

Moretto, Michele; D'Alpaos, Chiara

Working Paper

The Value of Flexibility in the Italian Water Service Sector: A Real Option Analysis

Nota di Lavoro, Fondazione Eni Enrico Mattei, No. 140.2004

Provided in Cooperation with:

Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Moretto, Michele; D'Alpaos, Chiara (2004) : The Value of Flexibility in the Italian Water Service Sector: A Real Option Analysis, Nota di Lavoro, Fondazione Eni Enrico Mattei, No. 140.2004, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<http://hdl.handle.net/10419/118016>

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.

**The Value of Flexibility in the
Italian Water Service Sector:
A Real Option Analysis**

Chiara D'Alpaos and Michele Moretto

NOTA DI LAVORO 140.2004

NOVEMBER 2004

NRM – Natural Resources Management

Chiara D'Alpaos and Michele Moretto, *Department of Economics, University of Brescia*

This paper can be downloaded without charge at:

The Fondazione Eni Enrico Mattei Note di Lavoro Series Index:
<http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm>

Social Science Research Network Electronic Paper Collection:
<http://ssrn.com/abstract=615672>

The opinions expressed in this paper do not necessarily reflect the position of
Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano (I), web site: www.feem.it, e-mail: working.papers@feem.it

The Value of Flexibility in the Italian Water Service Sector: A Real Option Analysis

Summary

We analyze the optimal investment strategy of a monopolist which has subscribed a concession contract to provide a public utility, i.e. water service. We present a strategic model in which a monopolist chooses both the timing of the investment and the capacity. We focus not only on the value of the immediate investment, but rather on the value of the investment opportunity. We then extend the model to two interdependent projects, where investing in the first project provides the opportunity to acquire the benefits of the new investment by making a new outlay. We show that flexibility to defer an investment may generate, *ceteris paribus*, additional profits which may induce positive effects in terms of policy and consumers surplus.

Keywords: Irreversible investment, Flexibility to defer, Capacity expansion choice

JEL Classification: D81, G31, L95

This study was carried out under the 2004-5 two-year research project “Measurement of the value of flexibility in integrated water services via simulation techniques and numerical methods” financed by the University of Brescia. The authors want to thank Gilberto Muraro, Cesare Dosi, Paola Valbonesi and the participants to the “9th Joint Conference on Food, Agriculture and the Environment (Conegliano, Italy, August 28-31)” for their helpful comments and suggestions. They also want to thank ATO Bacchiglione and its director Vanni Carraro, Studio Bonollo and Guido Zanovello of Studio Altieri for the information provided. Usual caveats apply.

Address for correspondence:

Michele Moretto
Department of Economics
University of Brescia
Via S. Faustino, 74b
25122 Brescia
Italy
Phone: +39 030 2988830
Fax: +39 030 2988837
E-mail: moretto@eco.unibs.it

1 Introduction

In recent years water sector reforms have concentrated on involving the private sector in the operation and management of water utilities. In Italy following the promulgation of Law 36/94, known as Legge Galli, an attempt has been made to open up the water service sector to competition in order to guarantee efficiency in production and management of the resource (declared to be scarce).¹ The increase in the opportunity cost of investments devoted to the provision of public services has induced the Government to promote the involvement of private firms in the production of water services. The aim is to capture new financial resources and reduce the inefficiency which has characterized the public production of water services up to now (Dosi and Muraro, 2003). Unlike what has happened in telecommunications where technological innovations eroding some monopolistic aspects have introduced competition into the sector, the structural and technical characteristics of the water sector constrain the legislator to promote efficiency through “competition for the market” (Muraro and Rebba, 2003).² ³ In other words the private firms interested in provision of the water service compete to be entitled to a contract which gives them the right to produce, operate and manage the water utilities for a certain period of time. Under Law n° 36/94 the legislator establishes a separation between water resource planning and the operation of water utilities. The resource planning is assigned to the local water authority (ATO)⁴ which, in turn, assigns the operation to a private provider which will be selected via an auction

¹See Muraro (2003).

²It is not reasonable to construct parallel pipelines to distribute drinking water and collect wastewater. An exception is represented by common carriage competition in Great Britain (Webb and Ehrhardt, 1998), where several water utilities compete for customers using a single set of pipes. This solution might be adopted for providing the service to big industrial users but it is difficult to implement for domestic users because of the existence of strong economies of scale and scope (Dosi and Muraro, 2003).

³The water sector is characterized by some constraints related to the nature of the resource itself and to technological and physical features of the infrastructures (i.e. water flows by gravity in the network). These put some limitations on network interconnections and provision of the service on a large scale.

⁴The Galli Law establishes new local water authorities (ATOs), whose borders are set by the Italian Regions. As an example of their jurisdiction consider that in Veneto Region there are 8 local water authorities. The ATO are now taking over control functions which were previously state-run (decentralization). Generally speaking the term ATO refers to both the water authority and the area where the authority operates. When the reform is accomplished, only one private firm will operate in each ATO.

mechanism. The ATO sets the price (tariff)⁵ cap for the water utilities (including aqueduct systems, sewerage systems and treatment plants). Furthermore, the ATO draws up the “Piano d’Ambito” (a 30 year plan) which includes the timing and level of infrastructure investments, and ensures that the provider fulfills the contract requirements.

In this specific case, the “Piano d’Ambito” sets out the typology and timing of the investments the provider has to make, ruling out any managerial flexibility. Designers and planners choose among different alternative technical solutions (e.g. ground water vs. river basin abstraction, branching pipe systems vs. interconnected pipe systems, etc.) and make capital budgeting decisions according to the Net Present Value (*NPV*) rule.

Nevertheless, a wide range of feasible alternative technical solutions exists from which designers and planners can choose as regards operation and management of the infrastructures making up the system. Technological innovations lead to the construction of more complex systems characterized by a high operational flexibility. It is quite common today to design “integrated” aqueduct systems (namely vertical integrated systems with several interconnections between the network infrastructures) which can be expanded by sequential or modularized investments (Zanovello, 1977). Such systems can easily be modified over time in order to meet the requirements of facing and adapting to changes in the state variables (e.g. average day demand, number of users, input costs, adoption of new technologies, etc.). Moreover the interconnection and integration between supply sources enables the system to handle crisis in the provision of the service caused, for example, by pollution emergencies or peaks in day demand curves.

This flexibility, arising from technical aspects, has an economic value, which is strongly related to the provider’s “ability” to decide whether and when it is optimal to invest. That is, a firm which has the possibility to decide whether and when it is optimal to invest is holding something like a financial (call) option. By deciding to exploit this “opportunity”, the firm exercises its (real) option and consequently pays an opportunity cost which becomes part of the investment costs.

In recent years, following early papers by Brennan and Schwartz (1985), McDonald and Siegel (1985, 1986), Majd and Pindyck (1987) and Paddock *et al.* (1988), there has been an increasing production of literature concerning

⁵The Law n° 36/94 defines a new pricing mechanism. The tariff determined on the basis of “Metodo Tariffario Normalizzato” (ex. Lege: “Decreto del Ministero dell’Ambiente e del Territorio I° agosto 1996”) introduces a price cap regulation which guarantees at the same time ex-post full recovery of the service costs and an “adequate” capital rate of return (Moretto and Valbonesi, 2003).

applications of the real option approach to investment decisions in varied industrial sectors.⁶ Teisberg (1993) and Saphores *et al.* (2004) apply the real option approach to regulated firms in the energy sector, while Teisberg (1994), Trigeorgis (1996) and Childs and Triantis (1999) are among the few interested in the analysis of multi-stage investments in R&D. Nevertheless, these contributions do not refer to interdependent projects concerned with different capacity levels to be realized by regulated firms.⁷

This paper is a first attempt to apply real option results to capital budgeting in the water service as a regulated sector. We present a simple model to value the flexibility of aqueduct systems. The aqueduct systems are characterized by a high degree of technological and operational flexibility and, among the water utility infrastructures, are the ones which require higher irreversible sunk costs.⁸ In particular our aim is to show that managerial and technical flexibility might turn out to be economically relevant in the case the “Piano d’Ambito” gives to the provider the option to strategically decide when to invest.⁹ We also correct the option value to take into account that the length of concession contracts is generally shorter than plants’ useful life. Finally we investigate the effects of flexibility on consumer surplus and tariff reduction.

The paper is organized as follows. The next section presents a simplified model to value the flexibility to defer investments. Section 3 deals with investment decisions in capacity expansion (i.e. a water abstraction plant) and investigates the profitability of devising interdependent projects to face uncertain future demand. Section 4 illustrates the concluding remarks.

⁶See also Dixit and Pindyck (1994) and Trigeorgis (1996) for a systematic treatment of the real option approach.

⁷Interdependent projects differ from multi-stage projects because in order to generate a stream of profits they do not require an earlier investment-installment cost to acquire a subsequent option to continue operating the project until the next installment becomes due (see Trigeorgis, 1996, Chapter 4).

⁸61% of the total turnover of the water service sector industry is represented by profits coming from the production and distribution of water (in 1999 it was equal to 3.85 billion Euros). The 2002 report to the Italian Parliament on the state of the art of the water sector and accomplishment of the reform laid down by the Galli Law points out the need for huge investments (15.78 Euros per year per capita) in the aqueduct system in order to improve the efficiency of existing infrastructures, search for new catchment areas and springs and construct new plants.

⁹However the supply of the service is obligatory.

2 The model

The aim of this section is to show how flexibility can be valued with reference to plants for the production of drinking water. To emphasize the role of flexibility embedded in water production plants, we introduce some simplifying assumptions in order to obtain a close form solution for the investment's value.¹⁰

Conventional capital budgeting techniques and in particular the *NPV* rule fail to capture the strategic impact of projects and the additional value deriving from the opportunity to delay an investment decision. The *NPV* rule gives a measure of an investment's profitability according to a now-or-never proposition, that is if the investor does not make the investment now, he will lose the opportunity forever. A project whose *NPV* is negative or equal to zero, though, might have a positive *NPV* in the future. Similarly a project whose *NPV* is positive might have an even greater *NPV* in the future. Therefore the *NPV* rule does not take into consideration the opportunity cost to delay the investment. By deciding to make an expenditure for an irreversible investment the investor gives up the possibility of waiting for new information that might affect the desirability or the timing of the investment itself should market conditions change adversely. This opportunity cost might be relevant in the water service sector where only a private firm has the right to make the investment. The ability to defer an irreversible investment expenditure might profoundly affect the decision to invest.

The real option approach, first proposed by Myers (1977), Kester (1984) and McDonald and Siegel (1986)¹¹, establishes a theoretical framework which permits introduction into the valuation model of the flexibility to postpone investments, whose value is not captured by *NPV*. In other words the real option approach provides the decision-maker with a tool to address the issues of irreversibility, uncertainty and timing, drawing the valuation procedures from the body of knowledge developed for financial options during the past decades.

The investor with an opportunity to invest is holding something like a financial call option where the investment project is the underlying asset, the

¹⁰We believe that the adoption of more sophisticated models which can be solved only by means of numerical methods would not give any additional value to the analysis and would not make any improvement in the quality of the results, owing to the quality of information the ATOs and the providers have at their disposal while awaiting the reform (Law 36/94) to be accomplished soon.

¹¹To learn about the theory of the real option approach and for an overview of recent developments, see Dixit and Pindyck (1994) and Trigeorgis (1996).

investment costs represent the strike price and the expiry of the concession contract is the upper bound of the call option’s maturity time.

2.1 An investment in capacity expansion

We use a simplified version of the model proposed by McDonald and Siegel (1986). In particular:

1. The investment project A is a large-scale project which generates, once installed, an instantaneous profit flow equal to:

$$\Pi_t^A = \Pi_t(X^A)$$

where X^A is the project’s dimension (expressed in m^3).

2. The project lifetime is T_u , i.e. at T_u the salvage value is zero.
3. Π_t evolves over time according to a geometric Brownian motion with instantaneous expected return $\mu \geq 0$ and instantaneous volatility $\sigma > 0$

$$d\Pi_t^A = \mu\Pi_t^A dt + \sigma\Pi_t^A dz_t \quad \text{with } \Pi_0^A = \Pi^A \quad (1)$$

where dz_t is the increment of a standard Brownian process with mean zero and variance dt (i.e. $E(dz_t) = 0$ and $E(dz_t^2) = dt$). From (1) we get $E(\Pi_t^A | \Pi^A) = \Pi^A e^{\mu t}$, therefore μ represents the expected cash flow growth rate.

4. Investment in project A entails a sunk capital cost I^A .
5. The investment exercise time is τ .

Since the investment project we are analyzing (aqueduct system) is not traded in limited supply for investment purposes by many investors it is not considered a traded asset. Therefore its expected rate of return μ falls below the equilibrium total expected rate of return, say $\hat{\mu}$, required in the market by investors from an equivalent-risk traded financial security. The resulting rate of return shortfall $\delta \equiv \hat{\mu} - \mu > 0$ (i.e. the difference between the equilibrium expected return on a similar traded financial security and the actual project drift, μ , on the non-traded asset) represents the opportunity cost (in annuity terms) to invest at time zero, i.e. it is analogous to a constant “dividend” yield.¹² Furthermore, since the equivalent traded financial

¹²In complete markets we can hypothesize the existence of a traded asset that maintains the same price as Π^A while it pays a constant dividend yield δ , with $\hat{\mu} - \delta = \mu$ (see McDonald and Siegel, 1984; Cox, Ingersoll and Ross, 1985).

security must satisfy the asset price equilibrium relationship $\hat{\mu} = r + RP$, where r is the risk-free rate and RP is the risk premium, we can write the expected risk-adjusted rate of return of the project as $\mu - RP = r - \delta$ where $r - \delta$ will be referred to hereafter as the cost of carry.

This is the basis of the risk-neutral valuation approach proposed by Cox and Ross (1976) and Harrison and Kreps (1979), in which the actual growth rate μ is replaced with a risk-neutral equivalent drift $r - \delta$. That is, the adjustment is analogous to discounting certainty-equivalent cash flows at the risk-free rate, so that we can rewrite (1) in the following form:

$$d\Pi_t^A = (r - \delta)\Pi_t^A dt + \sigma\Pi_t^A dz_t \quad \Pi_0^A = \Pi^A \quad (2)$$

Hence, given the current value of Π_t^A , the market value of the project can be evaluated as the expected present value of discounted cash flows using equivalent risk-neutral probabilities and the risk-free interest rate (Cox and Ross, 1976; Harrison and Kreps, 1979):

$$V^A(\Pi^A) = E_t \left\{ \int_0^{T_u} e^{-rt} \Pi_t^A dt \right\} \equiv \frac{\Pi^A(X^A)}{\delta} (1 - e^{-\delta T_u}) \quad (3)$$

where E denotes the expectation operator under the risk neutral probability measure. Since V^A is a multiple of Π^A it is also driven by a geometric Brownian motion with the same parameters $r - \delta$ and σ , i.e.:

$$dV_t^A = (r - \delta)V_t^A dt + \sigma V_t^A dz_t, \quad V_0^A = V^A \quad (4)$$

This means that the analysis could be replicated using the present value as the state variable. Hereinafter we may take V_t^A as the primitive exogenous state variable for the regulatory process. The above assumptions make the project's value of the opportunity to invest (Extended Net Present Value) analogous to a European call option on a constant dividend-paying asset (the plant), i.e.:

$$F^A(V_t^A, t) = E_t \left\{ e^{-r(\tau-t)} \max(V_\tau^A - I^A, 0) \right\}$$

where τ is the expiration date and V_τ^A is the project value at time τ .

Imposing a non-arbitrage condition, the extended net present value $F^A(V_t, t)$ can be obtained as the solution of the following second order differential equation (Black and Scholes, 1973; Merton, 1973):

$$\frac{1}{2}\sigma^2(V^A)^2 F_{VV}^A + (r - \delta)(V^A)F_V^A - rF^A - F_t^A = 0 \quad (5)$$

subject to the terminal condition:

$$F^A(V_\tau^A, \tau) = \max[(V_\tau^A - I^A)^+, 0] \quad (6)$$

and to the boundary conditions:

$$F^A(0, t) = 0 \quad \text{and} \quad \lim_{V_t^A \rightarrow \infty} F^A(V_t^A, t)/V_t^A = 1 \quad (7)$$

The solution of (5) is given by the well-known formula derived by Black and Scholes (1973):

$$F^A(V_t^A, t) = e^{-\delta(\tau-t)} \Phi(d_1) V_t^A - e^{-r(\tau-t)} \Phi(d_2) I^A \quad (8)$$

where:

$$d_1(V_t^A) = \frac{\ln(V_t^A/I^A) + (r - \delta + \sigma^2/2)(\tau - t)}{\sigma\sqrt{\tau - t}}, \quad d_2(V_t^A) = d_1(V_t^A) - \sigma\sqrt{\tau - t}$$

and $\Phi(\cdot)$ is the cumulative standard normal distribution function.

So far we have implicitly assumed that the firm can exploit the profits generated by the project for its entire lifetime, once it is realized. However, concession contracts have a limited length, around 30 years, generally shorter than the project lifetime. Therefore it is necessary to add, at least, two more assumptions to take into account the limited contract life. In particular:

7. The concession contract lasts for T_c years, so that $\tau \leq T_c < T_u$.
8. The salvage value is given by:

$$S = I^A e^{-\xi(T_c - \tau)/\tau}$$

Then, by assumption 7 in order to calculate the asset value we must consider the operating life (i.e. economic life) of the project instead of its useful life (i.e. technical life). Consequently whenever the provider decides to defer the investment, he reduces the time over which he can gain profits by running the plant. Assumption 8, simply assume a salvage value as a % of the replacement cost. This % depreciates at rate ξ over the remaining years to the end of the concession. Therefore if the firm invests at $\tau = 0$ the salvage value is obviously equal to zero but if the firm invests close to the end of the concession, $\tau = T_c$, the salvage value coincides the replacement cost.

The actual value of the project turns out to be less than (3) and equals to:

$$\begin{aligned}
V^A(\Pi^A) &= E \left\{ \int_0^{T_c-\tau} e^{-rt} \Pi_t^A dt + e^{-r(T_c-\tau)} S \right\} \\
&\equiv \frac{\Pi^A(X^A)}{\delta} (1 - e^{-\delta(T_c-\tau)}) + I^A e^{-(r+\frac{\xi}{\tau})(T_c-\tau)}
\end{aligned} \tag{9}$$

Since (9) tends to zero when τ tends to T_c , condition (6) has to be substituted by:¹³

$$\lim_{\tau \rightarrow T_c} F^A(V_\tau^A, \tau) = \lim_{\tau \rightarrow T_c} \max[(V_\tau^A - \hat{I}^A)^+, 0] = 0 \tag{10}$$

where $\hat{I}^A = I^A(1 - e^{-(r+\frac{\xi}{\tau})(T_c-\tau)})$.

2.2 Interdependent projects

Interdependent projects can be considered as a portfolio of growth options. We extend the above benchmark case of a single indivisible project assuming that the provider has the possibility of choosing between two alternative projects A and B of different scales. With respect to the assumptions previously introduced we add:

1. Project A is equal to the one described in the previous section, while project B is larger in scale and generates, once installed, an instantaneous profit flow equal to $\Pi_t^B(X^B)$ with $X^B > X^A$.
2. The cash flow is simplified into a linear function as:

$$\Pi_t^B(X^B) = \pi_t X^B \quad \Pi_t^A(X^A) = \pi_t X^A$$

where π_t is the instantaneous profit per cubic meter (m^3) equal for both the projects and described by the following geometric Brownian motion:

$$d\pi_t = (r - \delta)\pi_t dt + \sigma \pi_t dz_t \quad \pi_0 = \pi$$

where $r - \delta \geq 0$ is the instantaneous risk-adjusted expected rate of return and $\sigma > 0$ is the instantaneous volatility.

¹³Brennan and Schwartz (1985) introduce a similar boundary condition. Their analysis, though, do not take into account the reduction in the asset value, because in their case the contract lease does not provide for any limitations on the number of years for which the resource can be exploited.

3. Investment in projects A and B entails sunk capital costs I^A and I^B respectively, with $I^B > I^A$.
4. The investor can operate only one project at a time and the investment is constrained to be sequential, with investment A occurring before B .
5. Finally, for the sake of simplicity, we assume that for both projects the expiration time is infinite.

The last two assumptions require some further comments. Firstly, since the investment is sequential, the private firm can always invest in the smaller scale project and subsequently invest in the bigger scale one, incorporating the former into the latter by paying an additional cost. Moreover, an infinite expiration time appears to be non-restrictive referring to aqueduct systems whose lifetime is very long. This implies that we can assume $T_c = T_u = T$.

Hence, the market value of the project B can be evaluated as the expected present value of its discounted cash flows.

$$V^B(\pi) = E \left\{ \int_0^T e^{-rt} \Pi_t^B dt \right\} = \frac{\pi X^B}{\delta} (1 - e^{-\delta T}) \quad (11)$$

Now, contrary to what has been done in the previous section, while determining the market value of project A we must take into account that once A is installed, it is optimal to switch to project B whenever the instantaneous profit π becomes large enough. In particular, we can express $V^A(\pi)$ as

$$V^A(\pi) = \max_{\tau^*} E \left\{ \int_0^{\tau^*} e^{-rt} \Pi_t^A ds + e^{-r\tau^*} (V^B(\pi_{\tau^*}) - I^B) \right\} \quad (12)$$

where τ^* is the optimal switching time from A to B .

It is easy to check that the solution to problem (12) is to switch from A to B as soon as π exceeds the critical threshold π_{AB}^* (see Appendix A):¹⁴

$$\pi_{AB}^* = \frac{\alpha}{\alpha - 1} \delta \frac{I^B}{(X^B - X^A)(1 - e^{-\delta T})} \quad (13)$$

¹⁴The switching rule (13) can be rewritten as follows:

$$V^B(\pi_{AB}^*) - \nu^A(\pi_{AB}^*) = \frac{\alpha}{\alpha - 1} I^B$$

where $\nu^A(\pi_{AB}^*) = \frac{\pi_{AB}^* X^A}{\delta} (1 - e^{-\delta T})$ represents the value of project A when there is no option to switch.

where $\alpha \equiv \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{r-\delta}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 1$. Moreover, the project's market value turns out to be:

$$V^A(\pi) = \begin{cases} \frac{\pi X^A}{\delta}(1 - e^{-\delta T}) + \left(\frac{\pi}{\pi_{AB}^*}\right)^\alpha \frac{I^B}{\alpha-1} & \text{if } \pi \leq \pi_{AB}^* \\ \frac{\pi X^B}{\delta}(1 - e^{-\delta T}) - I^B & \text{if } \pi > \pi_{AB}^* \end{cases} \quad (14)$$

Some comments on (14) are necessary. It is worth pointing out that for $\pi \in (0, \infty)$ $V^A(\pi) \leq V^B(\pi)$. The two functions coincide if and only if $\pi = 0$, while for $\pi \in [\pi_{AB}^*, \infty)$ $V^A(\pi) - V^B(\pi) = -I^B$. In other words the current value of project B 's expected cash flows is always greater than A 's, also taking into consideration the value of the opportunity to switch, eventually, from A to B at cost I^B .

In order to determine under which conditions it is optimal to proceed with sequential investments, let's consider the opportunity to invest in project A , which entails the option to switch subsequently to project B . For each $t \leq \infty$, this is equivalent to solving the following problem:

$$F^A(\pi_t) = \max_{\tau^*} E_t \left\{ e^{-r(\tau^*-t)} (V^A(\pi_{\tau^*}) - I^A) \right\} \quad (15)$$

By (14) the expression for $V^A(\pi_{\tau^*})$ is non-linear in π , therefore there is a discontinuity in the threshold π_A^* beyond which it is optimal to invest in project A . This threshold is given by (see Appendix B):

$$\pi_A^* = \begin{cases} \frac{\alpha}{\alpha-1} \delta \frac{I^A}{X^A(1-e^{-\delta T})} & \text{if } \frac{X^B}{X^A} - 1 < \frac{I^B}{I^A} \\ \frac{\alpha}{\alpha-1} \delta \frac{I^B + I^A}{X^B(1-e^{-\delta T})} & \text{if } \frac{X^B}{X^A} - 1 \geq \frac{I^B}{I^A} \end{cases} \quad (16)$$

The first expression shows that $\pi_A^* < \pi_{AB}^*$ therefore it is optimal to invest first in project A and then to wait until the instantaneous profit exceeds π_{AB}^* to invest in project B incorporating A . By analyzing (16), investment in A is myopic: it occurs as if the option of ultimately switching to B were not present, that is $\nu^A(\pi_A^*) = \frac{\pi_A^* X^A (1 - e^{-\delta T})}{\delta} = \frac{\alpha}{\alpha-1} I^A$.

On the contrary when $\pi_A^* \geq \pi_{AB}^*$ it is optimal to invest in both the projects simultaneously and, therefore, proceed directly with the implementation of B .

3 The value of flexibility to invest in an aqueduct system

3.1 The case of a water abstraction plant

With reference to the previous section let's suppose, as an example, that the "Piano d'Ambito" plans an investment capacity expansion due to an increase in water demand (i.e. number of users) or an increase in water supply (i.e. average day demand per capita). In order to meet the requirements the provider could choose between two different alternative projects: a) buy the volume X necessary to provide the water service to the new users via another private firm (alternative O), it being allowed by the law; b) construct a new water abstraction plant (well field)¹⁵ designed on the basis of volume X (alternative A).

Since the price of trading water among ATO is established by the regulator according to solidarity and fairness criteria, we can form the hypothesis that the expected Net Present Value of this alternative is zero, that is $NPV^O = 0$.

Alternative A consists of: a) well field (3 wells); b) pumping station; c) treatment plant; d) storage system (capacity equal to 10,000 m^3); e) treatment plant; f) electrical system for the equipment installed. The treatment plant includes a filtration process on Granular Activated Carbon (GAC) and the storage system includes disinfection and chlorination procedures.¹⁶ In fact groundwater extraction guarantees the provision of good quality water, which does not need highly specific treatment to meet the regulations for drinking water standards.

The project's useful life T_u is equal to 50 years and the system guarantees a water provision of about 300 l/s (equivalent to 9,460,800 $m^3/year$) but it is subject to water losses in the network i ranging from 20 to 30%. We assume that the plant's construction and installment costs are not time-dependent and amount to about 3,500,000 Euros.

We evaluate the flexibility of waiting to invest in project A , by treating the opportunity to defer the investment as a European Call Option. As it has already been pointed out, the discounted expected cash flows represent

¹⁵ A well field is the sinking of several moderately sized boreholes, spaced apart in some pattern, their yields being collected together. This system is used in order to develop a good yield from an area where a single well could not be expected to guarantee a large enough yield.

¹⁶ For a more detailed overview of technical solutions, technologies and design criteria see Hammer (1993) and Twort *et al.* (2000).

the current value of the asset and the investment cost I^A represents the exercise price of the option. Assuming profit is a linear function of the dimension X^A , profit at time t can be written as:

$$\Pi_t^A = R_t^A(1 - i)X^A - C_t^A X^A \quad (17)$$

where R_t^A are the revenues per cubic meter at time t ; C_t^A are operating costs (including maintenance costs) per cubic meter⁰ at time t ; X^A is the plant dimension; i are the volume losses in the network. We also make the following simplifying assumptions:

1. Revenues are deterministic and we draw their value using projections of water price and demand estimated by the ATO on the basis of the “Metodo Tariffario Normalizzato” over the entire concession period.
2. The operating costs¹⁷ (sum of production, maintenance and running costs)¹⁸ are a random variable following a geometric Brownian motion with a growth rate $r - \delta$ and volatility σ :

$$dC_t = (r - \delta)C_t dt + \sigma C_t dz_t$$

3. The risk-free discount rate r is known, deterministic and not time-dependent.
4. Revenues can be discounted at the constant risk-free rate r , the number of users (consumers) being certain over time (Brennan and Schwartz, 1985).
5. The discounted value of the project’s future cash flows is a good approximation of the present value of the asset.
6. The project’s salvage value at the end of its lifetime is zero.

¹⁷Variable costs, in particular the expenditure for chemicals used in water treatment (chlorination) and energy (pumping plant), are the most relevant ones as regards an abstraction plant consisting of wells. In this case the expenditure for chemicals is non-significant when compared with energy costs and can therefore be ignored. The price of energy is likely to follow an exogenous diffusive and geometric stochastic process.

¹⁸Fixed costs for running the plant are generally estimated as a percentage of operating costs (20-30%) and vary significantly depending on the management and the organization of the firm running the service.

Recalling (3), the value of the project is:¹⁹

$$\begin{aligned}
 V^A &= E \left[\int_0^{T_u} (e^{-rt}(1-i)R_t^A - e^{-rt}C_t^A)X^A dt \right] \\
 &= \left[\frac{(1-i)R^A}{r} (1 - e^{-rT_u}) - \frac{C^A}{\delta} (1 - e^{-\delta T_u}) \right] X^A
 \end{aligned} \tag{18}$$

Estimates of costs, revenues and other variables were derived from discussions with water industry experts. Table 1 shows estimates of the project's technical and economic parameters (e.g. dimension, project life, investment cost, etc.).

| | |
|---------------------------------------|-----------|
| X^A (m^3/s) | 0.300 |
| I^A (<i>Euro</i>) | 3,500,000 |
| T_u (<i>years</i>) | 50 |
| C^A (<i>Euro/m³</i>)* | 0.13 |
| R^A (<i>Euro/m³</i>)** | 0.30 |
| i | 20% |
| | 30% |
| δ | 1% |
| | 2% |
| | 3% |
| | 4% |
| r^{***} | 5% |
| σ^{****} | 30% |
| | 40% |

Table 1: Summary information for alternative A.

*Designers and industry experts interviewed agree on estimating the average operational costs of this type of plant at

¹⁹Water service experts use an expected rate of return (WACC) $\hat{\mu}$ equal to 7%. This value is the capital rate of return provided for by Law 36/94 and subsequent implementation decrees. In this case (18) should be written as:

$$V^A = E \left[\int_0^T (e^{-rt}(1-i)R_t^A - e^{-\hat{\mu}t}C_t^A)X^A dt \right]$$

where the cost growth rate is μ . Obviously the two expressions for the project's value are equivalent.

around 0.13 Euro/ m^3 . The average has been calculated over a distribution.

**Revenues per cubic meter have been determined by a statistical analysis performed over a distribution whose parameters have been estimated on the basis of the average tariff paid by users for the provision of drinking water.

***The risk-free rate is assumed to be equal to the rate of return of stated-owned bonds.

****Variance has been estimated considering analogous investment projects realized in the past, whose operating costs were known throughout the project life. A scenario analysis was conducted to prove the consistency of these estimates which can be considered representative for this kind of plant.

If the private firm can decide at time $\tau = 3, 5, 10$ years to proceed or not with the investment, the Extended Net Present Value of the projects can be determined using (8). Tables 2 and 3 display the results. The value of the flexibility to defer the investment (that is the difference between the Extended Net Present Value, F^A , and the Net Present Value, NPV^A) decreases for increasing values of δ and increasing exercise time of the option.

Let's consider first the case where $\sigma = 30\%$, $i = 20\%$ and $\delta = 2\%$. Project A whose NPV^A is negative ($NPV^A = -700$ thousands of Euros) might have a positive NPV^A in the future (e.g. $F^A=1.100$ thousands of Euros when $\tau = 10$). Therefore, the optimal strategy is to delay the investment. On the contrary, everything else being equal and assuming $i = 30\%$, project A has such a highly negative NPV^A that is never profitable either to invest or wait to invest.

Let's now consider the case where $\sigma = 30\%$ and $\delta = 3\%$. Assuming $i = 20\%$, F^A is less than the corresponding NPV^A , therefore there is no advantage in deferring the investment and the provider should start construction immediately. On the contrary, assuming $i = 30\%$, F^A is greater than the corresponding NPV^A and consequently it is expedient to delay the investment.

In all other cases (i.e. $\delta = 4\%$ and $i = 20 - 30\%$) the option value is not high enough to suggest waiting to invest, therefore the optimal investment strategy is to start construction immediately.

Finally, comparing Table 2 and Table 3 it is easily demonstrated that for increasing values of σ the Extended Net Present Value of the project

increases and consequently the option value of deferring the investment increases.

| | | τ | | | | | | | |
|----------|----|--------|--------|--------|-------|-------|-------|-------|-------|
| | | NPV | | F^A | | | | | |
| | | 0 | | 3 | | 5 | | 10 | |
| | | i=20% | i=30% | i=20% | i=30% | i=20% | i=30% | i=20% | i=30% |
| δ | 2% | -700 | -5,900 | 400 | - | 600 | - | 900 | - |
| | 3% | 6,300 | 1,100 | 6,000 | 1,500 | 5,800 | 1,600 | 5,300 | 1,800 |
| | 4% | 11,600 | 6,400 | 10,400 | 5,800 | 9,600 | 5,400 | 8,100 | 4,700 |

Table 2: NPV^A and F^A for $\sigma = 30\%$ and different expiration times of the option.

| | | τ | | | | | | | |
|----------|----|---------|--------|--------|-------|-------|-------|-------|-------|
| | | NPV^A | | F^A | | | | | |
| | | 0 | | 3 | | 5 | | 10 | |
| | | i=20% | i=30% | i=20% | i=30% | i=20% | i=30% | i=20% | i=30% |
| δ | 2% | -700 | -5,900 | 600 | - | 800 | - | 1,100 | - |
| | 3% | 6,300 | 1,100 | 6,100 | 1,700 | 5,900 | 1,900 | 5,500 | 2,000 |
| | 4% | 11,600 | 6,400 | 10,500 | 5,900 | 9,700 | 5,600 | 8,300 | 5,000 |

Table 3: NPV^A and F^A for $\sigma = 40\%$ and different expiration times of the option.

As already mentioned in section 2.1, the literature on the estimate of Extended Net Present Value in regulated industrial sectors does not consider that in general the length of concession is shorter than the project lifetime. This results in an over-estimation of the current value of the asset and a consequent distortion in the option value.

For example, in the above case we assumed that the private firm has the possibility of making profits throughout the useful life of the project, but usually concession contracts last for about 30 years. Therefore in determining the asset's present value we have to take into consideration the plant's operating life (economic life, $T_c = 30$ years) instead of its useful life (technical life, $T_u = 50$ years). Consequently, by exercising the option to defer the investment, the private firm reduces the period of time over which it can make profits from running the plant and then it reduces the expected

revenue cash flow. In the light of these considerations the present value of the project should be given by (9) including a salvage value.

Nevertheless, since the Galli Law does not make an explicit reference to the procedures to be used to guarantee the firm an amount of money corresponding to the asset's salvage value and the formula adopted to determine the water tariff ("Metodo Tariffario Normalizzato") already includes some form of the depreciation allowances, we maintain here the assumption of salvage value equal to zero.²⁰ The present value of the project is now:

$$\begin{aligned} V^A &= E \left[\int_0^{T_c - \tau} e^{-rt} [(1-i)R_t^A - C_t^A] X^A dt \right] = \\ &= \left[\frac{(1-i)R^A}{r} (1 - e^{-r(T_c - \tau)}) - \frac{C^A}{\delta} (1 - e^{-\delta(T_c - \tau)}) \right] X^A \end{aligned}$$

while the formula for evaluating its Extended Net Present Value (8) does not vary.

Analyzing the results obtained assuming $\sigma = 30\%$ and 40% and $i = 20\%$ (illustrated in Figure 1 and 2 respectively) we find that, everything else being equal, the value of flexibility increases as σ increases but, as it has been previously shown, it decreases when δ increases. It is also worth noting that when τ is equal to zero the Extended Net Present Value, F^A , and the conventional Net Present Value, NPV^A , coincide. In particular when τ is equal to 30 years (i.e. when the concession contract ceases) the Extended Net Present Value of the asset is zero. The option value to delay represents the opportunity cost of waiting to invest (Figure 3 and 4).

Let's consider, as an example, the scenario characterized by $\sigma = 30\%$, $\delta = 2\%$. In this case the Net Present Value of the project is $NPV^A = 4,000,000$ Euros. The extended NPV has a maximum for $\tau = 9$ and it is about $F^A = 4,970,000$ Euros (Figure 1). Therefore the firm's opportunity cost to invest by waiting 9 years is approximately 970,000 Euros or, put differently, the Net Present Value of investing today is $NPV^A - F^A = 4,000,000 - 4,970,000 = -970,000$, i.e. the NPV of investing today which includes the opportunity cost is negative.

²⁰This assumption seems to be non-restrictive at least for one more reason. The capital depreciation functions are generally of hyperbolic type (Mauer and Ott, 1995) with an estimated rate of depreciation ξ substantially high. Nevertheless, introducing a salvage value in the valuation model would not substantially modify the results obtained as regards the NPV and the Extended Net Present Value. Under the hypothesis of the salvage value being equal to zero we obtain a cautious estimate of the flexibility value.

Figure 1:
 F^A assuming $\sigma = 30\%$ and $i = 20\%$ (in thousands of Euros).

Figure 2:
 F^A assuming $\sigma = 40\%$ and $i = 20\%$ (in thousands of Euros).

Figure 3:
 Opportunity cost to defer the investment assuming $\sigma = 30\%$ and $i = 20\%$ (in thousands of Euros).

Figure 4:
 Opportunity cost to defer the investment assuming $\sigma = 40\%$ and $i = 20\%$ (in thousands of Euros).

The analysis of flexibility could have interesting effects in terms of policy and consumer surplus (i.e. tariff reduction). The possibility of delaying investment decisions may induce the firm to bid more aggressively in order to win the concession race (Muraro, 2002). For example assuming water losses in the network equal to 20% and $\sigma = 30\%$, the value of flexibility has a maximum for $\tau = 15$ and $\tau = 9$ years for $\delta = 1\%$ and $\delta = 2\%$ respectively (Figure 1). For these reference cases the potential tariff reductions are displayed in Table 5.²¹

| | $\tau_{\max F^A}$ | ΔR |
|----------------|-------------------|------------|
| $\delta = 1\%$ | 15 years | 28% |
| $\delta = 2\%$ | 9 years | 4% |

Table 5: Maximum tariff reduction assuming $\sigma = 30\%$.

3.2 The case of interdependent projects

Most of the investments occurring in the water service sector and in particular investments in aqueduct systems offer a wide range of choice between alternative technical solutions. In fact the planners can combine the single plants and elements making up the system in several different ways in order to guarantee greater operational flexibility (D'Alpaos, 2003). It is quite common today to design complex aqueduct systems which can be expanded by sequential or modularized investments. Such systems can easily be modified over time in order to meet the requirements of facing and adapting to changes in the state variables (e.g. future demand, number of users, input cost increments, adoption of new technologies, etc.). This flexibility arising from technical aspects has an economic value.

²¹ Assuming $\delta = 1\%$ the NPV^A is negative, therefore we determined the tariff reduction assuming a Net Present Value equal to zero as the benchmark.

As an example let's consider a firm's need to invest in capacity expansion in order to face uncertain future growth in demand and suppose it has the opportunity of proceeding with sequential investments, whose characteristics are analogous to those of alternative A described in section 4.1. Assuming that the firm can switch from a smaller scale project to a bigger scale one by paying an additional cost. The costs related to different discharge values are displayed in Table 4.

| | Discharge (l/s) | | | | |
|---------------------|---------------------|-------|-------|--------|--------|
| | 300 | 900 | 1,200 | 1,500 | 2,100 |
| I ($Euro 10^3$) | 3,500 | 7,100 | 9,400 | 12,200 | 15,000 |

Table 4: Plant costs depending on different discharge values.

By using (13) and (16) we can obtain the thresholds on the basis of which we evaluate the profitability of proceeding or not with a sequential investment, with the investment in A occurring before B . The results of the simulations we performed for different discharge values assuming $i = 20\%$ and $\sigma = 30\%$ are shown in Table 5 and 6.

The results clearly show the importance of scale economies in investment decisions related to capacity expansion.²² When the dimension of project A is equal to 300 l/s and the dimension of B is equal to 900 l/s , assuming $\delta = 2\%$ and $\delta = 4\%$, the optimal investment strategy consists in investing first in A and then switching to B as soon as the instantaneous profit π becomes greater than the threshold π_{AB}^* . Everything else being equal, when the dimension of project B is equal to or greater than 1200 l/s it is always optimal to invest in the bigger scale project, i.e. the condition $\pi_{AB}^* > \pi_A^*$ is satisfied. Assuming that project A is designed for a discharge value greater than or equal to 900 l/s the optimal strategy consists in undertaking sequential investments.

Moreover, since the condition $\pi_0 = 0.8 \cdot 0.3 - 0.13 < \pi_A^*$ always obtains, whenever it is optimal to invest in sequential investments, it is more profitable to start constructing A (there is no time lag on A) and wait to invest in project B (Table 5 and 6).

²²Generally, in fact, the section of the supply network and distribution network are sized on the basis of the average day demand thanks to the possibility of constructing reservoirs. Construction costs, furthermore, depend on the length of the pipes according to a virtually linear law. In this regard, see the study carried out by Venturi *et al.* (1970) on estimate of the construction cost functions in parametric form for various types of plant.

Analogous considerations can be made taking into account the results shown in Tables 7 and 8 assuming $\sigma = 40\%$, $i = 20\%$ and value losses of δ equal to 2% and 4% respectively. Everything else being equal, the trigger π_{AB}^* increases when σ increases.

| Discharge (l/s) | | | | |
|---------------------|---|---|---|---|
| | 900 | 1200 | 1500 | 2100 |
| 300 | $\pi_{AB}^* = 0.111$ $\pi_A^* = 0.108$ | $\pi_{AB}^* = 0.097$ $\pi_A^* = 0.100$ | $\pi_{AB}^* = 0.094$ $\pi_A^* = 0.097$ | $\pi_{AB}^* = 0.077$ $\pi_A^* = 0.082$ |
| 900 | | $\pi_{AB}^* = 0.290$ $\pi_A^* = 0.072$ | $\pi_{AB}^* = 0.188$ $\pi_A^* = 0.072$ | $\pi_{AB}^* = 0.116$ $\pi_A^* = 0.072$ |
| 1200 | | | $\pi_{AB}^* = 0.377$ $\pi_A^* = 0.073$ | $\pi_{AB}^* = 0.155$ $\pi_A^* = 0.073$ |
| 1500 | | | | $\pi_{AB}^* = 0.272$ $\pi_A^* = 0.075$ |

Table 5: Optimal trigger assuming $\delta = 2\%$ and $\sigma = 30\%$.

| Discharge (l/s) | | | | |
|---------------------|---|---|---|---|
| | 900 | 1200 | 1500 | 2100 |
| 300 | $\pi_{AB}^* = 0.079$ $\pi_A^* = 0.078$ | $\pi_{AB}^* = 0.070$ $\pi_A^* = 0.072$ | $\pi_{AB}^* = 0.068$ $\pi_A^* = 0.070$ | $\pi_{AB}^* = 0.056$ $\pi_A^* = 0.059$ |
| 900 | | $\pi_{AB}^* = 0.210$ $\pi_A^* = 0.053$ | $\pi_{AB}^* = 0.136$ $\pi_A^* = 0.053$ | $\pi_{AB}^* = 0.084$ $\pi_A^* = 0.053$ |
| 1200 | | | $\pi_{AB}^* = 0.377$ $\pi_A^* = 0.052$ | $\pi_{AB}^* = 0.155$ $\pi_A^* = 0.052$ |
| 1500 | | | | $\pi_{AB}^* = 0.167$ $\pi_A^* = 0.054$ |

Table 6: Optimal trigger assuming $\delta = 4\%$ and $\sigma = 30\%$.

| Discharge (l/s) | | | | |
|---------------------|---|---|---|---|
| | 900 | 1200 | 1500 | 2100 |
| 300 | $\pi_{AB}^* = 0.149$ $\pi_A^* = 0.147$ | $\pi_{AB}^* = 0.131$ $\pi_A^* = 0.135$ | $\pi_{AB}^* = 0.128$ $\pi_A^* = 0.131$ | $\pi_{AB}^* = 0.105$ $\pi_A^* = 0.111$ |
| 900 | | $\pi_{AB}^* = 0.394$ $\pi_A^* = 0.099$ | $\pi_{AB}^* = 0.255$ $\pi_A^* = 0.099$ | $\pi_{AB}^* = 0.157$ $\pi_A^* = 0.099$ |
| 1200 | | | $\pi_{AB}^* = 0.517$ $\pi_A^* = 0.098$ | $\pi_{AB}^* = 0.209$ $\pi_A^* = 0.098$ |
| 1500 | | | | $\pi_{AB}^* = 0.314$ $\pi_A^* = 0.102$ |

Table 7: Optimal trigger assuming $\delta = 2\%$ and $\sigma = 40\%$.

| | | Discharge (l/s) | | | |
|------|---|---|---|---|------|
| | | 900 | 1200 | 1500 | 2100 |
| 300 | $\pi_{AB}^* = 0.106$ $\pi_A^* = 0.104$ | $\pi_{AB}^* = 0.093$ $\pi_A^* = 0.096$ | $\pi_{AB}^* = 0.091$ $\pi_A^* = 0.093$ | $\pi_{AB}^* = 0.074$ $\pi_A^* = 0.079$ | |
| 900 | | $\pi_{AB}^* = 0.280$ $\pi_A^* = 0.070$ | $\pi_{AB}^* = 0.181$ $\pi_A^* = 0.070$ | $\pi_{AB}^* = 0.112$ $\pi_A^* = 0.070$ | |
| 1200 | | | $\pi_{AB}^* = 0.363$ $\pi_A^* = 0.070$ | $\pi_{AB}^* = 0.149$ $\pi_A^* = 0.070$ | |
| 1500 | | | | $\pi_{AB}^* = 0.233$ $\pi_A^* = 0.073$ | |

Table 8: Optimal trigger assuming $\delta = 4\%$ and $\sigma = 40\%$.

4 Final remarks

In this paper we propose an option approach to evaluate the strategic value of flexibility to defer investment decisions in the Italian water service sector. We show how some technical flexibility might turn into managerial flexibility which has a substantial economic value.

The value of flexibility might be beneficial for the consumers. In fact if the provider can choose whether and when it is optimal to invest, he might bid more aggressively offering a lower tariff.

A Appendix

Within the range of π where it is non-optimal to invest in the larger scale project, the value of alternative A can be obtained as the solution of the following second order differential equation (Dixit and Pindyck, 1994):

$$\frac{1}{2}\sigma^2 \pi^2 V_{\pi\pi}^A + (r - \delta)\pi V_{\pi}^A - rV^A + \Pi^A = 0 \quad (19)$$

subject to the following boundary conditions (*value matching condition* and *smooth pasting condition*):

$$V^A(\pi_{AB}^*) = V^B(\pi_{AB}^*) - I^B \quad \text{and} \quad V_{\pi}^A(\pi_{AB}^*) = V_{\pi}^B(\pi_{AB}^*), \quad (20)$$

The optimal timing to switch from A to B turns out to be:

$$\tau_{AB}^* = \min(t \geq 0 \mid V^A(\pi_{AB}^*) = V^B(\pi_{AB}^*) - I^B). \quad (21)$$

The general solution of equation (19) can be written as:

$$V^A(\pi) = K_1\pi^{\alpha} + K_2\pi^{\beta} + v^A(\pi) \quad (22a)$$

where $1 < \alpha < r/(r - \delta)$, $\beta < 0$ are respectively the positive and negative root of the characteristic equation $\Psi(x) = \frac{1}{2}\sigma^2x(x - 1) + (r - \delta)x - r = 0$, and K_1 , K_2 are two constants to be determined. The first two terms in (22a) represent the solution of the homogeneous equation, while the third term represents a particular solution. As particular solution we take the expected discounted value $v^A(\pi)$ of the benefits that project A generates in the absence of the option to switch to project B (Harrison 1985, page 44):

$$v^A(\pi) = E \left\{ \int_0^T e^{-rt} \Pi_t^A dt \right\} = \frac{\Pi^A}{\delta} (1 - e^{-\delta T}) \quad (23)$$

To make sure $v^A(\pi)$ is positive we assume $\delta > 0$. Finally, in order to have a finite value for $V^A(\pi)$ when π gets very small, we set $K_2 = 0$ (i.e. $\lim_{\pi \rightarrow 0} V^A(\pi) = 0$). Therefore the general solution can be re-written in the following form:

$$V^A(\pi) = K_1\pi^{\alpha} + \frac{\Pi^A}{\delta} (1 - e^{-\delta T}) \quad (24)$$

Finally, since $K_1\pi^{\alpha}$ represents the correction we have to impose on the value of project A by the option to switch to B in the future, the constant K_1 must necessarily be positive. We obtain K_1 and π_{AB}^* by imposing the boundary conditions (20).

B Appendix

Unlike what happens when dealing with the European Call Option, to evaluate a perpetual option we use a differential equation which is not time-dependent.

Considering project A , the solution of (15) can be obtained by solving the following second order differential equation (McDonald and Siegel 1986; Dixit and Pindyck, 1994):

$$\frac{1}{2}\sigma^2 \pi^2 F_{\pi\pi}^A + (r - \delta)\pi F_{\pi}^A - rF^A = 0 \quad (25)$$

imposing the usual boundary conditions:

$$F^A(\pi_A^*) = V^A(\pi_A^*) - I^A \quad \text{and} \quad F_{\pi}^A(\pi_A^*) = V_{\pi}^A(\pi_A^*), \quad (26)$$

Nevertheless, when analyzing (14) (or 24) we notice that the expression referring to the value of project A reveals two different forms depending on $\pi < \pi_{AB}^*$ or vice versa $\pi > \pi_{AB}^*$. Therefore we have two different boundary conditions (26) depending on $\pi_A^* > \pi_{AB}^*$ or $\pi_A^* < \pi_{AB}^*$. In particular we get:

$$\pi_A^* = \begin{cases} \frac{\alpha}{\alpha-1} \delta \frac{I^A}{X^A(1-e^{-\delta T})} & \text{if } \frac{X^B}{X^A} - 1 < \frac{I^B}{I^A} \\ \frac{\alpha}{\alpha-1} \delta \frac{I^B + I^A}{X^B(1-e^{-\delta T})} & \text{if } \frac{X^B}{X^A} - 1 \geq \frac{I^B}{I^A} \end{cases} \quad (27)$$

References

- [1] Black, F., and M. Scholes, (1973), “The pricing of option and corporate liabilities”, *Journal of Political Economy*, 81, pp. 637-659.
- [2] Brennan, M.J., and E.S. Schwartz, (1985), “Evaluating Natural Resource Investments”, *The Journal of Business*, 58, 2, pp. 137-157.
- [3] Brennan, M.J., and L. Trigeorgis. (eds.), (1998), *Flexibility, Natural Resources and Strategic Options*, Oxford University Press, Oxford, UK.
- [4] Child, P.D., and A.J. Triantis, (1999), “Dynamic R&D Investment Policies”, *Management Science*, 45, 10, pp. 1359-1377.
- [5] Cox, J.C., and S.A. Ross, (1976), “The Valuation of Options for Alternative Stochastic Processes”, *Journal of Financial Economics*, 3, 145-166.
- [6] Cox, J.C., J. Ingersoll, and S.A. Ross, (1985), “An Intertemporal General Equilibrium Model of Asset Prices”, *Econometrica* 53, 363-384.
- [7] D’Alpaos, C., (2003), *Teoria delle opzioni reali e valutazione degli investimenti: il caso del servizio idrico integrato*, Tesi di Dottorato di Ricerca.
- [8] Dixit, A., and R.S. Pindyck (1994), *Investment under Uncertainty*, Princeton University Press.
- [9] Dosi, C., and G. Muraro, (2003), “I servizi idrici e il ruolo dell’intervento pubblico”, in Muraro G., and P. Valbonesi (eds), *I servizi idrici tra mercato e regole*, Carocci Editore, Roma, pp. 19-39.
- [10] Kester, W.C., (1984), “Today’s Option for Tomorrow’s Growth”, *Harvard Business Review*, 62, 2, pp. 153-160.
- [11] Hammer, M., (1993), *Manuale di tecnologia dell’acqua*, Tecniche Nuove, Milano.
- [12] Harrison, J.M., and D. M. Kreps, (1979), “Martingales and arbitrage in multiperiod securities markets”, *Journal of Economic Theory*, 2, pp. 381-420.
- [13] Majd, S., and R.S. Pindyck, (1987), “Time to Build, Option Value, and Investment Decisions”, *Journal of Financial Economics*, 19 (marzo), pp. 7-27.

- [14] Mauer, D.C., and S.H. Ott, (1995), "Investment under Uncertainty: The Case of Replacement Investment Decisions", *Journal of Financial and Quantitative Analysis*, 30, pp. 581-605.
- [15] McDonald, R., and D.R. Siegel, (1984), "Option pricing when the underlying asset earns a below-equilibrium rate of return: A note", *Journal of Finance*, 39, 1, pp. 261-265.
- [16] McDonald, R., and D.R. Siegel, (1985), "Investment and the Valuation of Firms When There is an Option to Shut Down", *International Economic Review*, 26, pp. 331-349.
- [17] McDonald, R., and D.R. Siegel, (1986), "The Value of Waiting to Invest", *The Quarterly Journal of Economics*, 101, pp. 707-728.
- [18] Merton, R.C., (1973), "Theory of rational option pricing", *Bell Journal of Economics and Management Science*, 4, 1, pp. 449-470.
- [19] Moretto, M., and P. Valbonesi P., (2003), "La regolamentazione dei prezzi", in Muraro G., and P. Valbonesi (eds), *I servizi idrici tra mercato e regole*, Carocci Editore, Roma, pp. 97-163.
- [20] Myers, S.C., (1977), "Determinants of corporate borrowing", *Journal of Financial Economics*, 5, 2, pp.147-176.
- [21] Muraro, G., (2002), "La gara per il servizio idrico integrato. Commento al Regolamento ex art. 20 della L. 36/94", *Il Diritto della Regione*, 4, pp. 705-724.
- [22] Muraro, G., (2003), "Il servizio idrico integrato in Italia, tra vincoli europei e scelte nazionali", *Mercato, Concorrenza e Regole*, 2, pp. 365-383.
- [23] Muraro, G., and V. Rebba, (2003), "La concorrenza per il mercato", in Muraro G., e P. Valbonesi (eds), *I servizi idrici tra mercato e regole*, Carocci Editore, Roma, pp. 237-303.
- [24] Paddock, J.L., D.R. Siegel, and J.L. Smith (1988), "Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases", *The Quarterly Journal of Economics*, 103, pp. 479-508.
- [25] Saphores, J.D, E. Gravel and J.T. Bernard, (2004), "Regulation and Investment under Uncertainty: An Application to a Power Grid Interconnection", *Journal of Regulatory Economics*, 25, 2, pp.169-186.

- [26] Teisberg, E.O., (1993), “Capital Investment Strategies under Uncertain Regulation”, *RAND Journal of Economics*, 24, 4, pp. 535-548.
- [27] Teisberg, E.O., (1994), “An option valuation analysis of investment choices by a regulated firm”, *Management Science*, 40, 4, pp. 591-604.
- [28] Trigeorgis, L., (1996), *Real Options-Managerial Flexibility and Strategy in Resource Allocation*, The MIT Press, Cambridge, MA.
- [29] Twort, C., D.D. Ratnayaka and M.J. Brandt, (2000), *Water Supply-Fifth Edition*, Arnold Hodder Headline Group, London.
- [30] Venturi, G., R. Zampini and A. Zanovello, (1970), “I costi negli impianti degli acquedotti”, in *Atti del III Convegno Nazionale delle Aziende Acquedottistiche Municipalizzate*, Torino 9-11 aprile, Conferederazione Italiana dei Servizi Pubblici degli Enti Locali, pp. 79-186.
- [31] Zanovello, A., (1977), “Sistemi di attingimenti integrati”, in *Atti del 5° Convegno Nazionale Aziende Acquedottistiche Municipalizzate*, Trieste 26-29 ottobre 1977, Terme, Roma, pp. 219-244.
- [32] Webb, M., and D. Ehrhardt, (1998), “Improving Water Services through Competition”, *Public Policy for the Private Sector*, Note 164, December, <http://rru.worldbank.org/viewpoint/HTMLNotes/164/164Summary.html>.

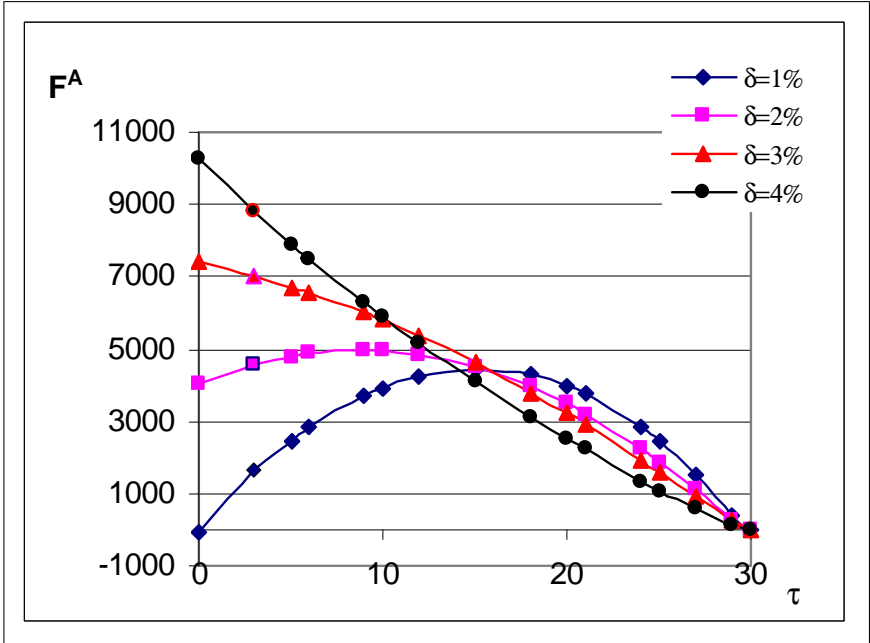


Figure 1

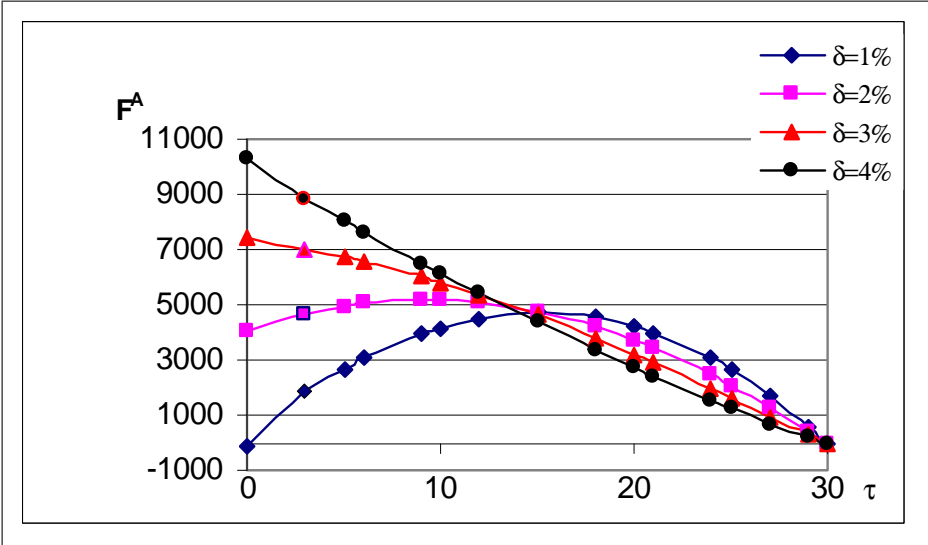


Figure 2

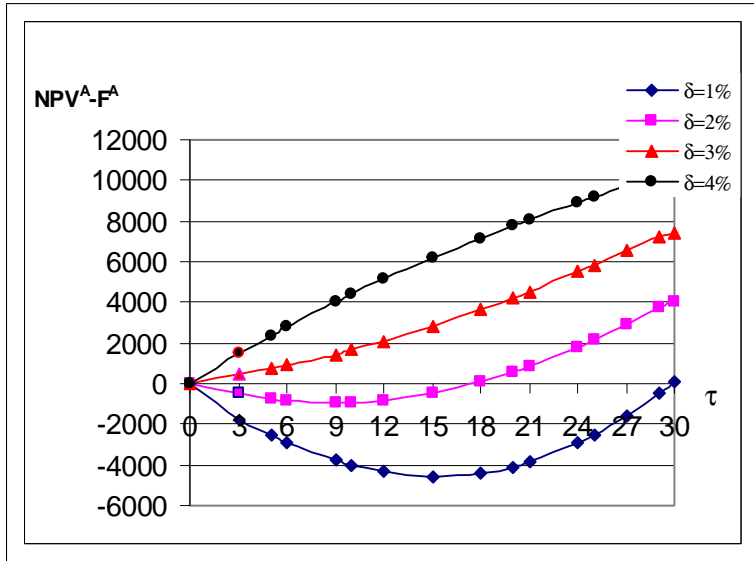


Figure 3

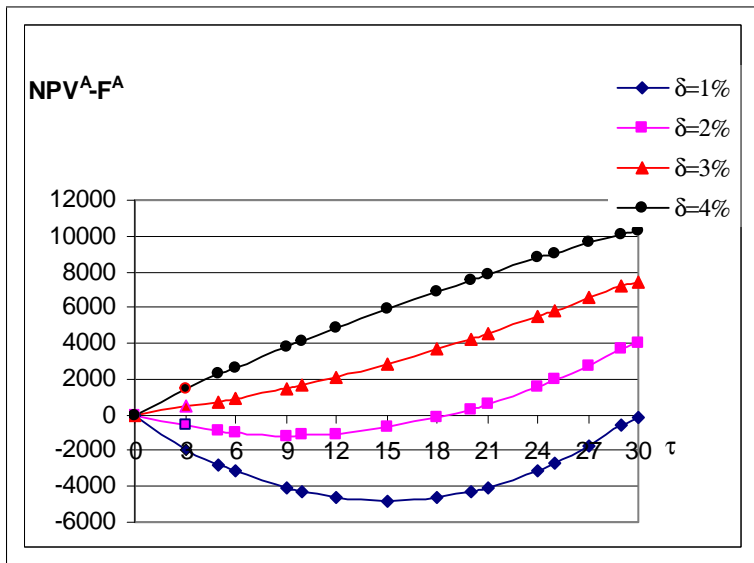


Figure 4

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

<http://www.feem.it/Feem/Pub/Publications/WPapers/default.html>

<http://www.ssrn.com/link/feem.html>

NOTE DI LAVORO PUBLISHED IN 2003

| | | |
|-----------|---------|--|
| PRIV | 1.2003 | <i>Gabriella CHIESA and Giovanna NICODANO: <u>Privatization and Financial Market Development: Theoretical Issues</u></i> |
| PRIV | 2.2003 | <i>Ibolya SCHINDELE: <u>Theory of Privatization in Eastern Europe: Literature Review</u></i> |
| PRIV | 3.2003 | <i>Wietze LISE, Claudia KEMFERT and Richard S.J. TOL: <u>Strategic Action in the Liberalised German Electricity Market</u></i> |
| CLIM | 4.2003 | <i>Laura MARSILIANI and Thomas I. RENSTRÖM: <u>Environmental Policy and Capital Movements: The Role of Government Commitment</u></i> |
| KNOW | 5.2003 | <i>Reyer GERLAGH: <u>Induced Technological Change under Technological Competition</u></i> |
| ETA | 6.2003 | <i>Efrem CASTELNUOVO: <u>Squeezing the Interest Rate Smoothing Weight with a Hybrid Expectations Model</u></i> |
| SIEV | 7.2003 | <i>Anna ALBERINI, Alberto LONGO, Stefania TONIN, Francesco TROMBETTA and Margherita TURVANI: <u>The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers</u></i> |
| NRM | 8.2003 | <i>Elissaios POPYRAKIS and Reyner GERLAGH: <u>Natural Resources: A Blessing or a Curse?</u></i> |
| CLIM | 9.2003 | <i>A. CAPARRÓS, J.-C. PEREAU and T. TAZDAÏT: <u>North-South Climate Change Negotiations: a Sequential Game with Asymmetric Information</u></i> |
| KNOW | 10.2003 | <i>Giorgio BRUNELLO and Daniele CHECCHI: <u>School Quality and Family Background in Italy</u></i> |
| CLIM | 11.2003 | <i>Efrem CASTELNUOVO and Marzio GALEOTTI: <u>Learning By Doing vs Learning By Researching in a Model of Climate Change Policy Analysis</u></i> |
| KNOW | 12.2003 | <i>Carole MAIGNAN, Gianmarco OTTAVIANO and Dino PINELLI (eds.): <u>Economic Growth, Innovation, Cultural Diversity: What are we all talking about? A critical survey of the state-of-the-art</u></i> |
| KNOW | 13.2003 | <i>Carole MAIGNAN, Gianmarco OTTAVIANO, Dino PINELLI and Francesco RULLANI (lix): <u>Bio-Ecological Diversity vs. Socio-Economic Diversity. A Comparison of Existing Measures</u></i> |
| KNOW | 14.2003 | <i>Maddy JANSSENS and Chris STEYAERT (lix): <u>Theories of Diversity within Organisation Studies: Debates and Future Trajectories</u></i> |
| KNOW | 15.2003 | <i>Tuzin BAYCAN LEVENT, Enno MASUREL and Peter NIJKAMP (lix): <u>Diversity in Entrepreneurship: Ethnic and Female Roles in Urban Economic Life</u></i> |
| KNOW | 16.2003 | <i>Alexandra BITUSIKOVA (lix): <u>Post-Communist City on its Way from Grey to Colourful: The Case Study from Slovakia</u></i> |
| KNOW | 17.2003 | <i>Billy E. VAUGHN and Katarina MLEKOV (lix): <u>A Stage Model of Developing an Inclusive Community</u></i> |
| KNOW | 18.2003 | <i>Selma van LONDEN and Arie de RUIJTER (lix): <u>Managing Diversity in a Globalizing World</u></i> |
| Coalition | | |
| Theory | 19.2003 | <i>Sergio CURRARINI: <u>On the Stability of Hierarchies in Games with Externalities</u></i> |
| Network | | |
| PRIV | 20.2003 | <i>Giacomo CALZOLARI and Alessandro PAVAN (lx): <u>Monopoly with Resale</u></i> |
| PRIV | 21.2003 | <i>Claudio MEZZETTI (lx): <u>Auction Design with Interdependent Valuations: The Generalized Revelation Principle, Efficiency, Full Surplus Extraction and Information Acquisition</u></i> |
| PRIV | 22.2003 | <i>Marco LiCalzi and Alessandro PAVAN (lx): <u>Tilting the Supply Schedule to Enhance Competition in Uniform-Price Auctions</u></i> |
| PRIV | 23.2003 | <i>David ETTINGER (lx): <u>Bidding among Friends and Enemies</u></i> |
| PRIV | 24.2003 | <i>Hannu VARTIAINEN (lx): <u>Auction Design without Commitment</u></i> |
| PRIV | 25.2003 | <i>Matti KELOHARJU, Kjell G. NYBORG and Kristian RYDQVIST (lx): <u>Strategic Behavior and Underpricing in Uniform Price Auctions: Evidence from Finnish Treasury Auctions</u></i> |
| PRIV | 26.2003 | <i>Christine A. PARLOUR and Uday RAJAN (lx): <u>Rationing in IPOs</u></i> |
| PRIV | 27.2003 | <i>Kjell G. NYBORG and Ilya A. STREBULAIEV (lx): <u>Multiple Unit Auctions and Short Squeezes</u></i> |
| PRIV | 28.2003 | <i>Anders LUNANDER and Jan-Eric NILSSON (lx): <u>Taking the Lab to the Field: Experimental Tests of Alternative Mechanisms to Procure Multiple Contracts</u></i> |
| PRIV | 29.2003 | <i>TangaMcDANIEL and Karsten NEUHOFF (lx): <u>Use of Long-term Auctions for Network Investment</u></i> |
| PRIV | 30.2003 | <i>Emiel MAASLAND and Sander ONDERSTAL (lx): <u>Auctions with Financial Externalities</u></i> |
| ETA | 31.2003 | <i>Michael FINUS and Bianca RUNDSHAGEN: <u>A Non-cooperative Foundation of Core-Stability in Positive Externality NTU-Coalition Games</u></i> |
| KNOW | 32.2003 | <i>Michele MORETTO: <u>Competition and Irreversible Investments under Uncertainty</u></i> |
| PRIV | 33.2003 | <i>Philippe QUIRION: <u>Relative Quotas: Correct Answer to Uncertainty or Case of Regulatory Capture?</u></i> |
| KNOW | 34.2003 | <i>Giuseppe MEDA, Claudio PIGA and Donald SIEGEL: <u>On the Relationship between R&D and Productivity: A Treatment Effect Analysis</u></i> |
| ETA | 35.2003 | <i>Alessandra DEL BOCA, Marzio GALEOTTI and Paola ROTA: <u>Non-convexities in the Adjustment of Different Capital Inputs: A Firm-level Investigation</u></i> |

| | | |
|------|---------|---|
| GG | 36.2003 | <i>Matthieu GLACHANT</i> : <u>Voluntary Agreements under Endogenous Legislative Threats</u> |
| PRIV | 37.2003 | <i>Narjess BOUBAKRI, Jean-Claude COSSET and Omrane GUEDHAMI</i> : <u>Postprivatization Corporate Governance: the Role of Ownership Structure and Investor Protection</u> |
| CLIM | 38.2003 | <i>Rolf GOLOMBEK and Michael HOEL</i> : <u>Climate Policy under Technology Spillovers</u> |
| KNOW | 39.2003 | <i>Slim BEN YOUSSEF</i> : <u>Transboundary Pollution, R&D Spillovers and International Trade</u> |
| CTN | 40.2003 | <i>Carlo CARRARO and Carmen MARCHIORI</i> : <u>Endogenous Strategic Issue Linkage in International Negotiations</u> |
| KNOW | 41.2003 | <i>Sonia OREFFICE</i> : <u>Abortion and Female Power in the Household: Evidence from Labor Supply</u> |
| KNOW | 42.2003 | <i>Timo GOESCHL and Timothy SWANSON</i> : <u>On Biology and Technology: The Economics of Managing Biotechnologies</u> |
| ETA | 43.2003 | <i>Giorgio Busetti and Matteo MANERA</i> : <u>STAR-GARCH Models for Stock Market Interactions in the Pacific Basin Region, Japan and US</u> |
| CLIM | 44.2003 | <i>Katrin MILLOCK and Céline NAUGES</i> : <u>The French Tax on Air Pollution: Some Preliminary Results on its Effectiveness</u> |
| PRIV | 45.2003 | <i>Bernardo BORTOLOTTI and Paolo PINOTTI</i> : <u>The Political Economy of Privatization</u> |
| SIEV | 46.2003 | <i>Elbert DIJKGRAAF and Herman R.J. VOLLEBERGH</i> : <u>Burn or Bury? A Social Cost Comparison of Final Waste Disposal Methods</u> |
| ETA | 47.2003 | <i>Jens HORBACH</i> : <u>Employment and Innovations in the Environmental Sector: Determinants and Econometrical Results for Germany</u> |
| CLIM | 48.2003 | <i>Lori SNYDER, Nolan MILLER and Robert STAVINS</i> : <u>The Effects of Environmental Regulation on Technology Diffusion: The Case of Chlorine Manufacturing</u> |
| CLIM | 49.2003 | <i>Lori SNYDER, Robert STAVINS and Alexander F. WAGNER</i> : <u>Private Options to Use Public Goods. Exploiting Revealed Preferences to Estimate Environmental Benefits</u> |
| CTN | 50.2003 | <i>László Á. KÓCZY and Luc LAUWERS</i> (Ixi): <u>The Minimal Dominant Set is a Non-Empty Core-Extension</u> |
| CTN | 51.2003 | <i>Matthew O. JACKSON</i> (Ixi): <u>Allocation Rules for Network Games</u> |
| CTN | 52.2003 | <i>Ana MAULEON and Vincent VANNETELBOSCH</i> (Ixi): <u>Farsightedness and Cautiousness in Coalition Formation</u> |
| CTN | 53.2003 | <i>Fernando VEGA-REDONDO</i> (Ixi): <u>Building Up Social Capital in a Changing World: a network approach</u> |
| CTN | 54.2003 | <i>Matthew HAAG and Roger LAGUNOFF</i> (Ixi): <u>On the Size and Structure of Group Cooperation</u> |
| CTN | 55.2003 | <i>Tajji FURUSAWA and Hideo KONISHI</i> (Ixi): <u>Free Trade Networks</u> |
| CTN | 56.2003 | <i>Halis Murat YILDIZ</i> (Ixi): <u>National Versus International Mergers and Trade Liberalization</u> |
| CTN | 57.2003 | <i>Santiago RUBIO and Alistair ULPH</i> (Ixi): <u>An Infinite-Horizon Model of Dynamic Membership of International Environmental Agreements</u> |
| KNOW | 58.2003 | <i>Carole MAIGNAN, Dino PINELLI and Gianmarco I.P. OTTAVIANO</i> : <u>ICT, Clusters and Regional Cohesion: A Summary of Theoretical and Empirical Research</u> |
| KNOW | 59.2003 | <i>Giorgio BELLETTINI and Gianmarco I.P. OTTAVIANO</i> : <u>Special Interests and Technological Change</u> |
| ETA | 60.2003 | <i>Ronnie SCHÖB</i> : <u>The Double Dividend Hypothesis of Environmental Taxes: A Survey</u> |
| CLIM | 61.2003 | <i>Michael FINUS, Ekko van IERLAND and Robert DELLINK</i> : <u>Stability of Climate Coalitions in a Cartel Formation Game</u> |
| GG | 62.2003 | <i>Michael FINUS and Bianca RUNDSHAGEN</i> : <u>How the Rules of Coalition Formation Affect Stability of International Environmental Agreements</u> |
| SIEV | 63.2003 | <i>Alberto PETRUCCI</i> : <u>Taxing Land Rent in an Open Economy</u> |
| CLIM | 64.2003 | <i>Joseph E. ALDY, Scott BARRETT and Robert N. STAVINS</i> : <u>Thirteen Plus One: A Comparison of Global Climate Policy Architectures</u> |
| SIEV | 65.2003 | <i>Edi DEFRANCESCO</i> : <u>The Beginning of Organic Fish Farming in Italy</u> |
| SIEV | 66.2003 | <i>Klaus CONRAD</i> : <u>Price Competition and Product Differentiation when Consumers Care for the Environment</u> |
| SIEV | 67.2003 | <i>Paulo A.L.D. NUNES, Luca ROSSETTO, Arianne DE BLAEIJ</i> : <u>Monetary Value Assessment of Clam Fishing Management Practices in the Venice Lagoon: Results from a Stated Choice Exercise</u> |
| CLIM | 68.2003 | <i>ZhongXiang ZHANG</i> : <u>Open Trade with the U.S. Without Compromising Canada's Ability to Comply with its Kyoto Target</u> |
| KNOW | 69.2003 | <i>David FRANTZ</i> (Iix): <u>Lorenzo Market between Diversity and Mutation</u> |
| KNOW | 70.2003 | <i>Ercole SORI</i> (Iix): <u>Mapping Diversity in Social History</u> |
| KNOW | 71.2003 | <i>Ljiljana DERU SIMIC</i> (Ixi): <u>What is Specific about Art/Cultural Projects?</u> |
| KNOW | 72.2003 | <i>Natalya V. TARANOVA</i> (Ixi): <u>The Role of the City in Fostering Intergroup Communication in a Multicultural Environment: Saint-Petersburg's Case</u> |
| KNOW | 73.2003 | <i>Kristine CRANE</i> (Ixi): <u>The City as an Arena for the Expression of Multiple Identities in the Age of Globalisation and Migration</u> |
| KNOW | 74.2003 | <i>Kazuma MATOBA</i> (Ixi): <u>Glocal Dialogue- Transformation through Transcultural Communication</u> |
| KNOW | 75.2003 | <i>Catarina REIS OLIVEIRA</i> (Ixi): <u>Immigrants' Entrepreneurial Opportunities: The Case of the Chinese in Portugal</u> |
| KNOW | 76.2003 | <i>Sandra WALLMAN</i> (Ixi): <u>The Diversity of Diversity - towards a typology of urban systems</u> |
| KNOW | 77.2003 | <i>Richard PEARCE</i> (Ixi): <u>A Biologist's View of Individual Cultural Identity for the Study of Cities</u> |
| KNOW | 78.2003 | <i>Vincent MERK</i> (Ixi): <u>Communication Across Cultures: from Cultural Awareness to Reconciliation of the Dilemmas</u> |
| KNOW | 79.2003 | <i>Giorgio BELLETTINI, Carlotta BERTI CERONI and Gianmarco I.P. OTTAVIANO</i> : <u>Child Labor and Resistance to Change</u> |
| ETA | 80.2003 | <i>Michele MORETTO, Paolo M. PANTEGHINI and Carlo SCARPA</i> : <u>Investment Size and Firm's Value under Profit Sharing Regulation</u> |

| | | |
|------|-------------|---|
| IEM | 81.2003 | <i>Alessandro LANZA, Matteo MANERA and Massimo GIOVANNINI: <u>Oil and Product Dynamics in International Petroleum Markets</u></i> |
| CLIM | 82.2003 | <i>Y. Hossein FARZIN and Jinhua ZHAO: <u>Pollution Abatement Investment When Firms Lobby Against Environmental Regulation</u></i> |
| CLIM | 83.2003 | <i>Giuseppe DI VITA: <u>Is the Discount Rate Relevant in Explaining the Environmental Kuznets Curve?</u></i> |
| CLIM | 84.2003 | <i>Reyer GERLAGH and Wietze LISE: <u>Induced Technological Change Under Carbon Taxes</u></i> |
| NRM | 85.2003 | <i>Rinaldo BRAU, Alessandro LANZA and Francesco PIGLIARU: <u>How Fast are the Tourism Countries Growing? The cross-country evidence</u></i> |
| KNOW | 86.2003 | <i>Elena BELLINI, Gianmarco I.P. OTTAVIANO and Dino PINELLI: <u>The ICT Revolution: opportunities and risks for the Mezzogiorno</u></i> |
| SIEV | 87.2003 | <i>Lucas BRETSCGHER and Sjak SMULDERS: <u>Sustainability and Substitution of Exhaustible Natural Resources. How resource prices affect long-term R&D investments</u></i> |
| CLIM | 88.2003 | <i>Johan EYCKMANS and Michael FINUS: <u>New Roads to International Environmental Agreements: The Case of Global Warming</u></i> |
| CLIM | 89.2003 | <i>Marzio GALEOTTI: <u>Economic Development and Environmental Protection</u></i> |
| CLIM | 90.2003 | <i>Marzio GALEOTTI: <u>Environment and Economic Growth: Is Technical Change the Key to Decoupling?</u></i> |
| CLIM | 91.2003 | <i>Marzio GALEOTTI and Barbara BUCHNER: <u>Climate Policy and Economic Growth in Developing Countries</u></i> |
| IEM | 92.2003 | <i>A. MARKANDYA, A. GOLUB and E. STRUKOVA: <u>The Influence of Climate Change Considerations on Energy Policy: The Case of Russia</u></i> |
| ETA | 93.2003 | <i>Andrea BELTRATTI: <u>Socially Responsible Investment in General Equilibrium</u></i> |
| CTN | 94.2003 | <i>Parkash CHANDER: <u>The γ-Core and Coalition Formation</u></i> |
| IEM | 95.2003 | <i>Matteo MANERA and Angelo MARZULLO: <u>Modelling the Load Curve of Aggregate Electricity Consumption Using Principal Components</u></i> |
| IEM | 96.2003 | <i>Alessandro LANZA, Matteo MANERA, Margherita GRASSO and Massimo GIOVANNINI: <u>Long-run Models of Oil Stock Prices</u></i> |
| CTN | 97.2003 | <i>Steven J. BRAMS, Michael A. JONES, and D. Marc KILGOUR: <u>Forming Stable Coalitions: The Process Matters</u></i> |
| KNOW | 98.2003 | <i>John CROWLEY, Marie-Cecile NAVES (Ixxiii): <u>Anti-Racist Policies in France. From Ideological and Historical Schemes to Socio-Political Realities</u></i> |
| KNOW | 99.2003 | <i>Richard THOMPSON FORD (Ixxiii): <u>Cultural Rights and Civic Virtue</u></i> |
| KNOW | 100.2003 | <i>Alaknanda PATEL (Ixxiii): <u>Cultural Diversity and Conflict in Multicultural Cities</u></i> |
| KNOW | 101.2003 | <i>David MAY (Ixxiii): <u>The Struggle of Becoming Established in a Deprived Inner-City Neighbourhood</u></i> |
| KNOW | 102.2003 | <i>Sébastien ARCAND, Danielle JUTEAU, Sirma BILGE, and Francine LEMIRE (Ixxiii) : <u>Municipal Reform on the Island of Montreal: Tensions Between Two Majority Groups in a Multicultural City</u></i> |
| CLIM | 103.2003 | <i>Barbara BUCHNER and Carlo CARRARO: <u>China and the Evolution of the Present Climate Regime</u></i> |
| CLIM | 104.2003 | <i>Barbara BUCHNER and Carlo CARRARO: <u>Emissions Trading Regimes and Incentives to Participate in International Climate Agreements</u></i> |
| CLIM | 105.2003 | <i>Anil MARKANDYA and Dirk T.G. RÜBBELKE: <u>Ancillary Benefits of Climate Policy</u></i> |
| NRM | 106.2003 | <i>Anne Sophie CRÉPIN (Ixiv): <u>Management Challenges for Multiple-Species Boreal Forests</u></i> |
| NRM | 107.2003 | <i>Anne Sophie CRÉPIN (Ixiv): <u>Threshold Effects in Coral Reef Fisheries</u></i> |
| SIEV | 108.2003 | <i>Sara ANIYAR (Ixiv): <u>Estimating the Value of Oil Capital in a Small Open Economy: The Venezuela's Example</u></i> |
| SIEV | 109.2003 | <i>Kenneth ARROW, Partha DASGUPTA and Karl-Göran MÄLER(Ixiv): <u>Evaluating Projects and Assessing Sustainable Development in Imperfect Economies</u></i> |
| NRM | 110.2003 | <i>Anastasios XEPAPADEAS and Catarina ROSETA-PALMA(Ixiv): <u>Instabilities and Robust Control in Fisheries</u></i> |
| NRM | 111.2003 | <i>Charles PERRINGS and Brian WALKER (Ixiv): <u>Conservation and Optimal Use of Rangelands</u></i> |
| ETA | 112.2003 | <i>Jack GOODY (Ixiv): <u>Globalisation, Population and Ecology</u></i> |
| CTN | 113.2003 | <i>Carlo CARRARO, Carmen MARCHIORI and Sonia OREFFICE: <u>Endogenous Minimum Participation in International Environmental Treaties</u></i> |
| CTN | 114.2003 | <i>Guillaume HAERINGER and Myrna WOODERS: <u>Decentralized Job Matching</u></i> |
| CTN | 115.2003 | <i>Hideo KONISHI and M. Utku UNVER: <u>Credible Group Stability in Multi-Partner Matching Problems</u></i> |
| CTN | 116.2003 | <i>Somdeb LAHIRI: <u>Stable Matchings for the Room-Mates Problem</u></i> |
| CTN | 117.2003 | <i>Somdeb LAHIRI: <u>Stable Matchings for a Generalized Marriage Problem</u></i> |
| CTN | 118.2003 | <i>Marita LAUKKANEN: <u>Transboundary Fisheries Management under Implementation Uncertainty</u></i> |
| CTN | 119.2003 | <i>Edward CARTWRIGHT and Myrna WOODERS: <u>Social Conformity and Bounded Rationality in Arbitrary Games with Incomplete Information: Some First Results</u></i> |
| CTN | 120.2003 | <i>Gianluigi VERNASCA: <u>Dynamic Price Competition with Price Adjustment Costs and Product Differentiation</u></i> |
| CTN | 121.2003 | <i>Myrna WOODERS, Edward CARTWRIGHT and Reinhard SELTEN: <u>Social Conformity in Games with Many Players</u></i> |
| CTN | 122.2003 | <i>Edward CARTWRIGHT and Myrna WOODERS: <u>On Equilibrium in Pure Strategies in Games with Many Players</u></i> |
| CTN | 123.2003 | <i>Edward CARTWRIGHT and Myrna WOODERS: <u>Conformity and Bounded Rationality in Games with Many Players</u></i> |
| | 1000 | Carlo CARRARO, Alessandro LANZA and Valeria PAPPONETTI: <u>One Thousand Working Papers</u> |

NOTE DI LAVORO PUBLISHED IN 2004

| | | |
|------|---------|--|
| IEM | 1.2004 | <i>Anil MARKANDYA, Suzette PEDROSO and Alexander GOLUB: <u>Empirical Analysis of National Income and So2 Emissions in Selected European Countries</u></i> |
| ETA | 2.2004 | <i>Masahisa FUJITA and Shlomo WEBER: <u>Strategic Immigration Policies and Welfare in Heterogeneous Countries</u></i> |
| PRA | 3.2004 | <i>Adolfo DI CARLUCCIO, Giovanni FERRI, Cecilia FRALE and Ottavio RICCHI: <u>Do Privatizations Boost Household Shareholding? Evidence from Italy</u></i> |
| ETA | 4.2004 | <i>Victor GINSBURGH and Shlomo WEBER: <u>Languages Disenfranchisement in the European Union</u></i> |
| ETA | 5.2004 | <i>Romano PIRAS: <u>Growth, Congestion of Public Goods, and Second-Best Optimal Policy</u></i> |
| CCMP | 6.2004 | <i>Herman R.J. VOLLEBERGH: <u>Lessons from the Polder: Is Dutch CO2-Taxation Optimal</u></i> |
| PRA | 7.2004 | <i>Sandro BRUSCO, Giuseppe LOPOMO and S. VISWANATHAN (lxv): <u>Merger Mechanisms</u></i> |
| PRA | 8.2004 | <i>Wolfgang AUSSENEGG, Pegaret PICHLER and Alex STOMPER (lxv): <u>IPO Pricing with Bookbuilding, and a When-Issued Market</u></i> |
| PRA | 9.2004 | <i>Pegaret PICHLER and Alex STOMPER (lxv): <u>Primary Market Design: Direct Mechanisms and Markets</u></i> |
| PRA | 10.2004 | <i>Florian ENGLMAIER, Pablo GUILLEN, Loreto LLORENTE, Sander ONDERSTAL and Rupert SAUSGRUBER (lxv): <u>The Chopstick Auction: A Study of the Exposure Problem in Multi-Unit Auctions</u></i> |
| PRA | 11.2004 | <i>Bjarne BRENDSTRUP and Harry J. PAARSCH (lxv): <u>Nonparametric Identification and Estimation of Multi-Unit, Sequential, Oral, Ascending-Price Auctions With Asymmetric Bidders</u></i> |
| PRA | 12.2004 | <i>Ohad KADAN (lxv): <u>Equilibrium in the Two Player, k-Double Auction with Affiliated Private Values</u></i> |
| PRA | 13.2004 | <i>Maarten C.W. JANSSEN (lxv): <u>Auctions as Coordination Devices</u></i> |
| PRA | 14.2004 | <i>Gadi FIBICH, Arieh GAVIOUS and Aner SELA (lxv): <u>All-Pay Auctions with Weakly Risk-Averse Buyers</u></i> |
| PRA | 15.2004 | <i>Orly SADE, Charles SCHNITZLEIN and Jaime F. ZENDER (lxv): <u>Competition and Cooperation in Divisible Good Auctions: An Experimental Examination</u></i> |
| PRA | 16.2004 | <i>Marta STRYSZOWSKA (lxv): <u>Late and Multiple Bidding in Competing Second Price Internet Auctions</u></i> |
| CCMP | 17.2004 | <i>Slim Ben YOUSSEF: <u>R&D in Cleaner Technology and International Trade</u></i> |
| NRM | 18.2004 | <i>Angelo ANTOCI, Simone BORGHESI and Paolo RUSSU (lxvi): <u>Biodiversity and Economic Growth: Stabilization Versus Preservation of the Ecological Dynamics</u></i> |
| SIEV | 19.2004 | <i>Anna ALBERINI, Paolo ROSATO, Alberto LONGO and Valentina ZANATTA: <u>Information and Willingness to Pay in a Contingent Valuation Study: The Value of S. Erasmo in the Lagoon of Venice</u></i> |
| NRM | 20.2004 | <i>Guido CANDELA and Roberto CELLINI (lxvii): <u>Investment in Tourism Market: A Dynamic Model of Differentiated Oligopoly</u></i> |
| NRM | 21.2004 | <i>Jacqueline M. HAMILTON (lxvii): <u>Climate and the Destination Choice of German Tourists</u></i> |
| NRM | 22.2004 | <i>Javier Rey-MAQUIEIRA PALMER, Javier LOZANO IBÁÑEZ and Carlos Mario GÓMEZ GÓMEZ (lxvii): <u>Land, Environmental Externalities and Tourism Development</u></i> |
| NRM | 23.2004 | <i>Pius ODUNGA and Henk FOLMER (lxvii): <u>Profiling Tourists for Balanced Utilization of Tourism-Based Resources in Kenya</u></i> |
| NRM | 24.2004 | <i>Jean-Jacques NOWAK, Mondher SAHLI and Pasquale M. SGRO (lxvii): <u>Tourism, Trade and Domestic Welfare</u></i> |
| NRM | 25.2004 | <i>Riaz SHAREEF (lxvii): <u>Country Risk Ratings of Small Island Tourism Economies</u></i> |
| NRM | 26.2004 | <i>Juan Luis EUGENIO-MARTÍN, Noelia MARTÍN MORALES and Riccardo SCARPA (lxvii): <u>Tourism and Economic Growth in Latin American Countries: A Panel Data Approach</u></i> |
| NRM | 27.2004 | <i>Raúl Hernández MARTÍN (lxvii): <u>Impact of Tourism Consumption on GDP. The Role of Imports</u></i> |
| CSRM | 28.2004 | <i>Nicoletta FERRO: <u>Cross-Country Ethical Dilemmas in Business: A Descriptive Framework</u></i> |
| NRM | 29.2004 | <i>Marian WEBER (lxvi): <u>Assessing the Effectiveness of Tradable Landuse Rights for Biodiversity Conservation: an Application to Canada's Boreal Mixedwood Forest</u></i> |
| NRM | 30.2004 | <i>Trond BJORN DAL, Phoebe KOUNDOURI and Sean PASCOE (lxvi): <u>Output Substitution in Multi-Species Trawl Fisheries: Implications for Quota Setting</u></i> |
| CCMP | 31.2004 | <i>Marzio GALEOTTI, Alessandra GORIA, Paolo MOMBRINI and Evi SPANTIDAKI: <u>Weather Impacts on Natural, Social and Economic Systems (WISE) Part I: Sectoral Analysis of Climate Impacts in Italy</u></i> |
| CCMP | 32.2004 | <i>Marzio GALEOTTI, Alessandra GORIA, Paolo MOMBRINI and Evi SPANTIDAKI: <u>Weather Impacts on Natural, Social and Economic Systems (WISE) Part II: Individual Perception of Climate Extremes in Italy</u></i> |
| CTN | 33.2004 | <i>Wilson PEREZ: <u>Divide and Conquer: Noisy Communication in Networks, Power, and Wealth Distribution</u></i> |
| KTHC | 34.2004 | <i>Gianmarco I.P. OTTAVIANO and Giovanni PERI (lxviii): <u>The Economic Value of Cultural Diversity: Evidence from US Cities</u></i> |
| KTHC | 35.2004 | <i>Linda CHAIB (lxviii): <u>Immigration and Local Urban Participatory Democracy: A Boston-Paris Comparison</u></i> |
| KTHC | 36.2004 | <i>Franca ECKERT COEN and Claudio ROSSI (lxviii): <u>Foreigners, Immigrants, Host Cities: The Policies of Multi-Ethnicity in Rome. Reading Governance in a Local Context</u></i> |
| KTHC | 37.2004 | <i>Kristine CRANE (lxviii): <u>Governing Migration: Immigrant Groups' Strategies in Three Italian Cities – Rome, Naples and Bari</u></i> |
| KTHC | 38.2004 | <i>Kiflemariam HAMDE (lxviii): <u>Mind in Africa, Body in Europe: The Struggle for Maintaining and Transforming Cultural Identity - A Note from the Experience of Eritrean Immigrants in Stockholm</u></i> |
| ETA | 39.2004 | <i>Alberto CAVALIERE: <u>Price Competition with Information Disparities in a Vertically Differentiated Duopoly</u></i> |
| PRA | 40.2004 | <i>Andrea BIGANO and Stef PROOST: <u>The Opening of the European Electricity Market and Environmental Policy: Does the Degree of Competition Matter?</u></i> |
| CCMP | 41.2004 | <i>Micheal FINUS (lxix): <u>International Cooperation to Resolve International Pollution Problems</u></i> |
| KTHC | 42.2004 | <i>Francesco CRESPI: <u>Notes on the Determinants of Innovation: A Multi-Perspective Analysis</u></i> |

| | | |
|------|---------|--|
| CTN | 43.2004 | <i>Sergio CURRARINI and Marco MARINI: <u>Coalition Formation in Games without Synergies</u></i> |
| CTN | 44.2004 | <i>Marc ESCRHUELA-VILLAR: <u>Cartel Sustainability and Cartel Stability</u></i> |
| NRM | 45.2004 | <i>Sebastian BERVOETS and Nicolas GRAVEL (lxvi): <u>Appraising Diversity with an Ordinal Notion of Similarity: An Axiomatic Approach</u></i> |
| NRM | 46.2004 | <i>Signe ANTHON and Bo JELLESMARK THORSEN (lxvi): <u>Optimal Afforestation Contracts with Asymmetric Information on Private Environmental Benefits</u></i> |
| NRM | 47.2004 | <i>John MBURU (lxvi): <u>Wildlife Conservation and Management in Kenya: Towards a Co-management Approach</u></i> |
| NRM | 48.2004 | <i>Ekin BIROL, Ágnes GYOVAI and Melinda SMALE (lxvi): <u>Using a Choice Experiment to Value Agricultural Biodiversity on Hungarian Small Farms: Agri-Environmental Policies in a Transitional Economy</u></i> |
| CCMP | 49.2004 | <i>Gernot KLEPPER and Sonja PETERSON: <u>The EU Emissions Trading Scheme. Allowance Prices, Trade Flows, Competitiveness Effects</u></i> |
| GG | 50.2004 | <i>Scott BARRETT and Michael HOEL: <u>Optimal Disease Eradication</u></i> |
| CTN | 51.2004 | <i>Dinko DIMITROV, Peter BORM, Ruud HENDRICKX and Shao CHIN SUNG: <u>Simple Priorities and Core Stability in Hedonic Games</u></i> |
| SIEV | 52.2004 | <i>Francesco RICCI: <u>Channels of Transmission of Environmental Policy to Economic Growth: A Survey of the Theory</u></i> |
| SIEV | 53.2004 | <i>Anna ALBERINI, Maureen CROPPER, Alan KRUPNICK and Nathalie B. SIMON: <u>Willingness to Pay for Mortality Risk Reductions: Does Latency Matter?</u></i> |
| NRM | 54.2004 | <i>Ingo BRÄUER and Rainer MARGGRAF (lxvi): <u>Valuation of Ecosystem Services Provided by Biodiversity Conservation: An Integrated Hydrological and Economic Model to Value the Enhanced Nitrogen Retention in Renaturated Streams</u></i> |
| NRM | 55.2004 | <i>Timo GOESCHL and Tun LIN (lxvi): <u>Biodiversity Conservation on Private Lands: Information Problems and Regulatory Choices</u></i> |
| NRM | 56.2004 | <i>Tom DEDEURWAERDERE (lxvi): <u>Bioprospection: From the Economics of Contracts to Reflexive Governance</u></i> |
| CCMP | 57.2004 | <i>Katrin REHDANZ and David MADDISON: <u>The Amenity Value of Climate to German Households</u></i> |
| CCMP | 58.2004 | <i>Koen SMEKENS and Bob VAN DER ZWAAN: <u>Environmental Externalities of Geological Carbon Sequestration Effects on Energy Scenarios</u></i> |
| NRM | 59.2004 | <i>Valentina BOSETTI, Mariaester CASSINELLI and Alessandro LANZA (lxvii): <u>Using Data Envelopment Analysis to Evaluate Environmentally Conscious Tourism Management</u></i> |
| NRM | 60.2004 | <i>Timo GOESCHL and Danilo CAMARGO IGLIORI (lxvi): <u>Property Rights Conservation and Development: An Analysis of Extractive Reserves in the Brazilian Amazon</u></i> |
| CCMP | 61.2004 | <i>Barbara BUCHNER and Carlo CARRARO: <u>Economic and Environmental Effectiveness of a Technology-based Climate Protocol</u></i> |
| NRM | 62.2004 | <i>Elissaios POPYRAKIS and Reyer GERLAGH: <u>Resource-Abundance and Economic Growth in the U.S.</u></i> |
| NRM | 63.2004 | <i>Györgyi BELA, György PATAKI, Melinda SMALE and Mariann HAJDÚ (lxvi): <u>Conserving Crop Genetic Resources on Smallholder Farms in Hungary: Institutional Analysis</u></i> |
| NRM | 64.2004 | <i>E.C.M. RUIJGROK and E.E.M. NILLESEN (lxvi): <u>The Socio-Economic Value of Natural Riverbanks in the Netherlands</u></i> |
| NRM | 65.2004 | <i>E.C.M. RUIJGROK (lxvi): <u>Reducing Acidification: The Benefits of Increased Nature Quality. Investigating the Possibilities of the Contingent Valuation Method</u></i> |
| ETA | 66.2004 | <i>Giannis VARDAS and Anastasios XEPAPADEAS: <u>Uncertainty Aversion, Robust Control and Asset Holdings</u></i> |
| GG | 67.2004 | <i>Anastasios XEPAPADEAS and Constadina PASSA: <u>Participation in and Compliance with Public Voluntary Environmental Programs: An Evolutionary Approach</u></i> |
| GG | 68.2004 | <i>Michael FINUS: <u>Modesty Pays: Sometimes!</u></i> |
| NRM | 69.2004 | <i>Trond BJØRNDAL and Ana BRASÃO: <u>The Northern Atlantic Bluefin Tuna Fisheries: Management and Policy Implications</u></i> |
| CTN | 70.2004 | <i>Alejandro CAPARRÓS, Abdelhakim HAMMOUDI and Tarik TAZDAÏT: <u>On Coalition Formation with Heterogeneous Agents</u></i> |
| IEM | 71.2004 | <i>Massimo GIOVANNINI, Margherita GRASSO, Alessandro LANZA and Matteo MANERA: <u>Conditional Correlations in the Returns on Oil Companies Stock Prices and Their Determinants</u></i> |
| IEM | 72.2004 | <i>Alessandro LANZA, Matteo MANERA and Michael MCALEER: <u>Modelling Dynamic Conditional Correlations in WTI Oil Forward and Futures Returns</u></i> |
| SIEV | 73.2004 | <i>Margarita GENIUS and Elisabetta STRAZZERA: <u>The Copula Approach to Sample Selection Modelling: An Application to the Recreational Value of Forests</u></i> |
| CCMP | 74.2004 | <i>Rob DELLINK and Ekko van IERLAND: <u>Pollution Abatement in the Netherlands: A Dynamic Applied General Equilibrium Assessment</u></i> |
| ETA | 75.2004 | <i>Rosella LEVAGGI and Michele MORETTO: <u>Investment in Hospital Care Technology under Different Purchasing Rules: A Real Option Approach</u></i> |
| CTN | 76.2004 | <i>Salvador BARBERÀ and Matthew O. JACKSON (lxx): <u>On the Weights of Nations: Assigning Voting Weights in a Heterogeneous Union</u></i> |
| CTN | 77.2004 | <i>Àlex ARENAS, Antonio CABRALES, Albert DÍAZ-GUILERA, Roger GUIMERA and Fernando VEGA-REDONDO (lxx): <u>Optimal Information Transmission in Organizations: Search and Congestion</u></i> |
| CTN | 78.2004 | <i>Francis BLOCH and Armando GOMES (lxx): <u>Contracting with Externalities and Outside Options</u></i> |
| CTN | 79.2004 | <i>Rabah AMIR, Effrosyni DIAMANTOUDI and Licun XUE (lxx): <u>Merger Performance under Uncertain Efficiency Gains</u></i> |
| CTN | 80.2004 | <i>Francis BLOCH and Matthew O. JACKSON (lxx): <u>The Formation of Networks with Transfers among Players</u></i> |
| CTN | 81.2004 | <i>Daniel DIERMEIER, Hülya ERASLAN and Antonio MERLO (lxx): <u>Bicameralism and Government Formation</u></i> |

| | | |
|------|----------|--|
| CTN | 82.2004 | <i>Rod GARRATT, James E. PARCO, Cheng-ZHONG QIN and Amnon RAPOPORT</i> (lxx): <u>Potential Maximization and Coalition Government Formation</u> |
| CTN | 83.2004 | <i>Kfir ELIAZ, Debraj RAY and Ronny RAZIN</i> (lxx): <u>Group Decision-Making in the Shadow of Disagreement</u> |
| CTN | 84.2004 | <i>Sanjeev GOYAL, Marco van der LEIJ and José Luis MORAGA-GONZÁLEZ</i> (lxx): <u>Economics: An Emerging Small World?</u> |
| CTN | 85.2004 | <i>Edward CARTWRIGHT</i> (lxx): <u>Learning to Play Approximate Nash Equilibria in Games with Many Players</u> |
| IEM | 86.2004 | <i>Finn R. FØRSUND and Michael HOEL</i> : <u>Properties of a Non-Competitive Electricity Market Dominated by Hydroelectric Power</u> |
| KTHC | 87.2004 | <i>Elissaios POPYRAKIS and Reyer GERLAGH</i> : <u>Natural Resources, Investment and Long-Term Income</u> |
| CCMP | 88.2004 | <i>Marzio GALEOTTI and Claudia KEMFERT</i> : <u>Interactions between Climate and Trade Policies: A Survey</u> |
| IEM | 89.2004 | <i>A. MARKANDYA, S. PEDROSO and D. STREIMIKIENE</i> : <u>Energy Efficiency in Transition Economies: Is There Convergence Towards the EU Average?</u> |
| GG | 90.2004 | <i>Rolf GOLOMBEK and Michael HOEL</i> : <u>Climate Agreements and Technology Policy</u> |
| PRA | 91.2004 | <i>Sergei IZMALKOV</i> (lxx): <u>Multi-Unit Open Ascending Price Efficient Auction</u> |
| KTHC | 92.2004 | <i>Gianmarco I.P. OTTAVIANO and Giovanni PERI</i> : <u>Cities and Cultures</u> |
| KTHC | 93.2004 | <i>Massimo DEL GATTO</i> : <u>Agglomeration, Integration, and Territorial Authority Scale in a System of Trading Cities. Centralisation versus devolution</u> |
| CCMP | 94.2004 | <i>Pierre-André JOUVET, Philippe MICHEL and Gilles ROTILLON</i> : <u>Equilibrium with a Market of Permits</u> |
| CCMP | 95.2004 | <i>Bob van der ZWAAN and Reyer GERLAGH</i> : <u>Climate Uncertainty and the Necessity to Transform Global Energy Supply</u> |
| CCMP | 96.2004 | <i>Francesco BOSELLO, Marco LAZZARIN, Roberto ROSON and Richard S.J. TOL</i> : <u>Economy-Wide Estimates of the Implications of Climate Change: Sea Level Rise</u> |
| CTN | 97.2004 | <i>Gustavo BERGANTIÑOS and Juan J. VIDAL-PUGA</i> : <u>Defining Rules in Cost Spanning Tree Problems Through the Canonical Form</u> |
| CTN | 98.2004 | <i>Siddhartha BANDYOPADHYAY and Mandar OAK</i> : <u>Party Formation and Coalitional Bargaining in a Model of Proportional Representation</u> |
| GG | 99.2004 | <i>Hans-Peter WEIKARD, Michael FINUS and Juan-Carlos ALTAMIRANO-CABRERA</i> : <u>The Impact of Surplus Sharing on the Stability of International Climate Agreements</u> |
| SIEV | 100.2004 | <i>Chiara M. TRAVISI and Peter NIJKAMP</i> : <u>Willingness to Pay for Agricultural Environmental Safety: Evidence from a Survey of Milan, Italy, Residents</u> |
| SIEV | 101.2004 | <i>Chiara M. TRAVISI, Raymond J. G. M. FLORAX and Peter NIJKAMP</i> : <u>A Meta-Analysis of the Willingness to Pay for Reductions in Pesticide Risk Exposure</u> |
| NRM | 102.2004 | <i>Valentina BOSETTI and David TOMBERLIN</i> : <u>Real Options Analysis of Fishing Fleet Dynamics: A Test</u> |
| CCMP | 103.2004 | <i>Alessandra GORIA e Gretel GAMBARELLI</i> : <u>Economic Evaluation of Climate Change Impacts and Adaptability in Italy</u> |
| PRA | 104.2004 | <i>Massimo FLORIO and Mara GRASSENTI</i> : <u>The Missing Shock: The Macroeconomic Impact of British Privatisation</u> |
| PRA | 105.2004 | <i>John BENNETT, Saul ESTRIN, James MAW and Giovanni URGÀ</i> : <u>Privatisation Methods and Economic Growth in Transition Economies</u> |
| PRA | 106.2004 | <i>Kira BÖRNER</i> : <u>The Political Economy of Privatization: Why Do Governments Want Reforms?</u> |
| PRA | 107.2004 | <i>Pebr-Johan NORBÄCK and Lars PERSSON</i> : <u>Privatization and Restructuring in Concentrated Markets</u> |
| SIEV | 108.2004 | <i>Angela GRANZOTTO, Fabio PRANOVI, Simone LIBRALATO, Patrizia TORRICELLI and Danilo MAINARDI</i> : <u>Comparison between Artisanal Fishery and Manila Clam Harvesting in the Venice Lagoon by Using Ecosystem Indicators: An Ecological Economics Perspective</u> |
| CTN | 109.2004 | <i>Somdeb LAHIRI</i> : <u>The Cooperative Theory of Two Sided Matching Problems: A Re-examination of Some Results</u> |
| NRM | 110.2004 | <i>Giuseppe DI VITA</i> : <u>Natural Resources Dynamics: Another Look</u> |
| SIEV | 111.2004 | <i>Anna ALBERINI, Alistair HUNT and Anil MARKANDYA</i> : <u>Willingness to Pay to Reduce Mortality Risks: Evidence from a Three-Country Contingent Valuation Study</u> |
| KTHC | 112.2004 | <i>Valeria PAPPONETTI and Dino PINELLI</i> : <u>Scientific Advice to Public Policy-Making</u> |
| SIEV | 113.2004 | <i>Paulo A.L.D. NUNES and Laura ONOFRI</i> : <u>The Economics of Warm Glow: A Note on Consumer's Behavior and Public Policy Implications</u> |
| IEM | 114.2004 | <i>Patrick CAYRADE</i> : <u>Investments in Gas Pipelines and Liquefied Natural Gas Infrastructure What is the Impact on the Security of Supply?</u> |
| IEM | 115.2004 | <i>Valeria COSTANTINI and Francesco GRACCEVA</i> : <u>Oil Security. Short- and Long-Term Policies</u> |
| IEM | 116.2004 | <i>Valeria COSTANTINI and Francesco GRACCEVA</i> : <u>Social Costs of Energy Disruptions</u> |
| IEM | 117.2004 | <i>Christian EGENHOFER, Kyriakos GIALOGLOU, Giacomo LUCIANI, Maroeska BOOTS, Martin SCHEEPERS, Valeria COSTANTINI, Francesco GRACCEVA, Anil MARKANDYA and Giorgio VICINI</i> : <u>Market-Based Options for Security of Energy Supply</u> |
| IEM | 118.2004 | <i>David FISK</i> : <u>Transport Energy Security. The Unseen Risk?</u> |
| IEM | 119.2004 | <i>Giacomo LUCIANI</i> : <u>Security of Supply for Natural Gas Markets. What is it and What is it not?</u> |
| IEM | 120.2004 | <i>L.J. de VRIES and R.A. HAKVOORT</i> : <u>The Question of Generation Adequacy in Liberalised Electricity Markets</u> |
| KTHC | 121.2004 | <i>Alberto PETRUCCI</i> : <u>Asset Accumulation, Fertility Choice and Nondegenerate Dynamics in a Small Open Economy</u> |
| NRM | 122.2004 | <i>Carlo GIUPPONI, Jaroslaw MYSLAK and Anita FASSIO</i> : <u>An Integrated Assessment Framework for Water Resources Management: A DSS Tool and a Pilot Study Application</u> |
| NRM | 123.2004 | <i>Margaretha BREIL, Anita FASSIO, Carlo GIUPPONI and Paolo ROSATO</i> : <u>Evaluation of Urban Improvement on the Islands of the Venice Lagoon: A Spatially-Distributed Hedonic-Hierarchical Approach</u> |

| | | |
|------|----------|--|
| ETA | 124.2004 | <i>Paul MENSINK: <u>Instant Efficient Pollution Abatement Under Non-Linear Taxation and Asymmetric Information: The Differential Tax Revisited</u></i> |
| NRM | 125.2004 | <i>Mauro FABIANO, Gabriella CAMARSA, Rosanna DURSI, Roberta IVALDI, Valentina MARIN and Francesca PALMISANI: <u>Integrated Environmental Study for Beach Management: A Methodological Approach</u></i> |
| PRA | 126.2004 | <i>Irena GROSFELD and Iraj HASHI: <u>The Emergence of Large Shareholders in Mass Privatized Firms: Evidence from Poland and the Czech Republic</u></i> |
| CCMP | 127.2004 | <i>Maria BERRITTELLA, Andrea BIGANO, Roberto ROSON and Richard S.J. TOL: <u>A General Equilibrium Analysis of Climate Change Impacts on Tourism</u></i> |
| CCMP | 128.2004 | <i>Reyer GERLAGH: <u>A Climate-Change Policy Induced Shift from Innovations in Energy Production to Energy Savings</u></i> |
| NRM | 129.2004 | <i>Elissaios PAPYRAKIS and Reyer GERLAGH: <u>Natural Resources, Innovation, and Growth</u></i> |
| PRA | 130.2004 | <i>Bernardo BORTOLOTTI and Mara FACCIO: <u>Reluctant Privatization</u></i> |
| SIEV | 131.2004 | <i>Riccardo SCARPA and Mara THIENE: <u>Destination Choice Models for Rock Climbing in the Northeast Alps: A Latent-Class Approach Based on Intensity of Participation</u></i> |
| SIEV | 132.2004 | <i>Riccardo SCARPA, Kenneth G. WILLIS and Melinda ACUTT: <u>Comparing Individual-Specific Benefit Estimates for Public Goods: Finite Versus Continuous Mixing in Logit Models</u></i> |
| IEM | 133.2004 | <i>Santiago J. RUBIO: <u>On Capturing Oil Rents with a National Excise Tax Revisited</u></i> |
| ETA | 134.2004 | <i>Ascensión ANDINA DÍAZ: <u>Political Competition when Media Create Candidates' Charisma</u></i> |
| SIEV | 135.2004 | <i>Anna ALBERINI: <u>Robustness of VSL Values from Contingent Valuation Surveys</u></i> |
| CCMP | 136.2004 | <i>Gernot KLEPPER and Sonja PETERSON: <u>Marginal Abatement Cost Curves in General Equilibrium: The Influence of World Energy Prices</u></i> |
| ETA | 137.2004 | <i>Herbert DAWID, Christophe DEISSEBERG and Pavel ŠEVČIK: <u>Cheap Talk, Gullibility, and Welfare in an Environmental Taxation Game</u></i> |
| CCMP | 138.2004 | <i>ZhongXiang ZHANG: <u>The World Bank's Prototype Carbon Fund and China</u></i> |
| CCMP | 139.2004 | <i>Reyer GERLAGH and Marjan W. HOFKES: <u>Time Profile of Climate Change Stabilization Policy</u></i> |
| NRM | 140.2004 | <i>Chiara D'ALPAOS and Michele MORETTO: <u>The Value of Flexibility in the Italian Water Service Sector: A Real Option Analysis</u></i> |

- (lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
- (lx) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002
- (lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
- (lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002
- (lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
- (lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
- (lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003
- (lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL), Venice, August 28-29, 2003
- (lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003
- (lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003
- (lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference “The Future of Climate Policy”, Cagliari, Italy, 27-28 March 2003
- (lxx) This paper was presented at the 9th Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

2003 SERIES

| | |
|-------------|--|
| CLIM | <i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti) |
| GG | <i>Global Governance</i> (Editor: Carlo Carraro) |
| SIEV | <i>Sustainability Indicators and Environmental Valuation</i> (Editor: Anna Alberini) |
| NRM | <i>Natural Resources Management</i> (Editor: Carlo Giupponi) |
| KNOW | <i>Knowledge, Technology, Human Capital</i> (Editor: Gianmarco Ottaviano) |
| IEM | <i>International Energy Markets</i> (Editor: Anil Markandya) |
| CSR | <i>Corporate Social Responsibility and Management</i> (Editor: Sabina Ratti) |
| PRIV | <i>Privatisation, Regulation, Antitrust</i> (Editor: Bernardo Bortolotti) |
| ETA | <i>Economic Theory and Applications</i> (Editor: Carlo Carraro) |
| CTN | <i>Coalition Theory Network</i> |

2004 SERIES

| | |
|-------------|--|
| CCMP | <i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti) |
| GG | <i>Global Governance</i> (Editor: Carlo Carraro) |
| SIEV | <i>Sustainability Indicators and Environmental Valuation</i> (Editor: Anna Alberini) |
| NRM | <i>Natural Resources Management</i> (Editor: Carlo Giupponi) |
| KTHC | <i>Knowledge, Technology, Human Capital</i> (Editor: Gianmarco Ottaviano) |
| IEM | <i>International Energy Markets</i> (Editor: Anil Markandya) |
| CSR | <i>Corporate Social Responsibility and Management</i> (Editor: Sabina Ratti) |
| PRA | <i>Privatisation, Regulation, Antitrust</i> (Editor: Bernardo Bortolotti) |
| ETA | <i>Economic Theory and Applications</i> (Editor: Carlo Carraro) |
| CTN | <i>Coalition Theory Network</i> |