a_{ik}) \leq \bar{R}_k, \forall k
\]

It is assumed that both constraints are optimally set by the regulator, in order to deal with values which are not captured by the model. If the environmental flow constraint captures non-consumptive values, the recharge constraint captures values which are inherently dynamic and as such cannot be described by this model. In particular, this constraint allows taking account of the dynamic externalities arising between the irrigators. These externalities have been described in the groundwater literature [4]. In both cases, third parties effects arise when water uses are such that the constraints become binding [9].

3.2. **Regulator’s program.** In this section, we analyze the program of the regulator in order to derive the “optimal” allocations of water and abatement in order to manage all the externalities at stake in the problem. This serves as a benchmark to which the next cases will be compared.

\(^2\)quotation marks are used here because this is a constrained optimal program, integrating the value of the constraints defined above.
The program of the regulator is to maximise the social welfare by respect to the quantity of water applied and the abatement decisions in the following manner:

$$
\max_{u_{ik}, a_{ik}} \sum_k \sum_i B(u_{ik}, a_{ik}) - \sum_k \Gamma_k r f_k
$$

subject to equations (1), (2) and (3) and a set of initial and terminal conditions. $\Gamma_k$ is the marginal damage associated with the discharge of salty water into the surface river system before zone $k+1$’s diversion point. Indeed, returns flows have an ambiguous effect on the environment. In quantitative terms, they generate positive externalities. In qualitative terms, however, they induce an increase of salts’ concentration in the surface system, causing damage.

This is a general constrained control problem, with two controls $u_{ik}$ and $a_{ik}$ and a state variable $q_k$ which spatial evolution is given in equation 1. Formulating the Lagrangian:

$$
L^*(u_{ik}, a_{ik}, \omega(k), \mu_1(k), \mu_2(k)) = \sum_k \sum_i B(u_{ik}, a_{ik}) - \sum_k \Gamma_k r f_k
$$

$$
+ \sum_k \omega(k)[q_k - d_k + r f_k - q_{k+1}] + \sum_k \mu_1(k)[q_k - d_k - Q] + \sum_k \mu_2(k)[\bar{R}_k - \sum_i p(u_{ik}, a_{ik})]
$$

The first order conditions for an interior solution are:

$$
\frac{\partial L}{\partial u_{ik}} = \frac{\partial B}{\partial u_{ik}} - \Gamma_k \frac{\partial r f_k}{\partial u_{ik}} + \omega(k) \left( \frac{\partial r f_k}{\partial u_{ik}} - \frac{\partial d_k}{\partial u_{ik}} - \mu_1(k) \frac{\partial d_k}{\partial u_{ik}} - \mu_2(k) \frac{\partial p(.)}{\partial u_{ik}} \right) = 0
$$

$$
\frac{\partial L}{\partial a_{ik}} = \frac{\partial B}{\partial a_{ik}} - \Gamma_k \frac{\partial r f_k}{\partial a_{ik}} + \omega(k) \frac{\partial r f_k}{\partial a_{ik}} - \mu_1(k) \frac{\partial d_k}{\partial a_{ik}} - \mu_2(k) \frac{\partial p(.)}{\partial a_{ik}} = 0
$$

$$
\frac{\partial L}{\partial q_k} = \omega(k) - \omega(k - 1) + \mu_1(k) = 0
$$

$$
q_k - d_k - Q \geq 0, \mu_1(k)[q_k - d_k - Q] = 0
$$

$$
\bar{R}_k - \sum_i p(u_{ik}, a_{ik}) \geq 0, \mu_2(k)[\bar{R}_k - \sum_i p(u_{ik}, a_{ik})] = 0
$$
Rearranging the expressions, we obtain:

\[ \omega(k) = \frac{1}{1 - \frac{\sigma_k \alpha_k}{\alpha_k}} \left( \rho_p (B - C u_{ik}) - \rho_E - \mu_1(k) \right) \left( 1 - \frac{\alpha_k}{1 - \sigma_k \alpha_k} \left( \varepsilon_k + \mu_2(k) + \Gamma_k \right) \right) \]

(4)

\[ \mu_2(k) = \sigma_k \omega(k) - \varepsilon_k + \frac{C_a}{\delta} - \sigma_k \Gamma_k \]

(5)

\[ \Delta \omega(k) = -\mu_1(k) \leq 0 \]

(6)

Equation (4) describes the cost \( \omega(k) \) of reducing the flow of water to downstream users by one unit. At the equilibrium, this cost is set equal to the marginal benefit of allocating an extra unit of water to agent \( ik \). The first term on the RHS of equation (4) is the net benefit of consuming an extra unit of water for agent \( i \): marginal benefit of consuming an extra unit of water, minus the extra cost of meeting the environmental flows constraint through diverting water. \( \frac{1}{1 - \frac{\sigma_k \alpha_k}{\alpha_k}} \) makes this net benefit per unit of water consumed. The second term of the RHS of equation (4) is the marginal cost of percolating one unit of water: direct damage to user \( ik \), extra cost of meeting the recharge constraint and cost of increasing stream salinity downstream. \( \frac{\alpha_k}{1 - \sigma_k \alpha_k} \) makes this net cost per unit of water percolated.

Equation (5) shows the cost of meeting the recharge constraint, which is set equal to the marginal benefit of reducing the recharge. This is equal to the benefit of not being affected by the recharge externality, minus the cost of reducing the flow downstream, minus the abatement cost and the cost of increasing stream salinity downstream.

Equation (6) illustrates the price path of reducing water to downstream users along the river. This path is decreasing, illustrating that as going downstream, less agents
are affected by individual decisions regarding diversion or abatement.

Remark: the implicit prices $\omega(k)$ and $\mu_1(k)$ only depend on $k$, and not on $i$, in reason of the particular structure of the model (with one diversion point and one discharge point per zone).

4. **Different designs for water markets**

4.1. **A definition of the different types of markets under scrutiny.** We consider three different cases. First, we analyse the “theoretical status quo” situation, that we describe as a market for diversion rights over the whole system of $m$ catchments (case A). We call this “status quo” as it is what the Australian water markets tend to become. The term “theoretical” refers to the fact that the development of markets is not so total in Australia (Turral et al., 2005). However, we consider this as the benchmark point of our analysis. We expect this system to fail to manage the recharge externalities. Building on this, we consider two ways of rendering this instrument more efficient, in order to fully attain the objectives of the regulator.

Then, we consider that the management of the recharge is accommodated by a series of cap-and-trade for diversion rights, each cap being defined at the catchment scale. This means that a diversion cap is defined for each zone, in consistency with the recharge constraint defined by the regulator. Trade is not allowed between zones (case B), so that the actual status quo situation is approximated. Indeed, the current development of water markets in Australia is such that one can consider that barriers to trade prevent any trade between zones, except a few exceptions. However, one has to keep in mind by comparing this situation with the actual status quo that currently caps are being defined in consistency with a scarcity constraint, without accounting for recharge externalities. This is important in the definition of initial rights.

\footnote{Another case would be to study these markets when trade is allowed between zones subject to constraints.}
Finally, we consider a system combining a market for diversion rights and a market for recharge rights, which is equivalent to considering an instrument for each externality at stake. The management of water scarcity through the use of water markets has been broadly analyzed, both theoretically and empirically. The second type of market we analyze is more innovative, as we propose to manage the recharge to the aquifer through the use of a market for tradeable recharge rights. Such a market has been proposed by Whitten et al. [11] but not formally studied. The main idea underlying the design of a recharge right market is that a limit has been computed on the quantity of water that should recharge the watertable, for a certain amount of time. A recharge right could be defined as share of the assimilative capacity of the watertable that a group of users have in common. Recharge rights are defined at the recharge zone level. This implies that any trade of these rights is restricted within the zone. Irrigators within a recharge zone are assigned an initial allocation of recharge rights. They can either use these rights, through their irrigation decisions, or sell these rights to other irrigators from the same zone. Improving irrigation technologies, or planting deep-rooted plants such as lucerne, enable the farmer to decrease its recharge/diversion ratio. This means that with the same amount of water diverted, he contributes less to the recharge of the aquifer, and at the same time he generates profit by selling his recharge rights in excess. It is important to notice that the definition of the recharge rights is dynamic. Indeed, the assimilative capacity of the aquifer might evolve each year, or each relevant time step. Consequently, the amount of recharge it gives right to might differ from year to year exactly in the same way as the cap on diversion depends on the extent of scarcity in a given year.

The analyses presented in the remainder of this paper are undertaken according to the constraints and definitions given in Table 1.

In each case, the resolution process is as follows (Montgomery, 1972). We derive the solution to the ”market constrained” problem, which corresponds to the maximization of individual benefits subject to the market’s constraints (compliance and market clearing). Then we derive the solution to the individual problems, and compare this solution to the previous one. This allows us to assess whether an equilibrium of
the market is consistent with pursuing individual maximization. Finally, we address the issue of whether a type of market is consistent with the "optimal" solution derived in the previous section.

4.2. Case A: a diversion rights market with a unique global cap.

□ Individual maximization.

\[
\max_{u_{ik}, a_{ik}, d_{ik}} \ B(u_{ik}, a_{ik}) - \rho_D d_{ik}
\]

subject to

\[
u_{ik} \leq d_{ik}
\]

The Lagrangian is:

\[
L_A(u_{ik}, a_{ik}, d_{ik}, \theta_{ik}) = B(u_{ik}, a_{ik}) - \rho_D d_{ik} + \theta_{ik} [d_{ik} - u_{ik}]
\]

First order conditions are:
\( \frac{\partial L_A}{\partial u_{ik}} = \frac{\partial B}{\partial u_{ik}} - \theta^A_{ik} = 0 \leftrightarrow \frac{\partial B}{\partial u_{ik}} = \theta^A_{ik} \) \hfill (7)

\( \frac{\partial L_A}{\partial a_{ik}} = \frac{\partial B}{\partial a_{ik}} = 0 \) \hfill (8)

\( \frac{\partial L_A}{\partial d_{ik}} = -\rho_D + \theta^A_{ik} = 0 \leftrightarrow \rho_D = \theta^A_{ik} \) \hfill (9)

**Global maximisation.**

\[
\max_{u_{ik}, a_{ik}, d_{ik}} \sum_k \sum_i B(u_{ik}, a_{ik})
\]

subject to

\( u_{ik} \leq d_{ik} \) and \( \left[ \sum_k \sum_i (d_{ik} - d_{0ik}) \right] = 0 \)

The Lagrangian is:

\[
L_A(u_{ik}, a_{ik}, \lambda^A_{ik}, \gamma^A) = \sum_k \sum_i B(u_{ik}, a_{ik}) + \sum_k \sum_i \lambda^A_{ik} (d_{ik} - u_{ik}) + \gamma^A \left[ \sum_k \sum_i (d_{ik} - d_{0ik}) \right]
\]

First order conditions:

\( \frac{\partial L_A}{\partial u_{ik}} = \frac{\partial B}{\partial u_{ik}} - \lambda^A_{ik} = 0 \leftrightarrow \frac{\partial B}{\partial u_{ik}} = \lambda^A_{ik} \) \hfill (10)

\( \frac{\partial L_A}{\partial a_{ik}} = \frac{\partial B}{\partial a_{ik}} = 0 \) \hfill (11)

\( \frac{\partial L_A}{\partial d_{ik}} = \lambda^A_{ik} + \gamma^A = 0 \leftrightarrow \lambda^A_{ik} = -\gamma^A \) \hfill (12)
Comparison individual / global programs.
The individual maximisation program is consistent with the global one if:
\[ \theta^A_{ik} = \lambda^A_{ik} \text{ and } \gamma^A_{ik} = -\rho D \]

Comparison global / optimal programs.
Comparing with the optimal program, it appears that such a specification of the market system cannot support the optimal decision. Indeed, in this case there is no incentive to abate more than in the unconstrained individual maximisation problem, as \( \frac{\partial B}{\partial a_{ik}} = 0 \).

4.3. Case B: zonal diversion rights markets, intra-zone trading.

Individual maximisation.

\[
\begin{align*}
\max_{u_{ik}, a_{ik}} & \quad B(u_{ik}, a_{ik}) \\
\text{subject to} & \quad u_{ik} \leq w_{ik}
\end{align*}
\]

First order conditions are:
\[
\begin{align*}
\frac{\partial L^{BI}}{\partial u_{ik}} &= \frac{\partial B}{\partial u_{ik}} - \theta^B_{ik} = 0 \\
\frac{\partial L^{BI}}{\partial a_{ik}} &= \frac{\partial B}{\partial a_{ik}} = 0 \\
\frac{\partial L^{BI}}{\partial w_{ik}} &= -\rho_k w_{ik} + \theta^B_{ik} = 0
\end{align*}
\]

Global maximisation.

\[
\begin{align*}
\max_{u_{ik}, a_{ik}} & \quad \sum_i B(u_{ik}, a_{ik}) \\
\text{subject to} & \quad u_{ik} \leq w_{ik} \text{ and } \sum_i (w_{ik} - w^0_{ik}) = 0
\end{align*}
\]
The Lagrangian is:

\[ L^B(u_{ik}, a_{ik}, \lambda^B_{ik}, \gamma^B_k) = \sum_i B(u_{ik}, a_{ik}) + \sum_i \lambda^B_{ik}(w_{ik} - u_{ik}) + \gamma^B_k [\rho w_k \sum_i (w_{ik} - w_{ik}^0)] \]

First order conditions:

\[ \frac{\partial L^B}{\partial u_{ik}} = \frac{\partial B}{\partial u_{ik}} - \lambda^B_{ik} = 0 \]
\[ \frac{\partial L^B}{\partial a_{ik}} = \frac{\partial B}{\partial a_{ik}} = 0 \]
\[ \frac{\partial L^B}{\partial w_{ik}} = \lambda^B_{ik} + \gamma^B_k = 0 \]

□ **Comparison individual / global programs.**

The individual maximisation program is consistent with the global one if:

\[ \theta^B_{ik} = \lambda^B_{ik} \text{ and } -\gamma^B_k = \rho_W \]

□ **Comparison global / optimal programs.**

This type of market is consistent with the optimal solution if:

\[ \gamma^B_k = -\lambda^B_{ik} = \Gamma_k \alpha_k \sigma_k + (1 - \sigma_k \alpha_k) \omega(k) + \mu_1(k) - \alpha_k \mu_2(k) \]

(13)

\[ 0 = -\Gamma_k \sigma_k \delta + \delta \sigma_k \omega(k) - \delta \mu_2(k) \]

(14)

Combining equations (13) and (14), we obtain:

\[ \gamma^B_k = \omega(k)(1 - 2\sigma_k \alpha_k) + \mu_1(k) \]

(15)
4.4. Case C: diversion and recharge rights markets.

□ Individual maximisation.

\[
\begin{align*}
\max_{u_{ik}, a_{ik}} & \quad B(u_{ik}, a_{ik}) \\
\text{subject to} & \quad u_{ik} \leq w_{ik} \text{ and } p(u_{ik}, a_{ik}) \leq r_{ik}
\end{align*}
\]

\[
\frac{\partial B}{\partial u_{ik}} = \theta_{ik}^D
\]

\[
\frac{\partial B}{\partial a_{ik}} = \theta_{ik}^{RD} \frac{\partial p}{\partial a_{ik}}
\]

\[
\theta_{ik}^D = \rho_V
\]

\[
\theta_{ik}^{RD} = \rho_{k}^R
\]

□ Global maximisation.

\[
\begin{align*}
\max_{u_{ik}, a_{ik}} & \quad \sum_k \sum_i B(u_{ik}, a_{ik}) \\
\text{subject to} & \quad u_{ik} \leq w_{ik} \text{ and } p(u_{ik}, a_{ik}) \leq r_{ik}
\end{align*}
\]

\[
\sum_k \sum_i (w_{ik} - w_{0ik}) = 0 \quad \text{and} \quad \sum_i (r_{ik} - r_{0ik}) = 0
\]

First order conditions:

\[
\begin{align*}
\frac{\partial L^D}{\partial u_{ik}} &= \frac{\partial B}{\partial u_{ik}} - \lambda_{ik}^D - \lambda_{ik}^{RD} \frac{\partial p}{\partial u_{ik}} = 0 \\
\frac{\partial L^D}{\partial a_{ik}} &= \frac{\partial B}{\partial a_{ik}} - \lambda_{ik}^{RD} \frac{\partial p}{\partial a_{ik}} = 0 \\
\frac{\partial L^D}{\partial u_{ik}} &= \lambda_{ik}^D + \gamma^D = 0
\end{align*}
\]
\[ \frac{\partial L^D}{\partial r_{ik}} = \lambda_{ik}^{RD} + \gamma_k^{RD} = 0 \]

\[ \lambda_{ik}^{D} + \lambda_{ik}^{RD} \frac{\partial p}{\partial u_{ik}} = \theta_{ik}^{D} \]  \hspace{1cm} (16)

\[ \lambda_{ik}^{RD} = \theta_{ik}^{RD} \]  \hspace{1cm} (17)

\[ \lambda_{ik}^{RD} = \Gamma_k \alpha_k - \sigma_k \omega(k) + \mu_2(k) \]  \hspace{1cm} (18)

\[ \lambda_{ik}^{D} = \omega(k) + \mu_1(k) - 2\mu_2(k) \]  \hspace{1cm} (19)

5. Concluding remarks

This paper presents a preliminary analysis of different market designs to manage coupled externalities. In order to attain two coupled objectives, the management of the recharge of a series of aquifers and the management of water scarcity in the surface system, we consider three types of market designs. We define for each their characteristics in terms of constraints they impose on the agents. We derive the first order conditions, and begin the process of comparing them with the “optimal” solution. This preliminary analysis suggests that if a system of coupled markets is able to manage the recharge externalities, the instream flow one may not be accommodated. A series of catchment-constrained diversion markets appear more efficient in managing both types of externalities.
Our analysis bears several limitations. First, we consider a static setting, while by nature irrigation-induced salinity is a dynamic process. However, in considering a market for rights, it is important to notice that recharge or diversion rights are not meant to be bankable. Indeed, they are defined at the irrigation-season time scale, which means that a system of banking/borrowing of rights would not be implementable. Second, the definition of objectives exogenously decided may be a somehow curious way of rendering the externalities endogenous from the regulator’s viewpoint. We argue that this reproduces what is observed on the field, and allows us to circumvent the difficulties attached to the definition of sensible damage functions. However, some difficulties remain about the definition of the environmental flows constraint “$q_k - d_k \geq \bar{Q}$”. Indeed, this means that all catchments are subject to the same constraint, which could be difficult to explain. In this perspective, the diversion rights market (Case A) does not even seem to be able to optimally allocate water, even when recharge externalities are not taken into account. A way to circumvent this would be to consider only a final environmental flow constraint, such as $q_n = q_0 - \sum_k d_k \geq \bar{q}$.

In the next step, we need to refine the analysis of the first order conditions, in order to fully account for the differences between the markets. Then we want to focus on the definition of the caps, $\bar{D}, \bar{W}_k, \bar{R}_k$ and their relations with the regulator’s constraints. Indeed, these appear to be the key definitions of the model.

References


Documents de travail parus en 2006

DR n°2006 - 01 : Stéphanie AULONG, Katrin ERDLENBRUCH, Charles FIGUIERES
« Mesures de biodiversité et politiques de conservation : des notions complexes présentées dans un exemple simple »

DR n°2006 - 02 : Aurélie BONEIN, Daniel SERRA
« L’influence de la connaissance du genre du partenaire dans les relations de confiance et de réciprocité : une étude expérimentale »

DR n°2006 - 03 : Charles FIGUIERES, Mabel TIDBALL
« Sustainable exploitation of a natural resource: a satisfying use of a Chichilnisky’s criterion »

DR n°2006 - 04 : David MASCLET, Marc WILLINGER
« Does contributing sequentially increase the level of cooperation in public good games? An experimental investigation »

DR n°2006 - 05 : Jean-Pascal GUIRONNET
« Capacité d’utilisation du capital humain et croissance de la productivité française de 1980 à 2002 »

DR n°2006 - 06 : Denis CLAUDE, Mabel TIDBALL
« Efficiency inducing taxation for polluting oligopolists : the irrelevance of privatization »

DR n°2006 - 07 : Stéphanie AULONG, Charles FIGUIERES, Sophie THOYER
« Agriculture production versus biodiversity protection: what role for north-south unconditional transfers? »

DR n°2006 - 08 : Patrice BOUGETTE, Stéphane TUROLLA
« Merger remedies at the European Commission: a multinomial analysis »

DR n°2006 - 09 : Leo K. SIMON, Sophie THOYER, Sylvie MORARDET, Rachael E. GOODHUE, Patrick RIO, Gordon C. RAUSser
« Structure and bargaining power in multilateral negotiations: Application to water management policies in France »

DR n°2006 - 10 : Aurélie BONEIN
« An empirical study of determinants in decision-making process »

DR n°2006 - 11 : Sophie LEGRAS, Robert LIFRAN
« Designing water markets to manage coupled externalities : a preliminary analysis »
Contacts:

Thierry BLAYAC: blayac@lameta.univ-montp1.fr
Valérie CLEMENT: clement@lameta.univ-montp1.fr