

Bontemps, Christophe; Couture, Stéphane; Favard, Pascal

Working Paper

Is the irrigation water demand really convex?

Nota di Lavoro, No. 82.2001

Provided in Cooperation with:

Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Bontemps, Christophe; Couture, Stéphane; Favard, Pascal (2001) : Is the irrigation water demand really convex?, Nota di Lavoro, No. 82.2001, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<https://hdl.handle.net/10419/155245>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

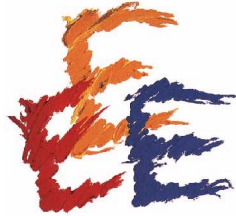
Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



Fondazione Eni Enrico Mattei

Is the Irrigation Water Demand Really Convex?

Christophe Bontemps*, Stéphane Couture*
and Pascal Favard**

NOTA DI LAVORO 82.2001

OCTOBER 2001

NRM – Natural Resources Management

*ESR-INRA

**Université de La Rochelle, LASER and LEERNa

This paper can be downloaded without charge at:

The Fondazione Eni Enrico Mattei Note di Lavoro Series Index:
http://www.feem.it/web/attiv/_attiv.html

Social Science Research Network Electronic Paper Collection:
<http://papers.ssrn.com/abstract=XXXXXX>

Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano, tel. +39/02/52036934 – fax +39/02/52036946
E-mail: letter@feem.it
C.F. 97080600154

SUMMARY

We estimate the irrigation water demand for a season under uncertainty using a dynamic programming model and a crop-growth simulation model (EPIC-PHASE) linked to a CRRA utility function representing the farmer's objective function. This model is used to generate the data allowing the estimation of irrigation water demand by a nonparametric procedure. An application shows that demand functions present four main areas: for very small quantities, the demand is inelastic. In the second area, where water is no more an essential input and is not yet a risk reducing input, the demand is elastic. But, we find a third, non-intuitive, area for larger quantities where the water is a risk reducing input and the demand becomes inelastic again. In the last area the water demand is obviously elastic for important total water quantities. This result is of great importance to analyse a regulation policy.

Keywords: Seasonal irrigation water demand, uncertainty, regulation policy

JEL: Q15, D81

NON TECHNICAL SUMMARY

The seasonal irrigation water demand under uncertainty, which lies at the core of this paper, is still very roughly known. We know, however, that irrigated agriculture accounts for a large proportion of water use, especially in many water-scarce areas. In this paper, we estimate the irrigation water demand, for various climatic conditions characterising the distribution of the necessarily stochastic, demand functions under uncertainty. We use a dynamic programming model to represent the farmer's decision program under uncertainty. A crop-growth simulation model (EPIC-PHASE), provides the response function to the decisions taken and climatic events and is linked to a CRRA utility function representing the farmer's objective function. This model is used to generate the data allowing the estimation of irrigation water demand by a nonparametric procedure. An application to irrigation water demand is proposed in the South-West of France. We show that the estimated demand functions present four main areas: for very small quantities, where the farmer considers water as an essential input to crop growth, the demand is inelastic. The second area corresponds to mean quantities where the plant has reached a satisfactory level of growth; water is no more an essential input and is not yet a risk reducing input. The farmer is more responsive to change in water price. But, we find a third, non-intuitive, area for larger quantities where the water is a risk reducing input and the demand becomes inelastic again. The last area is classic, the water demand is obviously elastic for important total water quantities. This result is of great importance to analyse a regulation policy.

CONTENTS

1.	Introduction	2
2.	Evaluating irrigation water demand under uncertainty	5
	2.1 Definitions	5
	2.2 Decision model	6
	2.3 Estimation procedure	10
3.	An application in the South-West of France	13
	3.1 Results	13
	3.2 Economic analysis	16
4.	Conclusion	18
	References	20
A	The nonparametric procedure of estimation	23
B	Data	24

1 Introduction

In many countries of the world, agricultural activities are risky, and irrigation affects these risks. Different types of risk exist: price risk, production risk, climatic risk; this last one seems to be the most important in agriculture. Stochastic weather conditions affect considerably the production of farmers and therefore their revenue. Thus, risk considerations may have important effects on irrigation decisions of risk-averse farmers because irrigation is a risk reducing input and a certain source of water unlike rainfall.

In France irrigated agriculture accounts for a large proportion of water use, especially in many water-scarce areas. This position can induce imbalance between water needs and resources that are likely to cause conflicts between different categories of users (rural, urban, industrial and other users). Agriculture is presented as the main cause of this disequilibrium. In these situations, the regulator may force all water users to pay the water at its real value. The application of this policy is inherent to the knowledge of the intertemporal water demand functions for each user. In France, farmers are charged for water. The fees are fixed at low levels, compared to the ones paid by the others consumers and it is well known that low prices induce over-consumption. Moreover the knowledge of farmers water consumption remains imprecise. In this context, estimating farmer's water demand over a season is difficult and several questions are still unanswered.

The problem of evaluating irrigation water demand is not recent and has become a growing field of research in the last few years. There is an important literature assessing how farmers react to changes in the price of water. Two approaches on irrigation water demand estimation exist. If data relating to observed water consumption exist then the authors use econometric models (Ogg and Gollehon [23]; Moore and Negri [20]; Moore *et al.* [21] and [22]; Hassine and Thomas [12]). However, in France as in many countries of the world, they are imprecise data on these consumptions. This point has induced the use of programming models for the estimation of the water demand. Demand estimates are derived from simulations of profit maximizing behavior. These modeling procedures require the use of standard mathematical techniques such as linear programming (Shunway [26]; Montginoul and Rieu [19]), or quadratic programming (Howitt *et al.* [13]). These authors seems to conclude that irrigation water demand is completely inelastic below a threshold price, and elastic beyond (Montginoul and Rieu [19]; Garrido *et al.* [9]; Varela-Ortega *et al.* [27]; Iglesias *et al.* [14]).

The programming method studies are based on the mathematical formalization of the farmer's behavior. This latter is assumed to maximize his final profit. The water demand function is derived from the following scheme. For a given price, one estimates the quantity of water maximizing the farmer's profit. Variations in water prices induce different levels of optimal water quantities. The authors use this information directly to represent the derived demand for irrigation water.

The weaknesses of these models are due to the formalization of the farmer's program and to the necessarily simplifying assumptions. Therefore, the demand estimates obtained strongly depend on the specifications made and these results can be biased.

One aim of this paper is to estimate the seasonal irrigation water demand using programming methods and complementing the previous studies. The approach to derive irrigation water demand by programming methods needs to be precisely defined and the farmer's maximization problem has to be detailed.

Our paper makes four contributions to the literature on seasonal irrigation water demand under risk.

First, we use dynamic programming to describe the farmer's program. The advantage of our approach is that it allows to represent precisely the problem of allocation of a limited water supply on a given crop field under risk and to show the impact of multiple applications of the water during the irrigation season. Few papers in this literature have dealt with the subject of irrigation scheduling (Bontemps and Couture [1] or [2]).

Second, we use a crop growth simulation model, EPIC-Phase, for estimating crop yield response function to irrigation water. A major advantage of this model compared to the pre-specified functions performed in the literature is that it represents more precisely the biological and physical process of plant growth.

Third, we specify a Constant Relative Risk Aversion (CRRA) utility function as objective criterion which appears appropriate to describe the farmer's behavior (Chavas and Holt [7]; Pope and Just [24]). The previous studies are based on the strong assumption that the farmer is risk-neutral and he maximizes his profit while it is recognized in the literature that farmers are risk averse (Bouzit [5]). Neglecting the risk-averse behavior in agricultural models can lead to important overstatement of the output level and to biased estimation of the irrigation water value, as well as incorrect prediction of choices. Moreover, there have been few attempts in the literature to prove the important role of information in the decision making process of farmers under uncertainty (Bontemps and Thomas [4]). To our

knowledge, taking into account risk aversion and information value for estimating irrigation water demand is rarely found in the literature.

Finally, the scheme used to derive irrigation water demand is based on the evaluation of the value of water for the farmer. We define this value as the maximum amount of money the farmer would be willing to pay for the use of one additional unit of the resource under water scarcity.

This model is used to characterize and to quantify the irrigation demand functions under uncertainty for various climatic conditions. We use this climatic variability to draw the distribution of this demand function for two different information sets. In the first case an *ex-ante* or *open-loop* decision rule¹ for input use (i.e. computing irrigation water applications before random shocks to weather conditions are observed) is performed while an *ex-post* or *feedback* strategy (i.e. when successive information components are processed by the farmer at different stages) characterizes the second case. The derivation of the demand functions for these two main strategies under various climatic conditions is of great interest and answers to the following questions: *What is the shape of the irrigation demand function under uncertainty? What is the distribution of this random function? How sensitive is it to the strategy used (or to the information set)?* and finally, *Is the irrigation water demand function convex?*

We have used this model to estimate the irrigation water demand for a season under stochastic weather conditions in the South-West of France². We obtain this function for various climatic conditions characterizing the distribution of the necessary stochastic demand functions under uncertainty. We have used a nonparametric estimation procedure in order to have a precise information on the shape of these functions. We show that irrigation water demand depends obviously on two variables: climate and information set. All the estimated demand functions have the same shape, presenting four main areas. For very small quantities, where the farmer considers water as an essential input to crop growth, the demand is inelastic. The second area corresponds to mean quantities where the plant has reached a satisfactory level of growth; water is no more an essential input and is not yet a risk reducing input. The farmer is more responsive to change in water price. But we find a

¹The farmer decides not to use all the information available at every stage in the decision process.

²The climate in our region is more humid than in the Mediterranean areas, but much more drier than in the north of France.

third, non-intuitive, area for larger quantities where the water is a risk reducing input and the demand becomes inelastic again. The last area is classic, the water demand is obviously elastic for important total water quantities. This result is of great importance in terms of regulation policy, since the real price for the region considered lies in the third inelastic area. If the regulator imposes a price (or a quota) regulation, the impact of the change in the price (or in the quota) will strongly depend on the location of the initial and final prices (quotas) within the four areas. Finally, we have provided a parametric estimation of the demand functions and compared their shapes to the nonparametric ones. The fit seems quite good but the parametric curves are convex and present only two well known areas. The use of these parametric representations of the demand functions for policy analysis may therefore be misleading.

The paper is structured in the following manner. Section 2 describes the procedure for evaluating the irrigation water demand function under uncertainty. We present the theoretical framework for calculating demand functions, and then describe the dynamic model of the farmer's decisions. Finally the numerical procedure of resolution and the nonparametric estimation are presented. In section 3 we present an application in the South-West of France. The main results and estimations are reported, as well as the graphical representation of the demand functions. The policy regulation implications of these results are developed and analyzed. Section 4 concludes the paper.

2 Evaluating irrigation water demand under uncertainty

2.1 Definitions

The methodology for evaluating irrigation water demand is based on the evaluation of the value of water for the farmer. The farmer uses water as long as the benefit from the use of an additional unit of the resource exceeds its cost. As water becomes scarce, the value of water for the farmer appears greater than the real water price. Therefore, the farmer would be ready to use more water. Under limited water supply, the farmer's water value is *"the maximum amount of money the farmer would be willing to pay for the use of an additional unit of the resource"*. For a given quantity of water allocated for the season, its value, noted $\lambda(Q)$ is the derivative of the maximized objective function evaluated for this given quantity. Under stochastic weather conditions, the objective criterion of the risk-averse farmer is the

expected utility of the profit, $U(\Pi(Q))$.

This opportunity cost $\lambda(Q)$ is defined as the derivative of the optimized utility function $U^*(\Pi(Q))$, these two functions depend on the total quantity of water Q :

$$\lambda(Q) = \frac{dU^*(\Pi(Q))}{dQ} \quad (1)$$

The knowledge of $\lambda(Q)$ for any total quantity of water, gives the *willingness to pay* function of the farmer. This function is just the inverse of the *irrigation water derived demand*. Therefore, the irrigation water demand function is completely derived once its inverse, the willingness to pay, is known.

Our goal is to characterize the distribution of this demand function over the climatic area, meaning that we will have as many different functions as we have different climates. We will present in section 3 several demand function according to the stochastic variability of the climatic factors.

To characterize the stochastic demand and willingness to pay functions we use the “*mean demand function*” and “*mean willingness to pay*”. These functions are defined using the above procedure on the “*mean utility function*”, noted $E_\Omega[U^*(\Pi(Q))]$ over the range of the climatic distribution, denoted Ω .

The *mean willingness to pay*, noted $\lambda_E(Q)$, is computed as :

$$\lambda_E(Q) = \frac{d E_\Omega [U^*(\Pi(Q))]}{dQ} \quad (2)$$

2.2 Decision model

2.2.1 General framework

We distinguish Ω , I_t , and ω_t . Ω is the stochastic climate of the whole season. I_t is the farmer’s characterization of this climate over the period t ; ω_t is the vector of real weather factors such as wind, rain, temperatures, and radiation, realized during the period t .

Consider a farmer facing a sequential decision problem of irrigation under uncertainty. At date $t = 1$, the farmer knows the total quantity of water available for the season, Q , the initial water stock in soil, \bar{V} , and the state of crop biomass, \bar{M} . The farmer has to take decisions on irrigation at each date $t = 1, \dots, T - 1$, and must choose the quantity of irrigation water

denoted q_t . Therefore, we have a dynamic model of sequential choice under limited water supply with uncertainty, integrating three state variables (M_t, V_t, Q_t) for $t = 1, \dots, T - 1$.

$$M_{t+1} - M_t = f_t(M_t, V_t, \omega_t) \quad (3)$$

$$V_{t+1} - V_t = g_t(M_t, V_t, q_t, \omega_t) \quad (4)$$

$$Q_{t+1} - Q_t = -q_t \quad (5)$$

The change in the level of the biomass at any date (equation 3) is a function (f_t) of the current date state variable, water stock in soil, and climatic conditions during the period. The change in water stock in soil (equation 4) depends moreover on the decision taken at the current date. The total quantity of water has a simple decreasing dynamic (equation 5).

The irrigation water supply is constrained as follows:

$$\sum_{t=1}^{T-1} q_t \leq Q \quad (6)$$

The application level, q_t - if this quantity is selected positive - is subject to technological and institutional constrains:

$$\underline{q} \leq q_t \leq \bar{q} \quad \text{for } q_t > 0 \quad (7)$$

with \underline{q} and \bar{q} exogenous³.

The final date ($t = T$) corresponds to harvesting when actual crop yield becomes known. Let Y denote the crop yield function ; that quantity depends only on the final biomass at date T and is denoted $Y(M_T)$.

The farmer's profit per hectare can be written as:

$$\Pi = r \cdot Y(M_T) - C_{FT} - \sum_{t=1}^{T-1} (c \cdot q_t + \delta_t \cdot C_F) \quad (8)$$

where r denotes the output price; C_{FT} denotes fixed production costs; c is the variable cost for each m^3 of water ; δ_t is a dummy variable taking the value 1 if the farmer irrigates and 0 if not. C_F represents the fixed costs for each irrigation done due to labor and energy costs. We assume in the following that there is no uncertainty on output price.

³Farmers can face some limitations on the quantity q_t of water applied for each irrigation since the investments are fixed in the short term (see Bontems and Favard [3]).

The farmer is represented by a strictly monotonic, increasing and concave Von-Neumann-Morgenstern utility function, denoted U . We chose the most common CRRA utility function:

$$U(\Pi) = \left(\frac{1}{1-\beta} \right) \cdot \Pi^{(1-\beta)} \quad (9)$$

with β ($\beta \neq 1$), the relative risk aversion coefficient. We have assumed a risk aversion coefficient of 0.001, in accordance with the literature⁴ (Jayet [16]).

The farmer's objective is to maximize the expected utility. We have to define now how the farmer does (or does not) incorporate the information he gets during the season. We focus here on two main procedures known as “*feedback*” and “*open-loop*”.

2.2.2 Information sets

- **The feedback strategy**

In this framework, the farmer incorporates all the information he gets during the decision process. At date 1, the farmer takes the decision q_1 according to his weather expectations. At date 2 he integrates the decision made at date 1 and the climate realized during period 1, he may revise his weather expectations using a bayesian rule:

Let $\Omega_c \subset \Omega$ for $c \in C$ denote a particular climate and let I_t be the subset of the climatic information on the period t for $t \in 1, \dots, T$. Let's assume that the corresponding probabilities $P[\Omega_c]$ for $c \in C$ as well as the conditional probabilities $P[I_t|\Omega_c]$ are known⁵. Then from the Bayes's formula we find the *a posteriori* probability:

$$P[\Omega_c|I_t] = \frac{P[I_t|\Omega_c] \cdot P[\Omega_c]}{\sum_{c=1}^C P[I_t|\Omega_c] \cdot P[\Omega_c]} \quad (10)$$

This procedure can be repeated up to date $T - 1$. The result of this classical process (see for example Sim [25]) is that the set of still possible states of the world is reduced via I_t, I_{t+1}, \dots, I_T until finally:

$$I_T \subseteq \Omega_c \text{ so that } P[\Omega_c|I_T] = 1 \text{ for some } c \in C \quad (11)$$

At this stage, the climate is finally known.

⁴The choice of this parameter is beyond the scope of this paper.

⁵In the procedure application (section3) we will use a 14 years database to compute these probabilities.

Through these computations the decision taken at date t clearly depends on the weather conditions observed during the period $[t - 1, t]$ and on the past decisions q_1, \dots, q_{t-1} . Formally, the farmer's sequential problem is:

$$\text{Max}_{q_1} E_{\Omega} \text{Max}_{q_2} E_{\Omega|I_1} \dots \text{Max}_{q_{T-1}} E_{\Omega|I_{T-2}} E_{\Omega|I_{T-1}} \left[U \left(r \cdot Y(M_T) - C_{FT} - \sum_{t=1}^{T-1} (c \cdot q_t + \delta_t \cdot C_F) \right) \right] \quad (12)$$

$$s/c \quad \begin{cases} M_{t+1} - M_t = f_t(M_t, V_t, \omega_t) \\ V_{t+1} - V_t = g_t(M_t, V_t, q_t, \omega_t) \\ Q_{t+1} - Q_t = -q_t \end{cases} \quad (13)$$

and subject to the technical constraint

$$\text{and } s/c \quad \begin{cases} \delta_t = \begin{cases} 0 & \text{si } q_t = 0 \\ 1 & \text{si } q_t > 0 \end{cases} \\ \underline{q} \leq q_t \leq \bar{q} \quad \text{iff } q_t > 0 \\ M_t \geq 0, \quad V_t \geq 0, \quad Q_t \geq 0 \\ M_1 = \bar{M}, \quad V_1 = \bar{V}, \quad Q_1 = Q \end{cases} \quad (14)$$

Where

E_{Ω} denotes the expectation over the climatic alea for the whole season or *a priori* distribution.

$E_{\Omega|I_{t-1}}$ represents the conditional expectation on Ω revised from the Bayes formula or *a posteriori* distribution.

• The open-loop strategy

On the contrary, the farmer's decision program is an "*open-loop*" one if he decides to choose all irrigations, $\{q_t\}_{t=1, \dots, T-1}$, before observing stochastic variables. In this case, all the decisions are made at date 1. At each period, the farmer does not revise his expectations. This procedure serves as benchmark since no information is incorporated during the season. The problem is the following:

$$\text{Max}_{\{q_t\}_{t=1, \dots, T-1}} E_{\Omega} \left[U \left(r \cdot Y(M_T) - C_{FT} - \sum_{t=1}^{T-1} (c \cdot q_t + \delta_t \cdot C_F) \right) \right] \quad (15)$$

subject to the above dynamics and technical constrains (13) and (14).

In this expression E_Ω represents, as in the previous section, the expectation on the whole climatic information set.

Under uncertainty, the two classes of strategies, *open-loop* and *feedback*, can be distinguished by the amount of information used and the anticipation of future knowledge. It is well-known that because information is never strictly useless, the farmer should prefer feedback to open-loop decisions. In real world situations, the farmer's strategy probably lies somewhere between these two extreme cases and some feedback must take place at some points in time.

2.3 Estimation procedure

2.3.1 Database

We need a database relating the total quantities of water to the maximized utilities in order to estimate the utility and the water demand functions. These data are obtained by solving the farmer's program described in the previous section (2.2) for different total quantities of water. Before solving the decision problem⁶ for the two strategies, we need to characterize the production function $Y(M_T)$. That function is not pre-specified. We use an agronomic model, EPIC-PHASE (Cabelguenne and Debaeke [6]) to numerically represent it; this model also generates information relating to state variables previously represented by the functions $f_t(\cdot)$ and $g_t(\cdot)$. Using this crop growth simulation model it is possible to simulate yields for a large variety of soils and climatic conditions. The output from EPIC-PHASE is used as input in the economic model. Then the economic model evaluates utilities for various amounts of water available and for various climates. Finally the decision problem is solved using a global optimization framework and the optimized utilities are computed.

The optimization problem we are facing here is not a trivial one: for a given climate, and a given quantity of water Q , one has to find the irrigation schedule (q_1, \dots, q_{T-1}) subject to (13) and (14) which maximizes the farmer's expected utility (equation (12) or (15)). Of course the farmer does not know the climate, and has to incorporate some information on it using an *open-loop* or a *feedback* strategy. We will need for that to incorporate the anticipated climate at beginning of the season or revised anticipations during the season.

⁶The numerical procedure of resolution integrating the agronomic model, an economic model, and an algorithm of search of the solution is detailed in Bontemps and Couture [1].

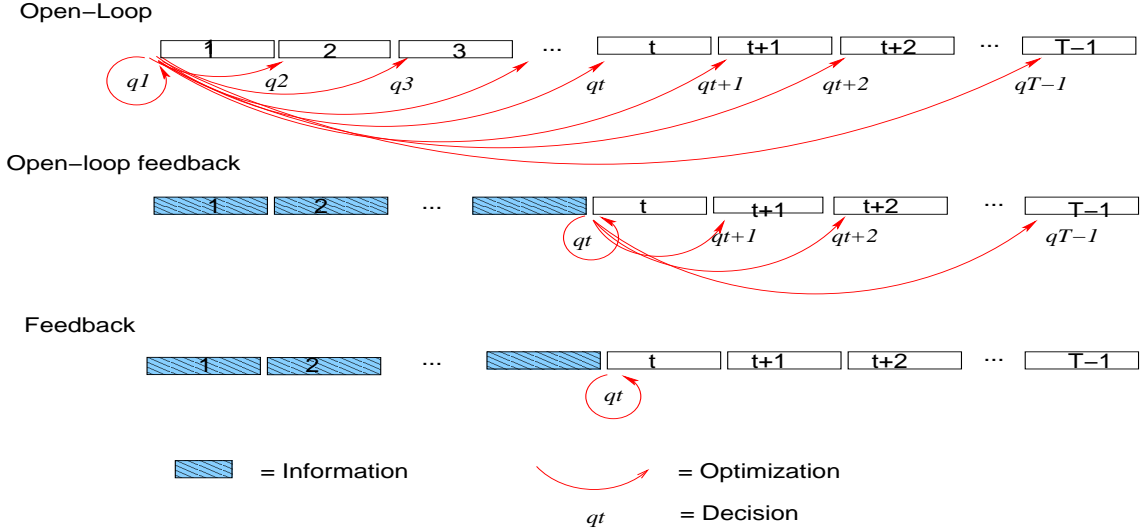


Figure 1: **Optimization process.**

The resolution of this problem is based on a method of global optimization over the set of possible irrigation schedules. In both cases, the set of constraints defined by (14) reduces the space of available irrigation schedules. Therefore the problem may be solved using an algorithm of search on all possible cases at each step. However, the objective functions being quite different, the procedure is different for the two cases.

In the *open-loop* case, the farmer has some anticipation on the climate and computes his optimal schedule at the beginning of the season. For any given value of the total quantity of water, and for any schedule, the model defined above may evaluate the utility function upon the anticipated climate. Because of the constraints inherent to the problem, the set of all possible irrigation schedules is not too large. One may then compute the expected utilities for each schedule. The optimal decision pattern is simply obtained by examining exhaustively the corresponding set of expected utilities. Finally, we repeat this procedure for different total quantities of water, and for various climates. Once the schedule maximizing the expected utility is found, we run the model on the real climate and find the real optimized utility, $U^*(Q)$.

In the *feedback* case, the problem is more tricky because at each decision step the farmer observes the climate and revises his anticipation before computing the schedule for the period. Because of the nature of our production function, which gives the output at the end of the

season, we use an approximation of the *feedback* program called "*open-loop feedback*" and assume that the farmer optimizes the schedule for the rest of the season. Since he does this operation at each decision period, it only retains the decision for the period considered, the approximation is therefore very close to the "*pure*" *feedback* strategy presented above (see Figure 1). The optimization program uses the same methodology than in the *open-loop* case. At each decision step we compute the set of the irrigation schedules still possible. We also compute the new anticipation using Bayes's formula and the observed climatic information. We run the crop simulation program over all these schedules taking into account the real observed climate at that period, and the expected ones. We find the optimal expected utility and schedule, take the corresponding decision and go to the next decision step⁷ until we reach the final decision⁸ and get the complete schedule. As in the latter case, we then run the real climate for that schedule and find the corresponding utility, $U^*(Q)$. We repeat this procedure for different quantities of water, and for various climatic years.

The database created in both situations consists in pairs (*quantity of water, optimized utility*) for various climates, and is well designed for estimating the utility and demand functions distributions over a climatic range. This database will be used through the non-parametric estimation procedure. An important feature of the demand functions we are estimating here is that they depend on stochastic climatic conditions, and therefore are stochastic. We will therefore estimate these functions for different climatic realizations and derive the main characteristics of the demand function distribution.

2.3.2 Estimation

In order to estimate the water value, it is necessary to estimate the optimized utility function and its derivative. We use a nonparametric method to estimate these functions. A major advantage of nonparametric approach is that it allows to estimate an unknown function without assuming its form⁹. Another feature is that the estimation is only based on the data ; nonparametric estimators are all based on a weighted sum of functions of the data. The general procedure for estimating the utility function for a given climate is described in Appendix A; the procedure is the same for estimating demand functions.

⁷Note that for the first step, the procedure is exactly the one used in the *open-loop* case.

⁸The program may stop before the last period if there is no more choice, for example if the total quantity of water has been used totally in the first decision periods.

⁹The choice of the specifications of the considered functions, in particular the yield-water function, is always being debated at the present time.

3 An application in the South-West of France

Demand functions were estimated using the former procedure with data from the South-West of France (these data are described in Appendix B). In this area, agriculture is the largest water consumer with 2/3 of total water consumption. During low river flow periods there is a strong competition for water with urban and industrial uses. In this area, irrigated agriculture is quite recent and concerns most crops. Irrigation needs depend strongly on weather conditions. Irrigation water is generally drawn from rivers supplied by mountain reservoirs. The irrigation tools used in the South-West of France are generally sprinkler systems. The reference crop is corn because it remains the main irrigated crop in this area.

3.1 Results

The stochastic variability is presented in these results through three climates a “dry” one corresponding to real data of the year 1989, a “humid” year (1993) and a “normal” one (1991).

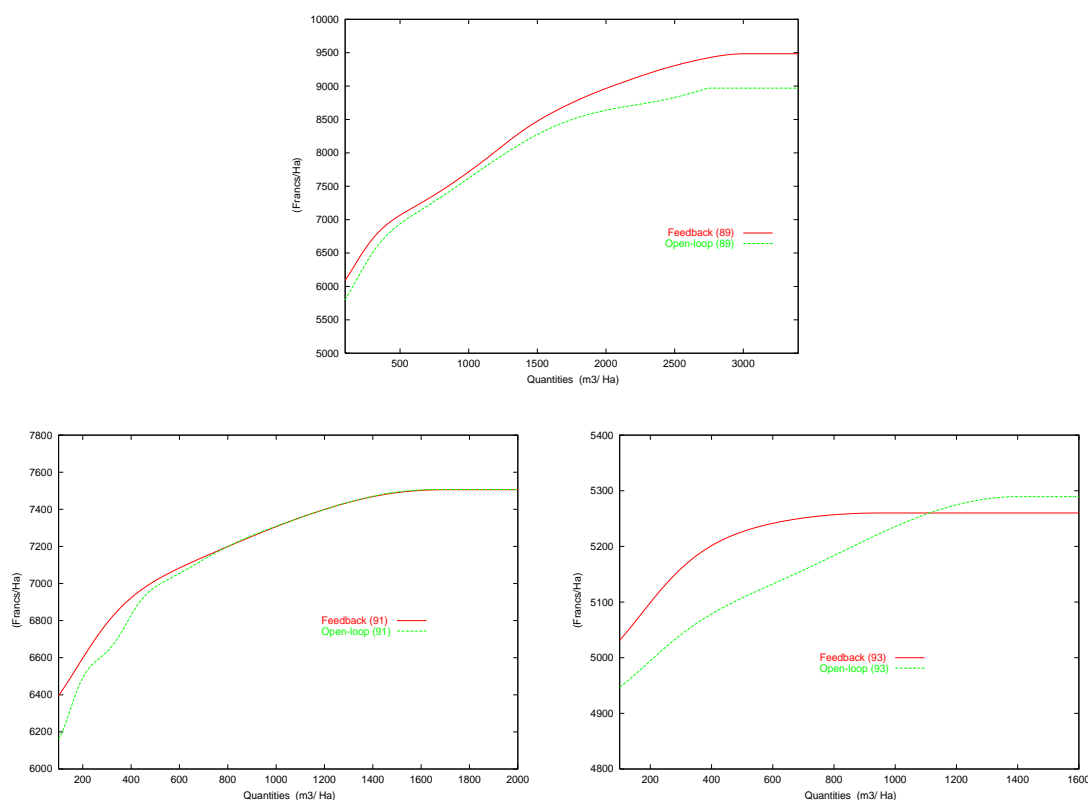


Table 1: Utility functions for “Dry”, “Medium” and “Humid” year.

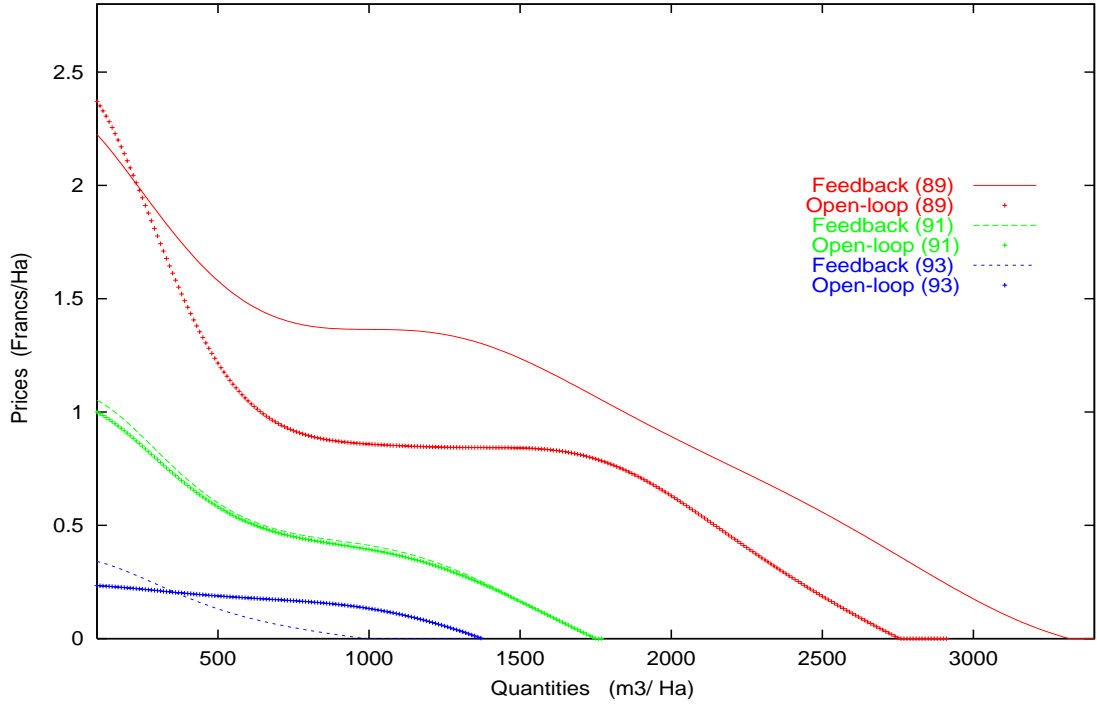


Figure 2: Demand functions for “*Dry*”, “*Medium*” and “*Humid*” year.

We use these climatic years as high and low bounds of the distributions under study. We have run the simulation model for 9 quantities¹⁰ of water for the irrigation season ($Q \in [0, 4000]m^3/ha$).

3.1.1 Utility

The first results we observe from the utilities estimations presented in Table 1 are in accordance with what could be expected: Within a climatic year the more information you have, the higher the utility. Between the climatic years the drier the climate, the higher the utility. We may also notice that the shapes of the functions are quite identical.

3.1.2 Demand

Figure 2 reveals that the shapes of the demand functions are more or less the same. They present four areas: In the first one the curve is highly decreasing, becomes almost flat in the second, decreases greatly again in the third before changing its curvature once more at the end. Another common feature of the distribution presented, is that in each case we find a

¹⁰This number is limited mainly because the computation time for the agronomic model EPIC is important and because the optimization procedure requires a great number of simulations.

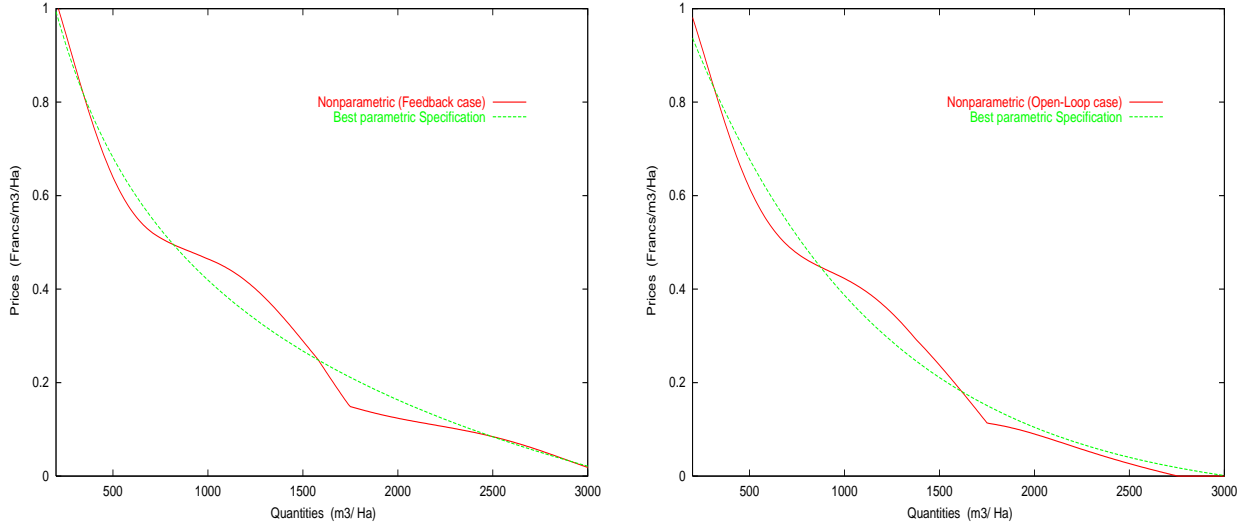


Table 2: Parametric versus Nonparametric comparison in the *feedback* and *open-loop* case

null price for some level of the total quantity of water and a maximum price for very small amounts of water. Note that, as for the utilities, the ordering of the functions is logical, between the three climates.

These curves give a good representation of what the distribution should be. We will not analyze in detail the general features of these curves, even if they represent the distribution bounds of the irrigation water demand under uncertainty, and focus in section (3.2) on the the shape of the mean willingness to pay functions (Figure 3). These curves are certainly the ones a regulator would closely look before setting either a price or a quota in situations where the water is scarce.

3.1.3 Parametric versus nonparametric demand functions

The nonparametric estimation of irrigation water demand provides a precise figure of the demand function without assuming any parametric specification of this function. However it may be interesting to have a parametric, and more practical, form for this function. Moreover, almost all irrigation demand studies use some *ad-hoc* parametric specifications for the profit or production functions (Moore *et al.* [22] or Hassine and Thomas[12]) and therefore indirectly specify the demand function. We have estimated parametrically by nonlinear regression, the mean demand functions using the data generated by the nonparametric procedure. We have tested several specifications having the same shape than the nonparametric demand function. The table 3 gives some of the specifications we have tested and their

Specifications	Parameters	Demands	
		Feedback	Open
(1) : $P = \alpha_1 + \beta_1 \cdot \exp(-\gamma_1 \cdot Q)$	$\hat{\alpha}_1$	-0.043948	-0.058292
	$\hat{\beta}_1$	1.220422	1.216876
	$\hat{\gamma}_1$	0.000941	0.001006
	r^2	0.993415	0.9951764
(2) : $P = \alpha_3 + \beta_3/\sqrt{Q}$	$\hat{\alpha}_3$	-0.113706	-0.147926
	$\hat{\beta}_3$	13.498286	13.459313
	r^2	0.896510	0.898665
(3) : $P = \alpha_4 + \beta_4/\sqrt{Q} + \gamma_4/\sqrt[3]{Q}$	$\hat{\alpha}_4$	-1.388966	-1.4001683
	$\hat{\beta}_4$	-42.634237	-41.660033
	$\hat{\gamma}_4$	31.563734	30.994017
	r^2	0.99467271	0.994237

Table 3: Results of nonlinear regressions

associated R^2 .

We have graphically represented the comparison of the best parametric specification and the nonparametric estimations of the mean demand functions in the table 4. We may notice two important points, first at this level¹¹, the parametric curves gives a good approximation of the nonparametric ones, but these parametric functions are, by construction, convex.

This means that the four areas we have discussed earlier and which are of great importance, are no longer present in the demand functions. The use of these parametric representations of the demand function for policy analysis may be misleading.

3.2 Economic analysis

3.2.1 Policy implication

The shape of the mean demand functions presented in figure 3 are similar whatever the information set. As previously mentioned, they present four main areas¹² schematically represented in figure 4.

For high prices (above 0.50 *francs/m*³), the water irrigation demand is inelastic. This

¹¹To have a better comparison and test between parametric and nonparametric curves one may use specific tests (see Härdle and Mammen [11]), we only provide here indications based on the R^2 .

¹²In the figure 2, these areas appear even more clearly for some climates and cases.

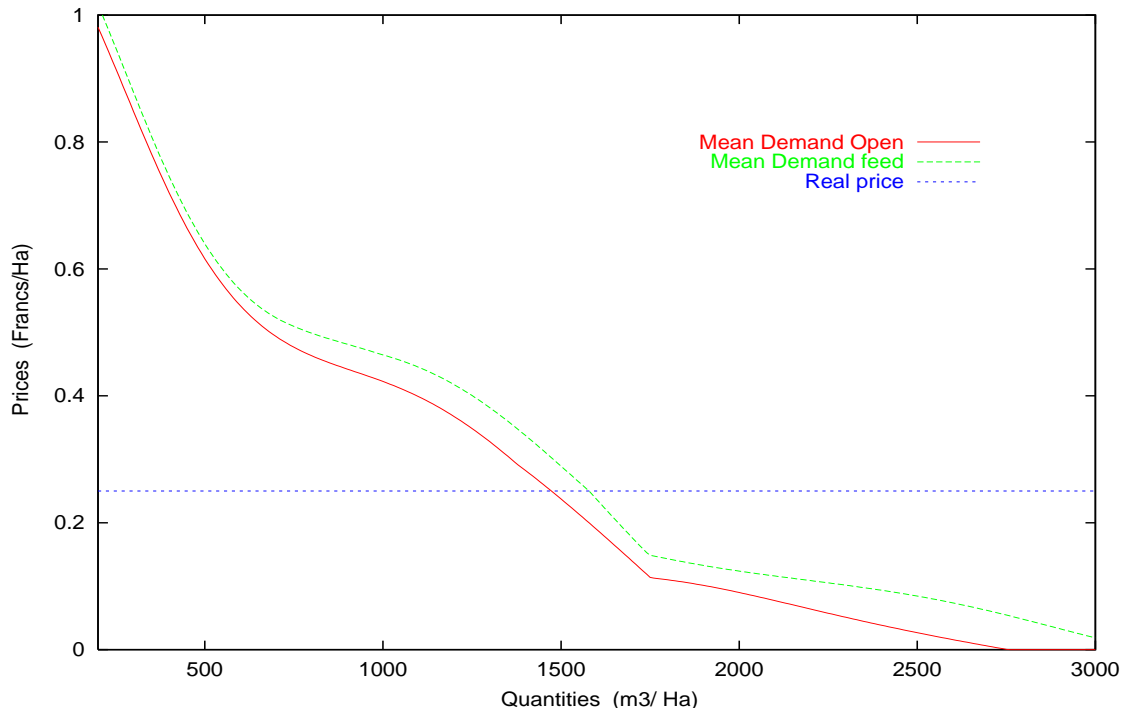


Figure 3: Mean demand functions in the ‘*open-loop*’ and “*feedback*” case.

area corresponds to very small quantities where the farmer considers water as an essential input to crop growth; consequently, he will reduce his consumption for significant changes in water price. The second area (prices between 0.40 and 0.50 *francs/m³*), corresponds to larger quantities where the farmer is more responsive to changes in water price. The plant has reached a satisfactory level of growth; water is no more an essential input and is not yet a risk reducing input. But, we find here a third, non-intuitive, area where the demand becomes inelastic again (prices beyond 0.40 *francs/m³*). In this area the water is a risk reducing input, the farmer chooses large water quantities to insure a maximum and certain level of profit. Therefore to reduce the farmer’s consumption the regulator has to increase strongly the price. Finally, for very large quantities, the demand is elastic in the fourth area.

Demands		
	Feedback	Open-loop
Price elasticity	-0.31	-0.34

Table 4: Price elasticities for a consumption of $1500m^3/Ha$.

The real price of the water is in the third area (0.25 *francs/m³*), where the demand is

quite inelastic. This *visual* analysis is confirmed by the computation of the price elasticities given in table 4. We find that the ratio of change in consumption is less than the ratio of change in price for the real water price.

All previous results are crucial information for the regulator in order to analyze the effects of a water regulation policy. There are two main ways of regulating, using quotas or prices.

Let's consider that the regulator imposes a quota, fixed¹³ to $1500 \text{ m}^3/\text{ha}$. We can analyze the impact of the reduction of this quota down to $1350 \text{ m}^3/\text{ha}$ (10% reduction) for the farmer. The loss in the farmer's surplus is around $50 \text{ francs}/\text{ha}$ (0.75%) whatever the case. If the regulator wants to maintain the farmer's revenue at the the initial level, he will have to subsidize the loss up to this sum.

If the regulator imposes a price regulation, the effects of the increase in price will depend on the area of the initial and final prices. For example, if we analyze the increase of $0.10 \text{ francs}/\text{m}^3$ starting with an initial price of $0.25 \text{ francs}/\text{m}^3$, in the third or *risk reduction* area, the total quantity of water is reduced by $230 \text{ m}^3/\text{ha}$ (15.65% of the initial consumption) and the surplus is reduced by $94 \text{ francs}/\text{ha}$ (1.29% of the initial surplus). The same increase from $0.40 \text{ francs}/\text{m}^3$ up to $0.50 \text{ francs}/\text{m}^3$, in the *intermediate* area, leads to a much greater reduction of water by $420 \text{ m}^3/\text{ha}$ (38.5%). The loss in terms of revenue is then $272 \text{ francs}/\text{ha}$ (3.83% of the initial surplus). As the real price lies in the *risk reducing* area, the water pricing policy will be efficient if the increased price reaches the *intermediate area*, even more if it reaches the left border of this area. An increase of the real price leading to a new price within the same area will have few impacts on water consumption.

4 Conclusion

Our paper presents estimations of the seasonal irrigation water demand under uncertainty. We based our approach on the evaluation of the farmer's willingness to pay for an additional unit of the ressource under water scarcity and stochastic weather conditions. Utility functions are obtained through a sequential decision program for two main strategies, open-loop and feedback.

The farmer's dynamic program of decision is solved by a numerical procedure integrating a crop-growth model, and an optimization process linked to the economic model. A non-parametric estimation process is finally performed to derive the demand fonctions from the

¹³This quantity corresponds to an average of the farmer's consumption in this area.

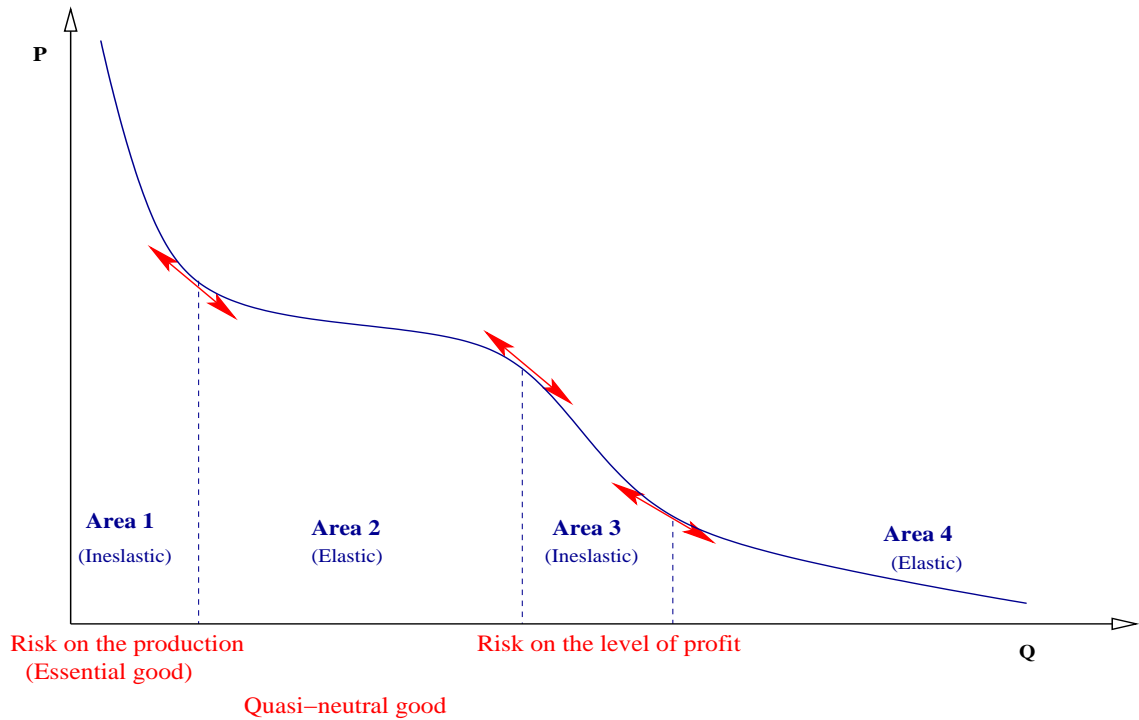


Figure 4: Schematic representation of the seasonal irrigation water demand curves.

utilities. This procedure is applied to estimate demand functions for data from South-west of France. We obtain these functions for various climatic conditions, and thus characterizing the distribution of the demand functions under uncertainty.

We show that irrigation demand functions depend on climate and information sets, but have the same shapes. They can be decomposed into four main areas. For small water quantities, the demand is inelastic and then becomes elastic while increasing water quantities. The demand becomes inelastic again and finally appears elastic for larger water quantities. This result (four-area decomposition of demand function) is a crucial information for the regulator to define a water regulation policy.

References

- [1] Bontemps C.; S. Couture [2001]. "Dynamics and uncertainty in irrigation management". *Cahiers d'Economie et Sociologie Rurales* No. 55-56, 2000.
- [2] Bontemps C.; S. Couture [2001]. "Evaluating irrigation water demand". *Environment and Development Economics*, forthcoming.
- [3] Bontemps P.; P. Favard [2001]. "Towards an acceptable way of reducing agricultural water over-consumption" *Mimeo*, Toulouse.
- [4] Bontemps P.; A. Thomas [2000]. "Information value and risk premium in agricultural production under risk: the case of split nitrogen application for corn". *American Journal of Agricultural Economics*, Vol.82, pp. 59-70.
- [5] Bouzit A.M. [1996]. Modélisation du comportement des agriculteurs face au risque: investigations de la théorie de l'utilité dépendant des rangs. *PH'D dissertation*. ENS Cachan.
- [6] Cabelguenne M.; P. DEBAEKE [1995]. *Manuel d'utilisation du modèle EWQTPR (Epic-Phase temps réel) version 2.13*. Ed. Station d'Agronomie Toulouse INRA.
- [7] Chavas J.P.; M.T. Holt [1996]. "Economic behavior under uncertainty: a joint analysis of risk preferences and technology". *Review of Economics and Statistics* 78: 329-335.
- [8] Couture S. [2000]. Aspects dynamiques et aléatoires de la demande en eau d'irrigation. *PH'D dissertation*. Université de Toulouse I.
- [9] Garrido A.; C. Varela-Ortega; J.M. Sumpsi [1997]. "The interaction of agricultural pricing policies and water districts' modernization programs: a question with unexpected answers." *Paper presented at the Eighth Conference of the European Association of Environmental and Resource Economists, Tilburg, The Netherlands, june 26-28*.
- [10] Härdle W. [1990]. *Applied nonparametric regression*. Econometric society monographs. Cambridge University Press.
- [11] Härdle W. and Mammen [1993]. "Comparing nonparametric versus parametric regression fits", *Annals of statistics*, Vol. 21, no 4, pp.1926-1947.

- [12] Hassine N.B.H.; A. Thomas [1997]. "Agricultural production, attitude towards risk, and the demand for irrigation water: the case of Tunisia." *Working paper, Université de Toulouse*.
- [13] Howitt R.E.; W.D. Watson; R.M. Adams [1980]. "A reevaluation of price elasticities for irrigation water." *Water Resources Research* 16: 623-628.
- [14] Iglesias E.; A. Garrido; J. Sumpsi; C. Varela-Ortega [1998]. "Water demand elasticity: implications for water management and water pricing policies." *Paper presented at the World Congress of Environmental and Resource Economists, Venice, Italy, june 26-28*.
- [15] ITCF. [1998]. "Données prix céréales". *Document de travail*.
- [16] Jayet P.A. (1992). "L'exploitation agricole et l'aversion au risque. Approximation MOTAD du modèle (E,V) et comportement de court terme dans un ensemble de production simplifié". *Méthode et Instrument* 1. ESR-INRA. Grignon.
- [17] Mack Y.; Müller [1989]. "Derivative estimation in nonparametric regression with random predictor variable". *Sankhya* 51: 59-72.
- [18] Michalland B. [1995]. Approche économique de la gestion de la ressource en eau pour l'usage de l'irrigation. *PH'D dissertation*. Université de Bordeaux.
- [19] Montginoul M.; T. Rieu [1996]. "Instruments économiques et gestion de l'eau d'irrigation en France." *La Houille Blanche* 8: 47-54.
- [20] Moore M.R.; D.H. Negri "A multicrop production model of irrigated agriculture, applied to water allocation policy of the bureau of reclamation." *Journal of Agricultural and resources Economics* 17: 30-43.
- [21] Moore M.R.; N.R. Gollehon; M.B. Carrey [1994], "Alternative models of input allocation in multicrop systems: irrigation water in the Central Plains, United States." *Agricultural Economics* 11: 143-158.
- [22] Moore M.R.; N.R. Gollehon; M.B. Carrey [1994]. "Multicrop production decisions in western irrigated agriculture: the role of water price." *American Journal of Agricultural Economics*: 359-74.
- [23] Ogg C.W.; N.R. Gollehon [1989]. "Western irrigation response to pumping costs: a water demand analysis using climatic regions." *Water Resource research* 25: 767-773.

- [24] Pope R.D.; R.E. Just [1991]. "On testing the structure of risk preferences in agricultural supply system". *American Journal of Agricultural Economics*: 743-748.
- [25] Sim H.W. [1989]. *Economic Decisions Under Uncertainty*. Physica-Verlag Heidelberg.
- [26] Shunway C.R. [1973]. "Derived demand for irrigation water: The California aqueduct." *Southwestern Journal of Agricultural Economics* 5: 195-200.
- [27] Varela-Ortega C.; J.M. Sumpsi; A. Garrido; M. Blanco M; E. Iglesias [1998]. "Water pricing policies, public decision making and farmers' response : implications for water policy." *Agricultural Economics* 19: 193-202.
- [28] Vieu P. [1993]. Bandwidth selection for kernel regression: a survey. In *Computer Intensive Methods in Statistics*, Vol. 1, W. Härdle et L. Simar eds., Physica-Verlag.

A The nonparametric procedure of estimation

We will detail the general procedure for a given climate, the procedure is the same for estimating the *mean utility* and *mean demand* function.

A.1 Utility function estimation

For this almost final step, we use the data resulting from the optimization procedure described above, and simply represented for a given climate as a sequence of couples $(Q_i, U_i^*)_{i=1, \dots, n}$.

For a given climate, the unknown function, $U^*(\cdot)$, is estimated from n couples (Q_i, U_i^*) . The kernel estimator of utility function evaluated for any value of Q , is a weighted sum of the observed responses Q_i , the weight being a continuous function of observed quantities, Q_i , and current evaluation point Q (see Härdle [10] for details). It is defined as:

$$\widehat{U}^*(Q) = \frac{\sum_{i=1}^n U_i^* \cdot K\left(\frac{Q_i - Q}{h}\right)}{\sum_{i=1}^n K\left(\frac{Q_i - Q}{h}\right)} \quad \forall Q \in R \quad (16)$$

where $K(\cdot)$ is a kernel function, continuously differentiable. We use a Gaussian kernel function among existing kernel functions¹⁴. Note that $\widehat{U}^*(Q)$ will inherit all the continuity and differentiability properties of K . Therefore $\widehat{U}^*(Q)$ is continuous and differentiable. The bandwidth, noted h , determines the degree of smoothness of $\widehat{U}^*(Q)$; its choice will be discussed later in this section.

A.2 Demand function estimation

In order to estimate the demand function, we will use the property that the utility function estimator is differentiable. If the estimate $\widehat{U}^*(Q)$ properly reflects the utility function, $U^*(Q)$, then the estimate of the utility function derivative is equal to the derivative of the estimate of the utility function (Härdle [10]). Therefore a derivation of (16) with respect to Q will give an estimator of the demand function¹⁵.

In other words, the estimator $\frac{\partial \widehat{U}^*}{\partial Q}(\cdot)$ of the unknown function $\frac{\partial U^*}{\partial Q}(\cdot)$ is just the derivative

¹⁴Estimations based on Epanechnikov kernel slightly differ from the Gaussian kernel estimator.

¹⁵Note that the Mack and Müller's estimator [17] is easier to use for derivation since it has a denominator which does not depend on the derivative variable (Q here). Since the derivation calculus are quite obvious in our case, we have used the 'classic' kernel estimator, but we suggest to use this estimator for advanced derivation estimation.

of the estimator $\widehat{U^*}(\cdot)$. More precisely:

$$\frac{\partial \widehat{U^*}}{\partial Q}(Q) = \frac{\partial}{\partial Q} \left(\frac{\sum_{i=1}^n U_i^* \cdot K\left(\frac{Q_i - Q}{h}\right)}{\sum_{i=1}^n K\left(\frac{Q_i - Q}{h}\right)} \right) \quad \forall Q \in R \quad (17)$$

This can be rewritten as:

$$\begin{aligned} \frac{\partial \widehat{U^*}}{\partial Q}(Q) &= \frac{1}{\left(\sum_{i=1}^n K\left(\frac{Q_i - Q}{h}\right)\right)^2} \cdot \left(- \left(\sum_{i=1}^n U_i^* \cdot \frac{1}{h} \cdot K'\left(\frac{Q_i - Q}{h}\right)\right) \cdot \left(\sum_{i=1}^n K\left(\frac{Q_i - Q}{h}\right)\right) \right. \\ &\quad \left. + \left(\sum_{i=1}^n U_i^* K\left(\frac{Q_i - Q}{h}\right)\right) \cdot \left(\sum_{i=1}^n \frac{1}{h} \cdot K'\left(\frac{Q_i - Q}{h}\right)\right) \right) \end{aligned}$$

We will not present the details of this calculus here, note however that since the kernel function $K(\cdot)$ is continuously differentiable, the estimator $\frac{\partial \widehat{U^*}}{\partial Q}(Q)$ is also continuously differentiable.

A.3 Smoothing parameter selection

Choosing the bandwidth, h , is always a crucial problem. If h is small, then we get an interpolation of the data. On the other hand, if h is high, then the estimator is a constant function that assigns the sample mean to each point. There exist several approaches to bandwidth selection (Vieu [28]) using theoretical considerations (*plug-in method*) or data-based method (*cross-validation method*).

A feature of these approaches is that the selected bandwidth is not fully adapted, particularly if observation data are small. We use as a benchmark the value obtained by cross-validation. The aim of this method is to choose a value for h minimizing the cross-validation criterion, defined as a sum of distances between the estimator $\widehat{U^*}(\cdot)$ evaluated at Q_i and the real data observed U_i^* . We denote the bandwidth selected by the cross-validation criterion by h^* . In practice, a refinement consists in using a slightly smaller bandwidth than h^* in order to limit oversmoothing. Following Härdle ([10] p. 160), the smoothing parameter selected for demand function estimator is the same that the one chosen for utility function estimator, even if this argument may be discussed.

B Data

A first set of data is required by the crop growth simulator model. This data set includes weather, soil, technical and irrigation practices, and crop data. The daily weather input file

Year	Output price	Water price	Fixed Cost per irrigation	Fixed cost
	r (Francs/Tonne)	c (Francs/ m^3)	C_F (Francs)	C_{FT} (Francs)
1989	1049	0.25	150	2150
1991	1038	0.25	150	2150
1993	778	0.25	150	2150

Table 5: Output and input prices (Source: ITCF [15]; Michalland [18] and Couture [8]).

was developed from data collected at the INRA station in Toulouse, for a 14-years series (1983-1996). The soil characteristic data were included in the crop growth model. The soil is clayey and chalky.

Economic output and input price data are included as a secondary data set, see table 5. Output prices are farm-level producer prices. Input prices include irrigation variable costs and fixed costs by watering, and other fixed production costs. The fixed cost, (C_F), per irrigation includes energy and labor costs. The fixed production costs, (C_{FT}), are composed of fertilizer, nitrate, seed, and hail insurance costs.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Papers Series

Our working papers are available on the Internet at the following addresses:

Server WWW: WWW.FEEM.IT

Anonymous FTP: FTP.FEEM.IT

To order any of these papers, please fill out the form at the end of the list.

CLIM	1.2000	<i>Claudia KEMFERT</i> : <u>The Impacts of Emissions Trading on World Economies. Contemplation of baseline emissions paths and a ceiling on emissions trading</u>
CLIM	2.2000	<i>Pascal FAVARD</i> : <u>Does Productive Capital Affect the Order of Resource Exploitation?</u>
CLIM	3.2000	<i>Robert T. DEACON</i> (xxxix): <u>The Political Economy of Environment-Development Relationships: A Preliminary Framework</u>
SUST	4.2000	<i>Piet RIETVELD and Roberto ROSON</i> : <u>Joint Costs in Network Services: the Two-way Problem in the Case of Unbalanced Transport Markets</u>
CLIM	5.2000	<i>Robert S. PINDYCK</i> (xxxix): <u>Irreversibilities and the Timing of Environmental Policy</u>
MGMT	6.2000	<i>Domenico SINISCALCO, Stefania BORGHINI, Marcella FANTINI and Federica RANGHIERI</i> (xI): <u>The Response of Companies to Information-Based Environmental Policies</u>
SUST	7.2000	<i>Guy D. GARROD, Riccardo SCARPA and Ken G. WILLIS</i> : <u>Estimating the Benefits of Traffic Calming on Through Routes: A Choice Experiment Approach</u>
CLIM	8.2000	<i>ZhongXiang ZHANG</i> : <u>Estimating the Size of the Potential Market for the Kyoto Flexibility Mechanisms</u>
VOL	9.2000	<i>Jean-Christophe PEREAU and Tarik TAZDAIT</i> (xli): <u>Partial and Global Cooperation with Unilateral Commitment in the Presence of Global Environmental Problems</u>
KNOW	10.2000	<i>Giacomo CALZOLARI and Giovanni IMMORDINO</i> : <u>Hormone Beefs, Chloridric Chicken and International Trade: Can Scientific Uncertainty be an Informational Barrier to Trade?</u>
CLIM	11.2000	<i>Laura MARSILIANI and Thomas I. RENSTRÖM</i> (xxxvi): <u>Imperfect Competition, Labour Market Distortions, and the Double Dividend Hypothesis</u>
KNOW	12.2000	<i>Patrizia BUSSOLI</i> : <u>An Empirical Analysis of Technological Convergence Process and RIVs in Europe at the Firm Level</u>
KNOW	13.2000	<i>Luigi BENFRATELLO and Alessandro SEMBENELLI</i> : <u>Research Joint Ventures and Firm Level Performance</u>
KNOW	14.2000	<i>Nicholas S. VONORTAS</i> : <u>US Policy towards Research Joint Ventures</u>
ETA	15.2000	<i>Y.H. FARZIN</i> : <u>The Effects of Emissions Standards on Industry in the Short Run and Long Run</u>
ETA	16.2000	<i>Francis BLOCH and Stéphane ROTTIER</i> (xli): <u>Agenda Control in Coalition Formation</u>
CLIM	17.2000	<i>Giovanni IMMORDINO</i> : <u>Looking for a Guide to Protect the Environment: the Development of the Precautionary Principle</u>
CLIM	18.2000	<i>Hans W. GOTTINGER</i> : <u>Negotiation and Optimality in an Economic Model of Global Climate Change</u>
VOL	19.2000	<i>Paola MILIZIA and Marialuisa TAMBORRA</i> : <u>Juridical Framework of Voluntary Agreements in Italy and Policy Relevance at the Local Level</u>
CLIM	20.2000	<i>Richard S.J. TOL, Wietze LISE and Bob van der ZWAAN</i> (xli): <u>Technology Diffusion and the Stability of Climate Coalitions</u>
CLIM	21.2000	<i>Pietro TEATINI and Giuseppe GAMBOLATI</i> (xlii): <u>The Impact of Climate Change, Sea-Storm Events and Land Subsidence in the Adriatic</u>
CLIM	22.2000	<i>Emiliano RAMIERI</i> (xlii): <u>An Overview of the Vulnerability of Venice to the Impacts of Climate Change and Sea Level Rise</u>
PRIV	23.2000	<i>Bernardo BORTOLOTTI, Marcella FANTINI and Carlo SCARPA</i> : <u>Why do Governments Sell Privatised Companies Abroad?</u>
ETA	24.2000	<i>Carlo CARRARO and Gilbert E. METCALF</i> : <u>Behavioral and Distributional Effects of Environmental Policy: Introduction</u>
ETA	25.2000	<i>Santiago J. RUBIO and Juana AZNAR</i> : <u>Sustainable Growth and Environmental Policies</u>
KNOW	26.2000	<i>Francesca RECANATINI and Randi RYTERMAN</i> : <u>Disorganisation or Self-Organisation?</u>
KNOW	27.2000	<i>Giorgio BARBA NAVARETTI and David TARR</i> : <u>International Knowledge Flows and Economic Performance. An Introductory Survey of the Evidence</u>
SUST	28.2000	<i>Francesca CODA CANATI</i> : <u>Secondary Raw Materials Market Creation: Waste Stock Exchange</u>
KNOW	29.2000	<i>Giorgio BRUNELLO and Simona COMI</i> : <u>Education and Earnings Growth. Evidence from 11 European Countries</u>
CLIM	30.2000	<i>Michael GRUBB</i> : <u>The Kyoto Protocol: an Economic Appraisal</u>
CLIM	31.2000	<i>Gérard MONDELLO and Mabel TIDBALL</i> (xxxix): <u>Environmental Liability and Technology Choice: A Duopolistic Analysis</u>

KNOW	32.2000	<i>Alberto PETRUCCI and Edmund PHELPS</i> : <u>Capital Subsidies Versus Labour Subsidies: A Trade-Off between Capital and Employment?</u>
VOL	33.2000	<i>Petr ŠAUER, Antonín DVORÁK and Petr FIALA</i> : <u>Negotiation between Authority and Polluters – Model for Support of Decision Making in Environmental Policy: Principles and Experimental Case Test</u>
SUST	34.2000	<i>Riccardo SCARPA, George W. HUTCHINSON and Sue M. CHILTON</i> : <u>Reliability of Benefit Value Transfers from Contingent Valuation Data with Forest-Specific Attributes</u>
CLIM	35.2000	<i>Allen PERRY (xlii)</i> : <u>Impact of Climate Change on Tourism in the Mediterranean: Adaptive Responses</u>
CLIM	36.2000	<i>Laura MARSILIANI and T.I. RENGSTRÖM (xxxvi)</i> : <u>Inequality, Environmental Protection and Growth</u>
CLIM	37.2000	<i>Massimiliano MONTINI (xlii)</i> : <u>Italian Policies and Measures to Respond to Climate Change</u>
CLIM	38.2000	<i>Horst STERR, Richard KLEIN and Stefan REESE (xlii)</i> : <u>Climate Change and Coastal Zones. An Overview of the State-of-the-Art on Regional and Local Vulnerability Assessment</u>
CLIM	39.2000	<i>Tullio SCOVAZZI (xlii)</i> : <u>Ideas Behind the New or Updated Mediterranean Legal Instruments</u>
CLIM	40.2000	<i>Dimitrios GEORGAS (xlii)</i> : <u>Assessment of Climatic Change Impacts on Coastal Zones in the Mediterranean. UNEP's Vulnerability Assessments Methodology and Evidence from Case Studies</u>
SUST	41.2000	<i>Herath M. GUNATILAKE and Ujjayant CHAKRAVORTY</i> : <u>Forest Resource Extraction by Local Communities: A Comparative Dynamic Analysis</u>
PRIV	42.2000	<i>Giancarlo SPAGNOLO</i> : <u>Optimal Leniency Programs</u>
CLIM	43.2000	<i>Paolo BUONANNO, Carlo CARRARO, Efrem CASTELNUOVO and Marzio GALEOTTI</i> : <u>Emission Trading Restrictions with Endogenous Technological Change</u>
CLIM	44.2000	<i>Alan S. MANNE and Richard G. RICHEL</i> : <u>A Multi-Gas Approach to Climate Policy – with and without GWPs</u>
WAT	45.2000	<i>Ujjayant CHAKRAVORTY and Chieko UMETSU</i> : <u>Basinwide Water Management: A Spatial Model</u>
CLIM	46.2000	<i>Don FULLERTON, Inkee HONG and Gilbert E. METCALF (xl)</i> : <u>A Tax on Output of the Polluting Industry is not a Tax on Pollution: The Importance of Hitting the Target</u>
PRIV	47.2000	<i>Axel GAUTIER and Dimitri PAOLINI</i> : <u>Delegation and Information Revelation</u>
ETA	48.2000	<i>Andreas PAPANDREOU</i> : <u>Externality, Convexity and Institutions</u>
ETA	49.2000	<i>Cesare DOSI and Michele MORETTO</i> : <u>The Timing of Adoption of Cleaner Technologies: Private Costs and Public Incentives</u>
ETA	50.2000	<i>Michele MORETTO and Roberto TAMBORINI</i> : <u>Liquidity: What can a “Hausbank” do that Other Lenders Cannot Do?</u>
PRIV	51.2000	<i>Michele MORETTO and Paola VALBONESI</i> : <u>Option to Revoke and Regulation of Local Utilities</u>
PRIV	52.2000	<i>Giancarlo SPAGNOLO</i> : <u>Self-Defeating Antitrust Laws</u>
PRIV	53.2000	<i>William L. MEGGINSON and Maria K. BOUTCHKOVA</i> : <u>The Impact of Privatisation on Capital Market Development and Individual Share Ownership</u>
KNOW	54.2000	<i>Giorgio BARBA NAVARETTI, Marzio GALEOTTI and Andrea MATTOZZI</i> : <u>Moving Skills from Hands to Heads: Import of Technology and Export Performance</u>
ETA	55.2000	<i>Elisabetta STRAZZERA, Riccardo SCARPA, Pinuccia CALIA, Guy GARROD and Ken WILLIS</i> : <u>Modelling Zero Bids in Contingent Valuation Surveys</u>
CLIM	56.2000	<i>Paola CONCONI</i> : <u>Can Green Lobbies Replace a World Environmental Organisation?</u>
VOL	57.2000	<i>Paola CONCONI and Carlo PERRONI (xli)</i> : <u>Issue Linkage and Issue Tie-in in Multilateral Negotiations</u>
ETA	58.2000	<i>Fernando JARAMILLO, Hubert KEMPF and Fabien MOIZEAU (xli)</i> : <u>Conspicuous Consumption, Social Status and Clubs</u>
SUST	59.2000	<i>Gianni CICIA and Riccardo SCARPA</i> : <u>Willingness to Pay for Rural Landscape Preservation: A Case Study in Mediterranean Agriculture</u>
CLIM	60.2000	<i>Josef JANSSEN</i> : <u>Will Joint Implementation Survive International Emissions Trading? Distinguishing the Kyoto Mechanisms</u>
CLIM	61.2000	<i>Carlo CARRARO</i> : <u>Costs, Structure and Equity of International Regimes for Climate Change Mitigation</u>
KNOW	62.2000	<i>Alberto BUCCI</i> : <u>On Scale Effects, Market Power and Growth when Human and Technological Capital are Complements</u>
KNOW	63.2000	<i>Alberto BUCCI and H.C. SAGLAM</i> : <u>Growth Maximising Patent Lifetime</u>
WAT	64.2000	<i>Michele MORETTO and Paolo ROSATO</i> : <u>The Value of Licences for Recreational Resources Use</u>
WAT	65.2000	<i>Edi DEFRADESCO and Paolo ROSATO</i> : <u>Recreation Management in Venice Lagoon</u>
KNOW	66.2000	<i>Carlo DELL'ARINGA and Claudio LUCIFORA</i> : <u>Inside the Black Box: Labour Market Institutions, Wage Formation and Unemployment in Italy</u>
CLIM	67.2000	<i>Erkki KOSKELA, Markku OLLIKAINEN and Mikko PUHAKKA</i> : <u>Renewable Resources in an Overlapping Generations Economy without Capital</u>
CLIM	68.2000	<i>A. Lans BOVENBERG and Lawrence H. GOULDER (xl)</i> : <u>Neutralising the Adverse Industry Impacts of CO2 Abatement Policies: What Does it Cost?</u>
KNOW	69.2000	<i>Ioanna KASTELLI</i> : <u>Science and Technology Policy in Greece. Policy Initiatives for R&D Cooperation</u>
CLIM	70.2000	<i>Katrin MILLOCK</i> : <u>Contracts for Clean Development – The Role of Technology Transfers</u>
VOL	71.2000	<i>Alberto CAVALIERE and Fabio FRONTOSO SILVESTRI (xliii)</i> : <u>Voluntary Agreements as Information Sharing Devices: Competition and Welfare Effects</u>

VOL	72.2000	<i>Na Li DAWSON and Kathleen SEGERSON</i> (xliii): <u>Voluntary Agreements with Industries: Participation Incentives with Industry-wide Targets</u>
VOL	73.2000	<i>Patricia M. BAILEY</i> (xliii): <u>The Application of Competition Law and Policy to Environmental Agreements in an Oligopolistic Market</u>
VOL	74.2000	<i>Joanna POYAGO-THEOTOKY</i> (xliii): <u>Voluntary Approaches and the Organisation of Environmental R&D</u>
VOL	75.2000	<i>Scott C. MATULICH, Murat SEVER and Fred INABA</i> (xliii): <u>Cooperative Bargaining to Internalise Open Access Externalities: Implications of the American Fisheries Act</u>
VOL	76.2000	<i>Allen BLACKMAN and James BOYD</i> (xliii): <u>Tailored Regulation: Will Voluntary Site-Specific Environmental Performance Standards Improve Welfare?</u>
VOL	77.2000	<i>Vincenzo DENICOLA'</i> (xliii): <u>A Signaling Model of Environmental Overcompliance</u>
VOL	78.2000	<i>Markus A. LEHMANN</i> (xliii): <u>Voluntary Environmental Agreements and Competition Policy. The Case of Germany's Private System for Packaging Waste Recycling</u>
VOL	79.2000	<i>Hans H.B. VEDDER</i> (xliii): <u>Voluntary Agreements and Competition Law</u>
VOL	80.2000	<i>Thomas P. LYON and John W. MAXWELL</i> (xliii): <u>Self-Regulation, Taxation and Public Voluntary Environmental Agreements</u>
VOL	81.2000	<i>Paola MANZINI and Marco MARIOTTI</i> (xliii): <u>A Bargaining Model of Voluntary Environmental Agreements</u>
VOL	82.2000	<i>Alain NADAI and Benoit MOREL</i> (xliii): <u>Product Ecolabelling, Competition and the Environment</u>
CLIM	83.2000	<i>Simone BORGHESI</i> : <u>Income Inequality and the Environmental Kuznets Curve</u>
KNOW	84.2000	<i>Giorgio BRUNELLO and Massimo GIANNINI</i> : <u>Stratified or Comprehensive? The Economic Efficiency of School Design</u>
KNOW	85.2000	<i>Giorgio BRUNELLO, Simona COMI and Claudio LUCIFORA</i> : <u>The College Wage Gap in 10 European Countries: Evidence from Two Cohorts?</u>
ETA	86.2000	<i>Michael FINUS</i> : <u>Game Theory and International Environmental Co-operation: A Survey with an Application to the Kyoto-Protocol</u>
CLIM	87.2000	<i>Clare GOODESS, Jean PALUTIKOF and Maureen AGNEW</i> (xlii): <u>Climate Change Scenarios for the Mediterranean: A Basis for Regional Impact Assessment</u>
CLIM	88.2000	<i>Ian COXHEAD</i> : <u>Tax Reform and the Environment in Developing Economies: Is a Double Dividend Possible?</u>
SUST	89.2000	<i>Peter BARTELMUS and André VESPER</i> (xliv): <u>Green Accounting and Material Flow Analysis. Alternatives or Complements?</u>
SUST	90.2000	<i>Mark DE HAAN and Steven J. KEUNING</i> (xliv): <u>The NAMEA as Validation Instrument for Environmental Macroeconomics</u>
SUST	91.2000	<i>Jochen JESINGHAUS</i> (xliv): <u>On the Art of Aggregating Apples & Oranges</u>
SUST	92.2000	<i>Jan KOLAR</i> (xliv): <u>Land Cover Accounting in the Czech Republic</u>
SUST	93.2000	<i>Anil MARKANDYA, Alistair HUNT and Pamela MASON</i> (xliv): <u>Valuing Damages for Green Accounting Purposes: The GARP II Approach</u>
SUST	94.2000	<i>Anil MARKANDYA, Pamela MASON and Marialuisa TAMBORRA</i> (xliv): <u>Green National Accounting: Synthesising and Extending the Welfare Based and Sustainability-standard Based Approaches</u>
SUST	95.2000	<i>Martin O'CONNOR</i> (xliv): <u>Towards a Typology of "Environmentally-Adjusted" National Sustainability Indicators: Key Concepts and Policy Application</u>
SUST	96.2000	<i>Anton STEURER</i> (xliv): <u>Towards an Environmental Accounting Framework for the EU</u>
SUST	97.2000	<i>Cesare COSTANTINO, Federico FALCITELLI and Angelica TUDINI</i> (xliv): <u>New Developments in Environmental Accounting at Istat</u>
CLIM	98.2000	<i>Stefan BAYER and Claudia KEMFERT</i> : <u>Reaching National Kyoto-Targets in Germany by Maintaining a Sustainable Development</u>
CLIM	99.2000	<i>ZhongXiang ZHANG</i> : <u>An Assessment of the EU Proposal for Ceilings on the Use of Kyoto Flexibility Mechanisms</u>
KNOW	100.2000	<i>Maria Rosa BATTAGGION and Patrizia BUSSOLI</i> : <u>Italian Policy towards Cooperation in R&D</u>
KNOW	101.2000	<i>Giorgio BARBA NAVARETTI, Patrizia BUSSOLI, Georg VON GRAEVENITZ and David ULPH</i> : <u>Information Sharing, Research Coordination and Membership of Research Joint Ventures</u>
WAT	102.2000	<i>Cesare DOSI and William K. EASTER</i> : <u>Water Scarcity: Institutional Change, Water Markets and Privatisation</u>
WAT	103.2000	<i>Cesare DOSI and Naomi ZEITOUNI</i> : <u>Controlling Groundwater Pollution from Agricultural Nonpoint Sources: An Overview of Policy Instruments</u>
KNOW	104.2000	<i>Alberto PETRUCCI</i> : <u>On Debt Neutrality in the Savers-Spenders Theory of Fiscal Policy</u>
SUST	105.2000	<i>Roberto ROSON and Stefano SORIANI</i> : <u>Intermodality and the Changing Role of Nodes in Transport Networks</u>
CLIM	106.2000	<i>Alain BOUSQUET and Pascal FAVARD</i> : <u>Does S. Kuznets' Belief Question the Environmental Kuznets Curves?</u>
CLIM	107.2000	<i>Ottavio JANNI</i> : <u>EU Biodiversity Conservation in Tropical Countries</u>

VOL	108.2000	<i>Katrin MILLOCK and François SALANIE: <u>Collective Environmental Agreements: An Analysis of the Problems of Free-Riding and Collusion</u></i>
VOL	109.2000	<i>Katrin MILLOCK: <u>The Combined Use of Taxation and Voluntary Agreements for Energy Policy</u></i>
VOL	110.2000	<i>Markus A. LEHMANN: <u>The Impact of Voluntary Environmental Agreements on Firms' Incentives for Technology Adoption</u></i>
SUST	1.2001	<i>Inge MAYERES and Stef PROOST: <u>Should Diesel Cars in Europe be Discouraged?</u></i>
SUST	2.2001	<i>Paola DORIA and Davide PETTENELLA: <u>The Decision Making Process in Defining and Protecting Critical Natural Capital</u></i>
CLIM	3.2001	<i>Alberto PENCH: <u>Green Tax Reforms in a Computable General Equilibrium Model for Italy</u></i>
CLIM	4.2001	<i>Maurizio BUSSOLO and Dino PINELLI: <u>Green Taxes: Environment, Employment and Growth</u></i>
CLIM	5.2001	<i>Marco STAMPINI: <u>Tax Reforms and Environmental Policies for Italy</u></i>
ETA	6.2001	<i>Walid OUESLATI: <u>Environmental Fiscal Policy in an Endogenous Growth Model with Human Capital</u></i>
CLIM	7.2001	<i>Umberto CIORBA, Alessandro LANZA and Francesco PAULI: <u>Kyoto Commitment and Emission Trading: a European Union Perspective</u></i>
MGMT	8.2001	<i>Brian SLACK (xlv): <u>Globalisation in Maritime Transportation: Competition, uncertainty and implications for port development strategy</u></i>
VOL	9.2001	<i>Giulia PESARO: <u>Environmental Voluntary Agreements: A New Model of Co-operation Between Public and Economic Actors</u></i>
VOL	10.2001	<i>Cathrine HAGEM: <u>Climate Policy, Asymmetric Information and Firm Survival</u></i>
ETA	11.2001	<i>Sergio CURRARINI and Marco MARINI: <u>A Sequential Approach to the Characteristic Function and the Core in Games with Externalities</u></i>
ETA	12.2001	<i>Gaetano BLOISE, Sergio CURRARINI and Nicholas KIKIDIS: <u>Inflation and Welfare in an OLG Economy with a Privately Provided Public Good</u></i>
KNOW	13.2001	<i>Paolo SURICO: <u>Globalisation and Trade: A "New Economic Geography" Perspective</u></i>
ETA	14.2001	<i>Valentina BOSETTI and Vincenzina MESSINA: <u>Quasi Option Value and Irreversible Choices</u></i>
CLIM	15.2001	<i>Guy ENGELÉN (xlii): <u>Desertification and Land Degradation in Mediterranean Areas: from Science to Integrated Policy Making</u></i>
SUST	16.2001	<i>Julie Catherine SORS: <u>Measuring Progress Towards Sustainable Development in Venice: A Comparative Assessment of Methods and Approaches</u></i>
SUST	17.2001	<i>Julie Catherine SORS: <u>Public Participation in Local Agenda 21: A Review of Traditional and Innovative Tools</u></i>
CLIM	18.2001	<i>Johan ALBRECHT and Niko GOBBIN: <u>Schumpeter and the Rise of Modern Environmentalism</u></i>
VOL	19.2001	<i>Rinaldo BRAU, Carlo CARRARO and Giulio GOLFETTO (xlili): <u>Participation Incentives and the Design of Voluntary Agreements</u></i>
ETA	20.2001	<i>Paola ROTA: <u>Dynamic Labour Demand with Lumpy and Kinked Adjustment Costs</u></i>
ETA	21.2001	<i>Paola ROTA: <u>Empirical Representation of Firms' Employment Decisions by an (S_s) Rule</u></i>
ETA	22.2001	<i>Paola ROTA: <u>What Do We Gain by Being Discrete? An Introduction to the Econometrics of Discrete Decision Processes</u></i>
PRIV	23.2001	<i>Stefano BOSI, Guillaume GIRMANS and Michel GUILLARD: <u>Optimal Privatisation Design and Financial Markets</u></i>
KNOW	24.2001	<i>Giorgio BRUNELLO, Claudio LUPI, Patrizia ORDINE, and Maria Luisa PARISI: <u>Beyond National Institutions: Labour Taxes and Regional Unemployment in Italy</u></i>
ETA	25.2001	<i>Klaus CONRAD: <u>Locational Competition under Environmental Regulation when Input Prices and Productivity Differ</u></i>
PRIV	26.2001	<i>Bernardo BORTOLOTTI, Juliet D'SOUZA, Marcella FANTINI and William L. MEGGINSON: <u>Sources of Performance Improvement in Privatised Firms: A Clinical Study of the Global Telecommunications Industry</u></i>
CLIM	27.2001	<i>Frédéric BROCHIER and Emiliano RAMIERI: <u>Climate Change Impacts on the Mediterranean Coastal Zones</u></i>
ETA	28.2001	<i>Nunzio CAPPUCCIO and Michele MORETTO: <u>Comments on the Investment-Uncertainty Relationship in a Real Option Model</u></i>
KNOW	29.2001	<i>Giorgio BRUNELLO: <u>Absolute Risk Aversion and the Returns to Education</u></i>
CLIM	30.2001	<i>ZhongXiang ZHANG: <u>Meeting the Kyoto Targets: The Importance of Developing Country Participation</u></i>
ETA	31.2001	<i>Jonathan D. KAPLAN, Richard E. HOWITT and Y. Hossein FARZIN: <u>An Information-Theoretical Analysis of Budget-Constrained Nonpoint Source Pollution Control</u></i>
MGMT Coalition	32.2001	<i>Roberta SALOMONE and Giulia GALLUCCIO: <u>Environmental Issues and Financial Reporting Trends</u></i>
Theory Network	33.2001	<i>Shlomo WEBER and Hans WIESMETH: <u>From Autarky to Free Trade: The Impact on Environment</u></i>
ETA	34.2001	<i>Margarita GENIUS and Elisabetta STRAZZERA: <u>Model Selection and Tests for Non Nested Contingent Valuation Models: An Assessment of Methods</u></i>

NRM	35.2001	<i>Carlo GIUPPONI</i> : <u>The Substitution of Hazardous Molecules in Production Processes: The Atrazine Case Study in Italian Agriculture</u>
KNOW	36.2001	<i>Raffaele PACI and Francesco PIGLIARU</i> : <u>Technological Diffusion, Spatial Spillovers and Regional Convergence in Europe</u>
PRIV	37.2001	<i>Bernardo BORTOLOTTI</i> : <u>Privatisation, Large Shareholders, and Sequential Auctions of Shares</u>
CLIM	38.2001	<i>Barbara BUCHNER</i> : <u>What Really Happened in The Hague? Report on the COP6, Part I, 13-25 November 2000, The Hague, The Netherlands</u>
PRIV	39.2001	<i>Giacomo CALZOLARI and Carlo SCARPA</i> : <u>Regulation at Home, Competition Abroad: A Theoretical Framework</u>
KNOW	40.2001	<i>Giorgio BRUNELLO</i> : <u>On the Complementarity between Education and Training in Europe</u>
Coalition Theory Network	41.2001	<i>Alain DESDOIGTS and Fabien MOIZEAU (xlvi)</i> : <u>Multiple Politico-Economic Regimes, Inequality and Growth</u>
Coalition Theory Network	42.2001	<i>Parkash CHANDER and Henry TULKENS (xlvi)</i> : <u>Limits to Climate Change</u>
Coalition Theory Network	43.2001	<i>Michael FINUS and Bianca RUNDSHAGEN (xlvi)</i> : <u>Endogenous Coalition Formation in Global Pollution Control</u>
Coalition Theory Network	44.2001	<i>Wietze LISE, Richard S.J. TOL and Bob van der ZWAAN (xlvi)</i> : <u>Negotiating Climate Change as a Social Situation</u>
NRM	45.2001	<i>Mohamad R. KHAWLIE (xlvii)</i> : <u>The Impacts of Climate Change on Water Resources of Lebanon-Eastern Mediterranean</u>
NRM	46.2001	<i>Mutasem EL-FADEL and E. BOU-ZEID (xlvii)</i> : <u>Climate Change and Water Resources in the Middle East: Vulnerability, Socio-Economic Impacts and Adaptation</u>
NRM	47.2001	<i>Eva IGLESIAS, Alberto GARRIDO and Almudena GOMEZ (xlvii)</i> : <u>An Economic Drought Management Index to Evaluate Water Institutions' Performance Under Uncertainty and Climate Change</u>
CLIM	48.2001	<i>Wietze LISE and Richard S.J. TOL (xlvii)</i> : <u>Impact of Climate on Tourist Demand</u>
CLIM	49.2001	<i>Francesco BOSELLO, Barbara BUCHNER, Carlo CARRARO and Davide RAGGI</i> : <u>Can Equity Enhance Efficiency? Lessons from the Kyoto Protocol</u>
SUST	50.2001	<i>Roberto ROSON (xlviii)</i> : <u>Carbon Leakage in a Small Open Economy with Capital Mobility</u>
SUST	51.2001	<i>Edwin WOERDMAN (xlviii)</i> : <u>Developing a European Carbon Trading Market: Will Permit Allocation Distort Competition and Lead to State Aid?</u>
SUST	52.2001	<i>Richard N. COOPER (xlviii)</i> : <u>The Kyoto Protocol: A Flawed Concept</u>
SUST	53.2001	<i>Kari KANGAS (xlviii)</i> : <u>Trade Liberalisation, Changing Forest Management and Roundwood Trade in Europe</u>
SUST	54.2001	<i>Xueqin ZHU and Ekko VAN IERLAND (xlviii)</i> : <u>Effects of the Enlargement of EU on Trade and the Environment</u>
SUST	55.2001	<i>M. Ozgur KAYALICA and Sajal LAHIRI (xlviii)</i> : <u>Strategic Environmental Policies in the Presence of Foreign Direct Investment</u>
SUST	56.2001	<i>Savas ALPAY (xlviii)</i> : <u>Can Environmental Regulations be Compatible with Higher International Competitiveness? Some New Theoretical Insights</u>
SUST	57.2001	<i>Roldan MURADIAN, Martin O'CONNOR, Joan MARTINEZ-ALER (xlviii)</i> : <u>Embodied Pollution in Trade: Estimating the "Environmental Load Displacement" of Industrialised Countries</u>
SUST	58.2001	<i>Matthew R. AUER and Rafael REUVENY (xlviii)</i> : <u>Foreign Aid and Direct Investment: Key Players in the Environmental Restoration of Central and Eastern Europe</u>
SUST	59.2001	<i>Onno J. KUIK and Frans H. OOSTERHUIS (xlviii)</i> : <u>Lessons from the Southern Enlargement of the EU for the Environmental Dimensions of Eastern Enlargement, in particular for Poland</u>
ETA	60.2001	<i>Carlo CARRARO, Alessandra POME and Domenico SINISCALCO (xlix)</i> : <u>Science vs. Profit in Research: Lessons from the Human Genome Project</u>
CLIM	61.2001	<i>Efrem CASTELNUOVO, Michele MORETTO and Sergio VERGALLI</i> : <u>Global Warming, Uncertainty and Endogenous Technical Change: Implications for Kyoto</u>
PRIV	62.2001	<i>Gian Luigi ALBANO, Fabrizio GERMANO and Stefano LOVO</i> : <u>On Some Collusive and Signaling Equilibria in Ascending Auctions for Multiple Objects</u>
CLIM	63.2001	<i>Elbert DIJKGRAAF and Herman R.J. VOLLEBERGH</i> : <u>A Note on Testing for Environmental Kuznets Curves with Panel Data</u>
CLIM	64.2001	<i>Paolo BUONANNO, Carlo CARRARO and Marzio GALEOTTI</i> : <u>Endogenous Induced Technical Change and the Costs of Kyoto</u>
CLIM	65.2001	<i>Guido CAZZAVILLAN and Ignazio MUSU (I)</i> : <u>Transitional Dynamics and Uniqueness of the Balanced-Growth Path in a Simple Model of Endogenous Growth with an Environmental Asset</u>
CLIM	66.2001	<i>Giovanni BAIOCCHI and Salvatore DI FALCO (I)</i> : <u>Investigating the Shape of the EKC: A Nonparametric Approach</u>

CLIM	67.2001	<i>Marzio GALEOTTI, Alessandro LANZA and Francesco PAULI (I): <u>Desperately Seeking (Environmental) Kuznets: A New Look at the Evidence</u></i>
CLIM	68.2001	<i>Alexey VIKHLYAEV (xlviii): <u>The Use of Trade Measures for Environmental Purposes – Globally and in the EU Context</u></i>
NRM	69.2001	<i>Gary D. LIBECAP and Zeynep K. HANSEN (li): <u>U.S. Land Policy, Property Rights, and the Dust Bowl of the 1930s</u></i>
NRM	70.2001	<i>Lee J. ALSTON, Gary D. LIBECAP and Bernardo MUELLER (li): <u>Land Reform Policies, The Sources of Violent Conflict and Implications for Deforestation in the Brazilian Amazon</u></i>
CLIM	71.2001	<i>Claudia KEMFERT: <u>Economy-Energy-Climate Interaction – The Model WIAGEM -</u></i>
SUST	72.2001	<i>Paulo A.L.D. NUNES and Yohanes E. RIYANTO: <u>Policy Instruments for Creating Markets for Biodiversity: Certification and Ecolabeling</u></i>
SUST	73.2001	<i>Paulo A.L.D. NUNES and Erik SCHOKKAERT (lii): <u>Warm Glow and Embedding in Contingent Valuation</u></i>
SUST	74.2001	<i>Paulo A.L.D. NUNES, Jeroen C.J.M. van den BERGH and Peter NIJKAMP (lii): <u>Ecological-Economic Analysis and Valuation of Biodiversity</u></i>
VOL	75.2001	<i>Johan EYCKMANS and Henry TULKENS (li): <u>Simulating Coalitionally Stable Burden Sharing Agreements for the Climate Change Problem</u></i>
PRIV	76.2001	<i>Axel GAUTIER and Florian HEIDER: <u>What Do Internal Capital Markets Do? Redistribution vs. Incentives</u></i>
PRIV	77.2001	<i>Bernardo BORTOLOTTI, Marcella FANTINI and Domenico SINISCALCO: <u>Privatisation around the World: New Evidence from Panel Data</u></i>
ETA	78.2001	<i>Toke S. AIDT and Jayasri DUTTA (li): <u>Transitional Politics. Emerging Incentive-based Instruments in Environmental Regulation</u></i>
ETA	79.2001	<i>Alberto PETRUCCI: <u>Consumption Taxation and Endogenous Growth in a Model with New Generations</u></i>
ETA	80.2001	<i>Pierre LASSERRE and Antoine SOUBEYRAN (li): <u>A Ricardian Model of the Tragedy of the Commons</u></i>
ETA	81.2001	<i>Pierre COURTOIS, Jean Christophe PÉREAU and Tarik TAZDAÏT: <u>An Evolutionary Approach to the Climate Change Negotiation Game</u></i>
NRM	82.2001	<i>Christophe BONTEMPS, Stéphane COUTURE and Pascal FAVARD: <u>Is the Irrigation Water Demand Really Convex?</u></i>

(xxxvi) This paper was presented at the Second EFIEA Policy Workshop on "Integrating Climate Policies in the European Environment. Costs and Opportunities", organised by the Fondazione Eni Enrico Mattei on behalf of the European Forum on Integrated Environmental Assessment, Milan, March 4-6, 1999

(xxxvii) This paper was presented at the Fourth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei, CORE of Louvain-la-Neuve and GREQAM of Marseille, Aix-en-Provence, January 8-9, 1999

(xxxviii) This paper was presented at the International Conference on "Trade and Competition in the WTO and Beyond" organised by the Fondazione Eni Enrico Mattei and the Department of International Studies of the University of Padua, Venice, December 4-5, 1998

(xxxix) This paper was presented at the 3rd Toulouse Conference on Environment and Resource Economics, organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE on "Environment, Energy Uses and Climate Change", Toulouse, June 14-16, 1999

(xl) This paper was presented at the conference on "Distributional and Behavioral Effects of Environmental Policy" jointly organised by the National Bureau of Economic Research and Fondazione Eni Enrico Mattei, Milan, June 11-12, 1999

(xli) This paper was presented at the Fifth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CODE, Universitat Autònoma de Barcelona, Barcelona January 21-22, 2000

(xlii) This paper was presented at the International Workshop on "Climate Change and Mediterranean Coastal Systems: Regional Scenarios and Vulnerability Assessment" organised by the Fondazione Eni Enrico Mattei in co-operation with the Istituto Veneto di Scienze, Lettere ed Arti, Venice, December 9-10, 1999.

(xliii) This paper was presented at the International Workshop on "Voluntary Approaches, Competition and Competitiveness" organised by the Fondazione Eni Enrico Mattei within the research activities of the CAVA Network, Milan, May 25-26, 2000.

(xliv) This paper was presented at the International Workshop on "Green National Accounting in Europe: Comparison of Methods and Experiences" organised by the Fondazione Eni Enrico Mattei within the Concerted Action of Environmental Valuation in Europe (EVE), Milan, March 4-7, 2000

(xlv) This paper was presented at the International Workshop on "New Ports and Urban and Regional Development. The Dynamics of Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, May 5-6, 2000.

(xlvi) This paper was presented at the Sixth Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, January 26-27, 2001

(xlvii) This paper was presented at the RICAMARE Workshop "Socioeconomic Assessments of Climate Change in the Mediterranean: Impact, Adaptation and Mitigation Co-benefits", organised by the Fondazione Eni Enrico Mattei, Milan, February 9-10, 2001

(xlviii) This paper was presented at the International Workshop "Trade and the Environment in the Perspective of the EU Enlargement", organised by the Fondazione Eni Enrico Mattei, Milan, May 17-18, 2001

(xlix) This paper was presented at the International Conference "Knowledge as an Economic Good", organised by Fondazione Eni Enrico Mattei and The Beijer International Institute of Environmental Economics, Palermo, April 20-21, 2001

(l) This paper was presented at the Workshop "Growth, Environmental Policies and + Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, June 1, 2001

(li) This paper was presented at the Fourth Toulouse Conference on Environment and Resource Economics on "Property Rights, Institutions and Management of Environmental and Natural Resources", organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE, Toulouse, May 3-4, 2001

(lii) This paper was presented at the International Conference on "Economic Valuation of Environmental Goods" organised by the Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001

2000 SERIES

MGMT	<i>Corporate Sustainable Management</i> (Editor: Andrea Marsanich)
CLIM	<i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti)
PRIV	<i>Privatisation, Antitrust, Regulation</i> (Editor: Bernardo Bortolotti)
KNOW	<i>Knowledge, Technology, Human Capital</i> (Editor: Dino Pinelli)
WAT	<i>Water and Natural Resources Management</i> (Editor: Carlo Giupponi)
SUST	<i>Sustainability Indicators and Impact Assessment</i> (Editor: Marialuisa Tamborra)
VOL	<i>Task Force on Voluntary Agreements</i> (Editor: Rinaldo Brau)
ETA	<i>Economic Theory and Applications</i> (Editor: Carlo Carraro)

2001 SERIES

MGMT	<i>Corporate Sustainable Management</i> (Editor: Andrea Marsanich)
CLIM	<i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti)
PRIV	<i>Privatisation, Antitrust, Regulation</i> (Editor: Bernardo Bortolotti)
KNOW	<i>Knowledge, Technology, Human Capital</i> (Editor: Dino Pinelli)
NRM	<i>Natural Resources Management</i> (Editor: Carlo Giupponi)
SUST	<i>Sustainability Indicators and Environmental Evaluation</i> (Editor: Marialuisa Tamborra)
VOL	<i>Voluntary and International Agreements</i> (Editor: Carlo Carraro)
ETA	<i>Economic Theory and Applications</i> (Editor: Carlo Carraro)

SUBSCRIPTION TO "NOTE DI LAVORO"

Starting from January 1998 Fondazione Eni Enrico Mattei issues a Periodic E-mail "Note di Lavoro" Bulletin listing the titles and the abstracts of its most recent Working Papers.

All the "Note di Lavoro" listed in the Bulletin are available on the Internet and are downloadable from Feem's web site "www.feem.it".

If you wish to receive hard copies you may choose from the payment options listed in the following table (minimum order: 10 papers)*.

*Orders for individual papers should clearly indicate the "Nota di Lavoro" number and can therefore be issued for published papers only.

All orders must be sent by fax to:

"Publications Office" - Fondazione Eni Enrico Mattei: Fax +39+2+52036946

PAYMENT OPTIONS

How many papers?	What's the price?	How to pay?
10 or more*	US\$ 4.00 each ITL 7,000 each	By Credit card or Bank transfer
Annual subscription (approx. 100 papers/year)	US\$ 250.00 ITL 425,000	By Credit card or Bank transfer

Please fill out the Working Paper Subscription Form indicating your preferences (Periodic E-mail "Note di Lavoro" Bulletin, Annual subscription, Order for individual papers - minimum 10)!

☞.....

WORKING PAPER SUBSCRIPTION FORM

Name: _____

Affiliation(if applicable): _____

Address: _____

Phone: _____ Fax: _____ E-mail: _____

I wish to: _____ Amount due: _____

receive the Periodic E-mail Working Papers Bulletin

place a full annual subscription for 2001 (US\$ 250.00/ITL 425,000) _____

order no.....individual papers (minimum 10 papers at US\$ 4.00/ITL 7,000 each)* _____

Total _____

I will pay by:

VISA American Express Card No. _____ Expiration Date: _____

Signature: _____

Bank transfer in US\$ (or Italian Lire in Italy) to Fondazione Eni Enrico Mattei - account no. 39341-56 -

SWIFT ARTIITM2 - ABI 03512 - CAB 01614 - Credito Artigiano - Corso Magenta 59, 20123 Milano, Italy.

Copy of the bank transfer should be faxed along with the order.

Please return this duly completed form to:

"Publications Office" - Fondazione Eni Enrico Mattei - Corso Magenta, 63 - 20123 Milano, Italy