

Vernasca, Gianluigi

Working Paper

Dynamic Price Competition with Price Adjustment Costs and Product Differentiation

Nota di Lavoro, No. 120.2003

Provided in Cooperation with:

Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Vernasca, Gianluigi (2003) : Dynamic Price Competition with Price Adjustment Costs and Product Differentiation, Nota di Lavoro, No. 120.2003, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<https://hdl.handle.net/10419/118146>

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.

Dynamic Price Competition with Price Adjustment Costs and Product Differentiation

Gianluigi Vernasca

NOTA DI LAVORO 120.2003

DECEMBER 2003

CTN – Coalition Theory Network

Gianluigi Vernasca, *Department of Economics, University of Warwick*

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://papers.ssrn.com/abstract_id=XXXXXX

The opinions expressed in this paper do not necessarily reflect the position of
Fondazione Eni Enrico Mattei

Dynamic Price Competition with Price Adjustment Costs and Product Differentiation

Summary

We study a discrete time dynamic game of price competition with spatially differentiated products and price adjustment costs. We characterise the Markov perfect and the open-loop equilibrium of our game. We find that in the steady state Markov perfect equilibrium, given the presence of adjustment costs, equilibrium prices are always higher than prices at the repeated static Nash solution, even though, adjustment costs are not paid in steady state. This is due to intertemporal strategic complementarity in the strategies of the firms and from the fact that the cost of adjusting prices adds credibility to high price equilibrium strategies. On the other hand, the stationary open-loop equilibrium coincides always with the static solution. Furthermore, in contrast to continuous time games, we show that the stationary Markov perfect equilibrium converges to the static Nash equilibrium when adjustment costs tend to zero. Moreover, we obtain the same convergence result when adjustment costs tend to infinity.

Keywords: Price adjustment costs, Difference game, Markov perfect equilibrium, Open-loop equilibrium

JEL: C72, C73, L13

I would like to thank Myrna Wooders for her valuable comments and suggestions. I wish also to thank Paolo Bertoletti, Jonathan Cave, Javier Fronti, Augusto Schianchi for useful conversations, and the participants of seminars at the University of Warwick, the University of Pavia and at the EARIE 2003 Conference in Helsinki. Any mistakes remain my own.

Address for correspondence:

Gianluigi Vernasca
Department of Economics
University of Warwick
Coventry CV4 7AL
United Kingdom
Phone: + 44 (0) 247652 23479
Fax: + 44 (0) 247652 3032
E-mail: G.Vernasca@warwick.ac.uk

1 Introduction

In this paper we develop a duopolistic dynamic game of price competition, in which products are horizontally differentiated and firms face adjustment costs every time they change their prices. Imposing adjustment costs creates a time dependent structure in our dynamic game and allows us to develop our model as a discrete time differential game, or difference game.¹ The main objective of our analysis is to study the effects of the presence of such adjustment costs on the strategic behaviour of firms under different assumptions on the ability of the firms to commit to price paths in advance. In particular, we focus on two different classes of strategies that have been widely used in the dynamic competition models, Markov and open-loop strategies.² Markov strategies depend only on payoff relevant variables that condense the direct effect of the past on the current payoff.³ The use of Markov strategies restrict equilibrium evaluation solely to subgame perfect equilibria, which have the desirable property of excluding non-credible threats. In contrast, open-loop strategies are functions of the initial state of the game and of the calendar time, and typically, are not subgame perfect. Thus, Markov and open-loop strategies correspond to extreme assumptions about player's capacities to make commitments about their future actions. Under the open-loop information pattern, the period of commitment is the same as the planning horizon while under Markovian strategies no commitment is possible.

The role of price stickiness has been analysed in many theoretical models of business cycles.⁴ Very little attention, however, has been paid to strategic incentives associated with price adjustment costs in dynamic oligopoly models. There are sev-

¹Differential games are dynamic games in continuous time, in which the different stages of the game are linked through a transition equation that describes the evolution of the state of the model. Furthermore, the transition equation depends on the strategic behaviour of the players. These kind of games are also called "state-space" games. Difference games are the discrete time counterpart of differential games. See Basar and Olsder (1995) for a detailed analysis. See also De Zeeuw and Van Der Ploeg (1991) for a survey on the use of difference games in economics.

²See Fudenberg and Tirole (1991) Ch. 13, for an introduction to Markov and open-loop equilibria and on their use in dynamic games. Amir (2001) provides an extensive survey on the use of these strategies in dynamic economic models.

³There is no generally accepted name in difference/differential games theory for such strategies and for the related equilibrium. Basar and Oldser (1995) use the term "Feedback Nash Equilibrium" while Papavassilopoulos and Cruz (1979) use the term "Closed-Loop Memoryless Equilibrium". However, after Maskin and Tirole (1988), the terms Markov strategies and Markov Perfect equilibrium has become standard in economic literature.

⁴Two different possibilities to model price adjustment costs have been considered in the literature on business cycles. First, there is a fixed cost per price change due to the physical cost of changing posted prices. These fixed costs are called "menu costs". See for example, Akerlof and Yellen (1985) and Mankiw (1985) among the others. Second, there are costs that capture the negative effect of price changes, particularly price increases on the reputation of firms. These costs are quadratic because reputation of firms is presumably more affected by large price changes than by small price changes. See for example, Rotemberg (1982). In our model, we follow the latter approach.

eral examples of differential games of Cournot competition with sticky prices, like Fershtman and Kamien (1987), Piga (2000) and Cellini and Lambertini (2001.a). The main result of these authors is that the subgame perfect equilibrium quantity is always below the static Cournot equilibrium, even if prices adjust instantaneously. This implies that the presence of price rigidity creates a more competitive market outcome. However, in those models, price rigidity is not modelled using adjustment costs, but instead refers to stickiness in the general price level. Thus those models deal only with one state variable, that is, the price level given by the inverse demand function, while in our model we have two state variables, the two prices of both firms. This fact adds considerably to the technical complexity of our problem. The main reason is that dynamic programming suffers the “curse of dimensionality”, that is the tendency of the state space, and thus computational difficulties, to grow exponentially with the number of state variables. As far as adjustment costs are concerned, most of the literature on dynamic competition has instead focused on adjustment costs in quantities. However, the same result described above still hold when these adjustment costs are considered. For example, Reynolds (1989, 1991) and Driskill and McCafferty (1989) study a dynamic duopoly with homogenous products and quadratic capacity adjustment costs in continuous time setting. The steady state output in the subgame perfect equilibrium is found to be larger than in the Cournot static game without adjustment costs. The main reason is the presence of intertemporal strategic substitutability in the strategic behaviour of the firms. A larger output of a firm today leads the firm being more aggressive tomorrow. The same result seems to hold independently on the kind of competition that is considered, as showed by Jun and Vives (2001) in their model of Bertrand competition with output adjustment costs.⁵

All the literature described so far shares the common feature of a continuous time setting. An interesting limit result that is common to models of dynamic oligopoly in continuous time is that, as adjustment costs or price stickiness tend to zero, the subgame perfect equilibrium approaches a limit that is different from the Nash equilibrium of the corresponding static game. Discrete time models of dynamic competition have been less developed, since it appears that the discrete time formulation is less tractable than the continuous time formulation. Discrete time models of dynamic competition with adjustment costs have been analysed in Maskin and Tirole (1987), Karp and Perloff (1993) and Lapham and Ware (1994) among others. In the first case Cournot competition with quantities adjustment costs is considered, but the equilibrium has been characterised only for the case in which adjustment costs approach infinity. More interesting for our purposes is the model of Lapham and Ware (1994). They show that the taxonomy of strategic incentives developed by Fudenberg and Tirole (1984) in a two-stage game can be extended to infinite horizon games with Markov strategies. However, their analysis is limited to the case in which

⁵This seems to provide a counterpoint to the idea of Kreps and Scheinkman (1983) that quantity precommitment and price competition yields Cournot outcomes.

adjustment costs are zero in equilibrium. Nevertheless, they find a limit result that contradicts the one of continuous time models. When adjustment costs tend to zero, their steady-state Markov perfect equilibrium converges to the Nash equilibrium of the static game.

In our model we characterize the Markov perfect equilibrium for different values of adjustment costs and product differentiation. Given the mathematical complexity involved in the analysis, some qualitative results are derived with numerical simulation. We find that the prices at the steady-state Markov perfect equilibrium are always higher than the prices at the static Nash equilibrium of the corresponding static game but they coincide in two limit cases – when adjustment costs tend to zero and when they tend to infinity. The economic force behind this result is the presence of intertemporal strategic complementarity: a firm, may strategically raise price today, and induce high prices from its rival tomorrow. The presence of adjustment costs enables firms to increase prices today and signal that they plan to keep prices higher next period. However, the magnitude of this strategic complementarity depends on the level of product differentiation. As products become less differentiated, higher equilibrium prices are sustainable only if adjustment costs are sufficiently high. Strategic complementarity is absent in open-loop strategies and the steady-state open-loop equilibrium is in correspondence one-to-one with the static Nash equilibrium. Our analysis is conducted under the assumptions that demand functions are linear function of prices and that profit functions and adjustment costs are quadratic and symmetric between firms. With this structure our model is a linear quadratic game. This kind of game is analytically convenient because the equilibrium strategies are known to be linear in the state variables of the model. Moreover, in some cases linear quadratic models or linear quadratic approximations of non-linear games provide a good representation of oligopolistic behaviour especially around a deterministic steady state.

The paper is organized as follows. In section 2 we describe the model. Section 3 presents the full computation of the Markov perfect equilibrium. In Section 4 we compare the Markov perfect equilibrium with the open-loop equilibrium and then we consider some limit results for these two equilibria. Section 5 concludes.

2 The Model

We start with the derivation of the demand functions. Consider a simple model of spatial competition *a' la* Hotelling in which there is a continuum of consumers uniformly distributed in the unit interval $[0, 1]$, with the position of a firm representing its ideal product. Consumers incur exogenous ‘transportation costs’ for having to consume one of the available brands instead of their ideal brand. This cost has the form of $(1/2s)$, where $s \in (0, \infty]$ provides a measure of substitutability between both

products.⁶ In particular, when the transportation cost tends to zero, products become close substitutes. In contrast, if $1/2s \rightarrow \infty$, a consumer prefers to choose the brand closest to its ideal point, independent of price. Thus, we can think at s as an indicator of market power of firms. Indeed, when products are highly differentiated (s is small), firms can increase prices without significantly affecting their own demand.

The utility function at time t of the consumer located at point α in the unit segment, for product i , is a linear function $U_t(v, \alpha_i, s, p_{it}) = v - \frac{|\alpha_i - F_i|}{2s} - p_{it}$. The term v represents the utility that a consumer derives for consuming her ideal product, that is assumed to be time invariant. Given our specification, the term v represents also an upper boundary level for the price set.⁷ If prices plus the exogenous transportation costs are greater than v , then no products will be bought by the consumers. In the following we shall assume that v is sufficiently high so that this does not occur. Finally, $F_i \in [0, 1]$ is the location of firm i , and the term $-p_{it}$ reflects the negative impact of price of product i on the utility of consumers. Following standard procedures, we solve for the demand functions of a consumer $\tilde{\alpha}$ who is at the point of indifference. The linear demand function faced by firm i is simply

$$y_{it}(p_{it}, p_{jt}) = \frac{1}{2} + s(p_{jt} - p_{it}) \quad (1)$$

with $i, j = 0, 1$ and $i \neq j$. If firms set the same price, both share equally the market. In our duopoly model the two firms are symmetric and they are located at each end of the unit interval. There is no uncertainty. Both firms face fixed quadratic adjustment costs: $\frac{1}{2}\lambda(p_{it} - p_{it-1})^2$, where $\lambda \geq 0$ is a measure of the cost of adjusting the price level.⁸ This formulation implies that adjustment costs are minimized when no adjustment takes place. The per-period profit function for firm i is the following concave function in its own prices:

$$\pi_{it}(p_{it}, p_{jt}, p_{it-1}) = p_{it}y_{it}(p_{it}, p_{jt}) - \frac{1}{2}\lambda(p_{it} - p_{it-1})^2 \quad (2)$$

At time t , firm i decides by how much to change its price $\Delta_{it} = (p_{it} - p_{it-1})$, or equivalently to set the new price level at time t . Thus, using the terminology of the optimal control theory, prices at time t are the control variables for the firms, while prices at time $t - 1$ are the state variables.

Firm i maximizes the following discounted stream of future profits over an infinite horizon:

⁶The formulation of the consumer problem is standard and follows the lines as in Doganouglu (1999). Differently from his analysis, we do not incorporate possible persistent effects in customer tastes.

⁷The fact that the set of prices is bounded assures that instantaneous profit functions are bounded as well, which is a sufficient condition for dynamic programming to be applicable. See Maskin and Tirole (1988.b).

⁸We use convex adjustment costs as in Rotemberg (1982). Quadratic price adjustment costs have been used also by Lapham and Ware (1994) and Jun and Vives (2001) because of their analytical tractability.

$$\Pi_i = \sum_{t=1}^{\infty} \beta^t \pi_{it}(p_{it}, p_{jt}, p_{it-1}) \quad (3)$$

where $\beta \in (0, 1)$ is the time invariant discount factor.⁹

With this structure, our model is a linear quadratic game. This kind of games is analytically convenient because the equilibrium strategies are known to be linear in the state variables.¹⁰

In our model, we mainly focus on strategic behaviour of the firms based on pure Markov strategies, that is, Markov strategies that are deterministic, in which the past influences current play only through its effect on the current state variables that summarise the direct effect of the past on the current environment. Optimal Markovian strategies have the property that, whatever the initial state and time are, all remaining decisions from that particular initial state and particular time onwards must also constitute optimal strategies. This means that Markov strategies are time-consistent. An equilibrium in Markov strategies is a subgame perfect equilibrium and it is called Markov perfect equilibrium¹¹.

Following Maskin and Tirole (1988), we define a Markov perfect equilibrium using the game theoretic analogue of dynamic programming¹²:

Definition 1 . *Let $V_{it}(p_{it-1}, p_{jt-1})$, with $i, j=1, 2$ and $i \neq j$, be the value of the game starting at period t where both players play their optimal strategy ($\tilde{p}_{it}(p_{it-1}, p_{jt-1})$ for $i, j=1, 2$ and $i \neq j$). This pair of strategies constitute a Markov Perfect Equilibrium (MPE) if and only if they solve the following dynamic programming problem:*

$$V_{it}(p_{it-1}, p_{jt-1}) = \underset{p_{it}}{Max} [\pi_{it}(p_{it}, p_{jt}, p_{it-1})] + \beta V_{it+1}(p_{it}, p_{jt}) \quad (4)$$

The pair of equations in 4) are the Bellman's equations of our problem that have to hold in equilibrium. Differentiating the right-hand side of the Bellman's equations 4) with respect the control variable of each firm, we obtain the following first order conditions:

⁹The presence of a discount factor less than one together with per-period payoff functions uniformly bounded assures that the objective functions faced by players are continuous at infinity. Under this condition a Markov perfect equilibrium, at least in mixed strategies, always exist in a game with infinite horizon. See Fudenberg and Tirole p. 515.

¹⁰For a detailed analysis of this point, see Papavassilopoulos, Medanic and Cruz (1979)

¹¹The concept of subgame perfection is much stronger than time consistency, since it requires that the property of subgame perfection hold at every subgame, not just those along the equilibrium path. On the other hand, dynamic (or "time") consistency would require that along the equilibrium path the continuation of the Nash equilibrium strategies remains a Nash equilibrium. For a discussion on the difference between subgame perfection and time consistency see Reinganum and Stokey (1985).

¹²By definition, Markov strategies are feedback rules. Furthermore, it is well known that dynamic programming produces feedback equilibria by its very construction, thus, it represents a natural tool to analyse Markov perfect equilibria.

$$\frac{\partial \pi_{it}(p_{it}, p_{jt}, p_{it-1})}{\partial p_{it}} + \beta \frac{\partial V_{it+1}(p_{it}, p_{jt})}{\partial p_{it}} = 0 \quad (5)$$

Given the linear quadratic nature, the first order conditions of each player completely characterize the Markov perfect equilibrium. To solve this system of equations, we need to guess a functional form for the unknown value functions $V_i(\cdot)$. However, we know that equilibrium strategies in linear quadratic games are linear functions of the state variables and value functions are quadratic. Then, we guess the following functional form for the value functions:¹³

$$V_{it+1}(p_{it}, p_{jt}) = a_i + b_i p_{it} + c_i p_{jt} + \frac{d_i}{2} p_{it}^2 + e_i p_{it} p_{jt} + f_i p_{jt}^2 \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (6)$$

where the parameters a_i, b_i, c_i, d_i, e_i and f_i are unknown parameters. Equation 6 hold for every t .

We are not interested in solving for all these parameters since we are analysing only the derivatives of the value functions that are given by:

$$\frac{\partial V_{it+1}(p_{it}, p_{jt})}{\partial p_{it}} = b_i + d_i p_{it} + e_i p_{jt} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (7.1)$$

$$\frac{\partial V_{it+1}(p_{it}, p_{jt})}{\partial p_{jt}} = c_i + e_i p_{it} + f_i p_{jt} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (7.2)$$

where the coefficients b_i, c_i, d_i, e_i and f_i are the parameters of interest that are to be determined by the method of undetermined coefficients (See Appendix). A solution for those coefficients, if it exists, will be a function of the structural parameters of the model given by s, β and λ . Substituting the relevant derivatives of the payoff functions and equations 7.1) and 7.2) into 5), we can obtain a solution for the current prices (p_{it}, p_{jt}) as a linear function of the state variables (p_{it-1}, p_{jt-1}) . This solution is given by the following pair of linear Markov strategies:

$$\tilde{p}_{it} = F_i + R_i p_{jt-1} + M_i p_{it-1} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (8)$$

where the coefficients F_i, R_i and M_i are functions directly and indirectly, through the unknown parameters of the derivatives given by 7.1) and 7.2), of the structural parameters of the model (s, β and λ). (See Appendix).

We can substitute optimal strategies given by 8), after taking into account for symmetry, into the Bellman's equations 4), and then differentiating 4) for the state variables (p_{jt-1}, p_{it-1}) . Using the first order conditions 5) to apply the Envelope theorem, we obtain the following system of four Euler equations:

¹³Since the mathematical analysis involved is standard, we follow the same procedure as in Lapham and Ware (1994).

$$\frac{\partial V_{it}}{\partial p_{it-1}} = \frac{\partial \pi_{it}^*}{\partial p_{it-1}} + \left[\frac{\partial \pi_{it}^*}{\partial \tilde{p}_{jt}} + \beta \frac{\partial V_{it+1}}{\partial \tilde{p}_{jt}} \right] \frac{\partial \tilde{p}_{jt}}{\partial p_{it-1}} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (9.1)$$

$$\frac{\partial V_{it}}{\partial p_{jt-1}} = \frac{\partial \pi_{it}^*}{\partial p_{jt-1}} + \left[\frac{\partial \pi_{it}^*}{\partial \tilde{p}_{jt}} + \beta \frac{\partial V_{it+1}}{\partial \tilde{p}_{jt}} \right] \frac{\partial \tilde{p}_{jt}}{\partial p_{jt-1}} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (9.2)$$

where the profit functions are given by $\pi_{it}^*(\tilde{p}_{it}(p_{it-1}, p_{jt-1}), \tilde{p}_{jt}(p_{it-1}, p_{jt-1}), p_{it-1})$. Using equations 7.1) and 7.2) in the above Euler equations, and using the method of undetermined coefficients, we obtain ten non-linear equations in ten unknowns parameters a_i, b_i, c_i, d_i, e_i and f_i for $i = 1, 2$ (system A3) in the Appendix). If a solution for these parameters exists, then the linear Markov perfect equilibrium given by 8) exists as well. Given the fact that we have to deal with ten non-linear equations, to simplify the mathematical tractability of the model, we restrict our analysis to a symmetric Markov perfect equilibrium.¹⁴ This implies that from equations 7.1) and 7.2) we have $b_1 = b_2 = b$, $c_1 = c_2 = c$, $d_1 = d_2 = d$, $e_1 = e_2 = e$ and $f_1 = f_2 = f$. Thus, Markov strategies are also symmetric, that is, $F_1 = F_2 = F$, $R_1 = R_2 = R$ and $M_1 = M_2 = M$. Suppose that a solution for the unknown parameters exists, and denote this solution with b^*, c^*, d^*, e^* and f^* . Using symmetry in the Markov strategies, and using the definitions given in the Appendix for the coefficients F, R and M , we can solve for the symmetric steady state level of the system of first order difference equations given by 8):

$$\bar{p}_i^{mpe} = \frac{1}{2} \frac{1 + 2\beta b^*}{s - \beta(d^* + e^*)} \quad \text{for } i = 1, 2 \quad (10)$$

where we assume $s \neq \beta(d^* + e^*)$. The equilibrium in 10) is the steady-state linear Markov perfect equilibrium of our model. Note that when s tends to infinity the equilibrium prices tend to zero. In the next section we will show how to derive a solution for the unknown parameters b^*, c^*, d^*, e^* and f^* . Then, we will consider in details the properties that the equilibrium given by 10) exhibits.

3 Computation and Properties of the Markov Perfect Equilibrium

In this section we compute more in detail the linear Markov perfect equilibrium of our model. We start with the derivation of the Nash equilibrium of the static game

¹⁴Strategic symmetric behaviour by firms is a standard assumption in the literature on dynamic competition. See for example, Jun and Vives (2001), Driskill and McAfferty (1989) and Doganoglu (1999) among the others. This assumption can be seen as a natural consequence of the fact that firms face a symmetric dynamic problem. However, we are aware that the presence of ten non-linear equations implies that many equilibria, symmetric and not, can arise from our model.

associated with our model without adjustment costs.¹⁵ This particular equilibrium represents a useful benchmark that can be compared with the Markov perfect and the open-loop equilibria of the model and it will be useful when will study the convergence properties of such equilibria when adjustment costs tend to zero. Assuming $\lambda = 0$, the symmetric static equilibrium of the repeated game without adjustment costs, denoted by p^s , is given by:

$$\bar{p}^s = \frac{1}{2s} \quad (11)$$

As we might expect, without adjustment costs, prices in equilibrium are functions of the measure of substitutability between the two goods. As for the Markov perfect equilibrium, when goods are perfectly homogeneous (s tends to infinity) static equilibrium prices are zero as in the classical Bertrand model.

In order to derive the properties of the Markov perfect equilibrium given by 10) we need to find a solution for the parameters of the value functions b^* , c^* , d^* , e^* and f^* . Despite the tractability of linear quadratic games, given the analytical difficulty to deal with a highly non-linear system of implicit functions, most of the results that we are going to present are obtained using numerical methods.¹⁶ Numerical techniques are often used in dynamic games in state-space form, as in Judd (1990) or Karp and Perloff (1993). The presence of nonlinearity implies that we must expect many solutions for the unknown parameters, and thus, multiple Markov perfect equilibria.¹⁷ In order to reduce this multiplicity, we concentrate our analysis to symmetric Markov perfect equilibria that are asymptotically stable as in Driskill and McCafferty (1989) and Jun and Vives (2001). An asymptotically stable equilibrium is one where the equilibrium prices converge to a finite stationary level for every feasible initial condition.¹⁸ The symmetric optimal Markov strategies are given by:

$$\tilde{p}_{it} = F + Rp_{jt-1} + Mp_{it-1} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (12)$$

From these strategies we can derive the conditions for stability of the symmetric linear Markov perfect equilibrium:

Proposition 1 *Assuming in 12) that $(2s + \lambda - \beta d) \neq (s + \beta e)$, then, this pair of strategies defines a stable equilibrium, if and only if, the eigenvalues of the symmetric*

¹⁵This particular equilibrium is important because it represents a subgame perfect equilibrium of the infinite repeated game without adjustment costs associated with our model.

¹⁶In particular, we use the Newton's method for nonlinear systems. For an introduction to the Newton's method, see Cheney and Kincaid (1999), Ch.3.

¹⁷Unfortunately, in literature, there are no general results on the uniqueness of Markov perfect equilibria in dynamic games. An interesting exception is Lokwood (1996) that provides sufficient conditions for uniqueness of Markov perfect equilibria in affine-quadratic differential games with one state variable.

¹⁸Given the lack of a transversality condition in the dynamic problem stated in Definition 1, we focus on asymptotically stable equilibria also because in this case we know that these equilibria will fulfil the transversality condition even implicitly.

matrix $A = \begin{bmatrix} M & R \\ R & M \end{bmatrix}$ are in module less than one. This implies that conditions for the stability of the system given by 12) are: $(d - e) < \frac{3s}{\beta}$ and $(d + e) < \frac{s}{\beta}$.

The result in Proposition 1 is derived from the theory of dynamic systems in discrete time.¹⁹ The condition that $(2s + \lambda - \beta d) \neq (s + \beta e)$ assures that the parameters of the Markov strategies 12) are well defined (see Appendix). Thus, when we look for a solution of the system A3) defined in the Appendix, this solution should respect the conditions in Proposition 1. Moreover, we consider only real solutions for the unknown parameters, and we consider only solutions that are locally isolated, or locally stable.²⁰ In addition, we impose that at that solution, equilibrium prices cannot be negative. Thus, we construct an asymptotically stable Markov perfect equilibrium numerically, instead of analytically as in Driskill and McCafferty (1989) and Jun and Vives (2001).

We now focus on the properties of our Markov perfect equilibrium when adjustment costs are positive and finite. We solve the system A3) in the Appendix for given values of the transportation cost (s), the discount factor (β), and the measure of adjustment costs (λ).²¹ Given the stability conditions stated above, we obtain a unique solution for the parameters b, c, d, e and f and thus, a unique Markov perfect equilibrium, for each set of values of the structural parameters of the model (s, β and λ)²². Given the difficult economic interpretation for these parameters, a sample of results is given in the Appendix. Here we report the implications of those solutions for the coefficients of the symmetric Markov strategies F, M and R . We are interested in particular on the coefficient R that represents the effect of one firm's today choice on the rival's choice tomorrow.

Proposition 2 *For a plausible range of the structural parameters of the model s, β and λ , we have the following results at the stable solutions of the system A3):*

- 1) *the coefficients of the Markov strategies are always positive;*
- 2) *R is first increasing and then decreasing in λ . The higher s the higher is the persistence of the increasing phase;*
- 3) *R is decreasing in s when adjustment costs are small. When adjustment costs become higher, R first increases and then decreases in s . The higher λ , the higher is the persistence of the increasing phase.*

¹⁹Driskill and McCafferty (1989) and Jun and Vives (2001) construct an asymptotically stable Markov equilibrium using similar conditions for differential equations, called Routh-Hurwitz conditions. For the case of a 2×2 system of difference equations, these conditions imply that $|\det(A)| < 1$ and $|\det(A) + 1| < \text{tr}(A)$, where tr is the trace of matrix A .

²⁰In practice, we want that at one particular solution, if we perturb that solution, the system of implicit functions A3) must remain close to zero.

²¹Most of our results are based on a value of β close to 1, a value that we take from the numerical analysis of Karp and Perloff (1993).

²²Driskill and McCafferty (1989) and Jun and Vives (2001), using a similar framework as ours, have shown that there is a unique linear Markov perfect equilibrium that satisfies asymptotic stability.

- 4) we have always $M > R$, however, the difference $(M - R)$ is decreasing in s ;
5) the coefficient M is increasing in λ and decreasing in s ;

The statements in Proposition 2 are summarised in the following table, in which we report a sample of the results of our numerical analysis made on system A3.

Table 1. Numerical values for the coefficients of Markov strategies.

λ	$s = 0.5, \beta = 0.95$			$s = 1, \beta = 0.95$			$s = 10, \beta = 0.95$		
	F	M	R	F	M	R	F	M	R
0.1	0.924	0.104	0.044	0.480	0.057	0.0265	0.049	0.006	0.003
0.5	0.704	0.313	0.099	0.414	0.204	0.0757	0.049	0.031	0.015
0.8	0.567	0.401	0.111	0.374	0.275	0.0919	0.048	0.047	0.022
1	0.541	0.446	0.115	0.352	0.313	0.0991	0.048	0.058	0.026
2	0.362	0.588	0.117	0.270	0.446	0.1154	0.046	0.104	0.044
5	0.174	0.757	0.093	0.154	0.633	0.1145	0.041	0.204	0.075
10	0.092	0.852	0.064	0.087	0.757	0.0931	0.033	0.313	0.099

In Proposition 2, we have identified the strategic behaviour of firms when adjustment costs are positive and finite. Not surprisingly, we have that the optimal price choice of a firm is an increasing function in the rival's price and this effect is captured by the coefficient R . Thus, the strategic behaviour of the firms in our model, is characterised by intertemporal strategic complementarity. Furthermore, the size of the effect of strategic complementarity as a function of λ follows a bell-shaped curve. For small adjustment costs, it increases, while, when adjustment costs become higher, it decreases until it reaches zero as λ approaches infinity. However, results 2) and 3) in the above Proposition say that this relationship depends on the measure of product differentiation s . When s is high, competition between firms becomes fiercer, since small changes in prices can have huge effects on consumer's demand. In this case, to sustain a credible strategy of increasing prices it is necessary to have a relatively higher level of adjustment costs than in the case in which s is small and firms have higher market power. Finally, result 4) in Proposition 2) says that as s increases, firms tend to assign a relatively higher weight to the rival's price in their strategic behaviour than in the case in which products are more differentiated. From Proposition 2, we can identify the effects of positive adjustment costs on the steady-state Markov perfect equilibrium of our model. The main result is stated in the following Proposition:

Proposition 3 *When adjustment costs are positive and finite, prices at the symmetric steady state Markov perfect equilibrium are always higher than prices in the equilibrium of the repeated static game. This is true, even though, no adjustment costs are paid in the steady state.*

The equilibrium values of the Markov perfect and the corresponding static Nash equilibrium for the same sample used in Table 1 are reported in the following table.

Table 2. Comparison between the symmetric Markov perfect and the counterpart static Nash equilibrium.

$s = 0.5, \beta = 0.95$			$s = 1, \beta = 0.95$		$s = 10, \beta = 0.95$	
λ	\bar{p}^{mpe}	\bar{p}^s	\bar{p}^{mpe}	\bar{p}^s	\bar{p}^{mpe}	\bar{p}^s
0.1	1.086	1	0.525	0.5	0.0503	0.05
0.5	1.199	1	0.575	0.5	0.0513	0.05
0.8	1.225	1	0.592	0.5	0.0521	0.05
1	1.234	1	0.599	0.5	0.0525	0.05
2	1.233	1	0.615	0.5	0.0543	0.05
5	1.168	1	0.609	0.5	0.0570	0.05
10	1.106	1	0.582	0.5	0.0573	0.05

From Proposition 3 we can say that in our dynamic game, the presence of adjustment costs and the hypothesis of Markov strategies create a strategic incentive for the firms to deviate from the equilibrium of the repeated static game even if adjustment costs are not paid in steady state. The result is a less competitive behaviour by the firms in the Markov equilibrium than in the static case. The economic force behind this result is the presence of intertemporal strategic complementarity that we have analysed above. A firm by pricing high today will induce high prices from the rival tomorrow, and the cost of adjusting prices lends credibility to this strategy, since it is costly to deviate from that strategy. The result in Proposition 3) contrasts with the one found in dynamic competition models with sticky prices, where general price stickiness creates a more competitive outcome in the subgame perfect equilibrium than in the static Nash equilibrium. The main reason is that in our model, price rigidity is modelled directly in the cost functions of the firms and there is a credibility effect associated with adjustment costs that can sustain high equilibrium price strategies, while, this credibility effect is absent with general price stickiness. We can notice that as products become close substitutes (s increases), the higher is the level of adjustment costs the higher is the difference between \bar{p}^{mpe} and \bar{p}^s relatively to the case where s is small. The intuition is the same as the one described above to explain results 2) and 3) of Proposition 2). When s is high, firms have a strong incentive to reduce their prices of a small amount in order to capture additional demand. Large adjustment costs can offset this incentive because the credibility of a high price equilibrium strategy will be stronger. Obviously, we know already from Proposition 2) that this credibility effect is not increasing monotonically with λ , because as adjustment costs become extremely high, the coefficient R tends to zero. We shall analyse this aspect in more detail when we will consider the properties of the Markov perfect equilibrium in the limit game. The result in Proposition 3) states that when adjustment costs are positive, firms are better off in the steady state Markov perfect equilibrium than in the static Nash equilibrium of the repeated game. Thus, the presence of positive adjustment costs can induce a tacit collusive behaviour by firms. However, this is true only if products are not homogeneous, that is $s < \infty$. If

products are perfect substitute, we already know that the Markov perfect equilibrium given by 10) converges to the static Nash equilibrium independently of the value of λ . Moreover, in this case, both equilibria are equal to zero and we fall into the classical "Bertrand paradox".

3.1 Markov Perfect Equilibrium in the Limit Game

We now consider the properties of the Markov perfect equilibrium of our model in different limit cases. Differently from previous section, the results we are going to show are obtained analytically. We start our analysis evaluating the steady state Markov perfect equilibrium given by 10) in two limit cases, when adjustment costs tend to zero ($\lambda \rightarrow 0$), and when they are infinite ($\lambda \rightarrow \infty$). This allows us to define the convergence properties of the steady-state Markov perfect equilibrium given by 10) toward the static Nash equilibrium 11), that, as we know from the introduction, is an important issue for the literature on dynamic competition. In order to describe the behaviour of the equilibrium in 10) in the two limit games, we need to evaluate the system A3) in the Appendix in the two extreme assumptions on the adjustment costs parameter λ . The results for our limit games are the following:

Proposition 4 *When adjustment costs tends to zero ($\lambda \rightarrow 0$), the symmetric solution for the unknown parameters is the following: $b^* = c^* = d^* = e^* = f^* = 0$, and the steady-state Markov perfect equilibrium corresponds with the static Nash equilibrium of the repeated game. When adjustment costs tend to infinity ($\lambda \rightarrow \infty$), the symmetric solution for the unknown parameters is: $b^* = \frac{1}{2}$, $c = 0$, $d^* = -2s$, $e^* = s$, $f^* = 0$, and the steady-state Markov perfect equilibrium converges to the static Nash equilibrium given by 10).*

Proof (see Appendix). The convergence of the steady state Markov perfect equilibrium toward the static Nash equilibrium when adjustment costs tend to zero confirms the result found in Lapham and Ware (1994), and it contradicts the results found in continuous time models of dynamic competition. In our discrete time model, as in Lapham and Ware (1994), the discontinuity found in continuous time models, when adjustment costs tend to zero, disappears. This result is supported by the numerical analysis developed by Karp and Perloff (1993), that gives also a possible explanation of why discrete and continuous time behave differently in the limit case of zero adjustment costs. In their model, they show that the steady-state Markov perfect equilibrium becomes more sensitive to λ when we pass from discrete time to continuous time. On the other hand, the second result is common in discrete and continuous time models, like in Maskin and Tirole (1987) and Reynolds (1991). The economic intuition behind this result is that: when adjustment costs become very large, the extra costs to change prices strategically outweigh the benefits, thus, firms are induced to behave nonstrategically and the steady-state subgame perfect equilibrium converges to the static solution. Of course, the case with infinite adjustment costs

is not very practical, especially for our purpose, since we are dealing with price adjustment costs that are normally associated with a small value of λ . However, this limit result is important because it shows that our value functions are continuous at infinity²³. Finally, we consider what happens to the steady state Markov perfect equilibrium when β tends to zero, that is, when only present matters for firms. Fershtman and Kamien (1987), using a continuous time model with sticky prices, found that when only present matters for firms their stationary Markov perfect equilibrium converges to the competitive outcome. On the other hand, Driskill and McCafferty (1989), using a similar model but with adjustment costs in quantities, found that the Markov perfect equilibrium converges to the static Nash equilibrium of the repeated game without adjustment costs. In our model, we have the following result:

Proposition 5 *As β , the discount factor, tends to zero, the steady state Markov perfect equilibrium given by 10) tends to the static Nash equilibrium of the repeated game without adjustment costs.*

The proof of this Proposition can be easily seen taking the limit of the Markov perfect equilibrium in 10) for $\beta \rightarrow 0$. In this case, it is simple to see that the result is the static Nash equilibrium given by 11).

As we might expect, if future does not matter for firms, the result is the equilibrium of the one shot game. We obtain a result similar to the one of Driskill and McCafferty (1989), however, if we allow products to be homogeneous our equilibrium converges to the competitive outcome as in Fershtman and Kamien (1989), that, in our case, implies equilibrium prices equal to zero.

4 The Open-Loop Equilibrium

In this section we will analyse what are the effects of adjustment costs on equilibrium price if we force firms to behave using open-loop strategies. While Markov strategies are feedback rules, open-loop strategies are trajectory, or path, strategies. In particular, open-loop strategies are functions of the initial state of the game (that is known a priori) and of the calendar time. Markov perfect and open-loop strategies correspond to extreme assumptions about player's capacities to make commitments about their future actions. Under the open-loop information pattern, the period of commitment is the same as the planning horizon, that in our case, is infinite. That is, at the beginning of the game, each player must make a binding commitment about the actions it will take at all future dates. Then, in general terms, a set of open-loop strategies constitutes a Nash equilibrium if, for each player, the path to which they are committed is an optimal response to the paths to which the other players have committed themselves. An open-loop strategy for player i is an infinite sequence

²³See Jensen and Lokwood (1998) for an analysis of discontinuity of value functions in dynamic games.

$p_i^{ol}(p_{i0}, p_{j0}, t) = \{p_{i1}, p_{i2}, \dots, p_{it}, \dots\} \in \mathfrak{R}^\infty$, specifying the price level at every period t over an infinite horizon as a function of the initial price levels (p_{i0}, p_{j0}) and the calendar time. Formally, we define an open-loop equilibrium in the following way:

Definition 2 *A pair of open-loop strategies (p_1^{ol}, p_2^{ol}) constitutes an open-loop equilibrium of our game if and only if the following inequalities are satisfied for each player:*

$$\Pi_i(p_i^{ol}, p_j^{ol}) \geq \Pi_i(p_i, p_j^{ol}) \quad \text{with } i, j = 1, 2 \quad \text{and } i \neq j$$

Typically these equilibria are not subgame perfect by definition, then, they may or not may be "time consistent". There are examples of dynamic games in which open-loop equilibria are subgame perfect²⁴, but in general when closed-loop strategies are feasible, subgame perfect equilibria will typically not be in open-loop strategies. In order to solve for the steady state open-loop equilibrium, we need to use the Pontryagin's maximum principle of the optimal control theory, since it can be shown that there is a close relationship between derivation of an open-loop equilibrium and solving jointly different optimal control problems, one for each player²⁵.

Proposition 6 *The steady-state open-loop equilibrium is in correspondence one-to-one with the Nash equilibrium of the counterpart static game.*

Proof. We need to solve a joint optimal control problem for both firms. The Hamiltonians are²⁶:

$$H_i = \beta^t \pi_{it}(p_{it}, p_{jt}, p_{it-1}) + \mu_{ii}(t)(p_{it} - p_{it-1}) + \mu_{ij}(t)(p_{jt} - p_{jt-1}) \quad \text{with } i, j = 1, 2 \quad \text{and } i \neq j \quad (13)$$

The corresponding necessary conditions for an open-loop solution are:

$$\frac{\partial H_i}{\partial p_{it}} = \beta^t \frac{\partial \pi_{it}(p_{it}, p_{jt}, p_{it-1})}{\partial p_{it}} + \mu_{ii}(t) = 0 \quad (14.1)$$

$$\mu_{ii}(t) - \mu_{ii}(t-1) = -\frac{\partial H_i}{\partial p_{it-1}} = -\beta^t \frac{\partial \pi_{it}(p_{it}, p_{jt}, p_{it-1})}{\partial p_{it-1}} + \mu_{ii}(t) \quad (14.2)$$

$$\mu_{ij}(t) - \mu_{ij}(t-1) = -\frac{\partial H_i}{\partial p_{jt-1}} = \mu_{ij}(t) \quad (14.3)$$

²⁴Cellini and Lambertini (2001.b) show that in a differential oligopoly game with capital accumulation, Markov perfect and open-loop equilibria are the same if the dynamic of the accumulation takes the form *a' la* Nerlove-Arrow or *a' la* Ramsey.

²⁵For a detailed analysis, see Basar and Olsder (1995), Ch.6.

²⁶A formalization of the Maximum Principle in discrete time can be found in Leonard and Van Long (1998), Ch. 4.

in steady state we have $\mu_{ii}(t) = \mu_{ii}(t - 1)$, $\mu_{ij}(t) = \mu_{ij}(t - 1)$, $p_{it} = p_{it-1}$ and $p_{jt} = p_{jt-1}$. Thus, from the last two conditions we obtain $\mu_{ii}(t) = \mu_{ij}(t) = 0$. Using these results, we can see that in steady state, the initial problem reduces to the static maximization problem ($\frac{\partial \pi_{it}(p_{it}, p_{jt})}{\partial p_{it}} = 0$). *Q.E.D.*

Thus, there is a direct correspondence between the steady state open-loop and the static Nash equilibrium of our model. In a stationary open-loop equilibrium there are no strategic incentives to deviate from the static outcome of the model without adjustment costs. The main reason is that open-loop strategies are independent on state variables and then, there is no way to affect rival's choice tomorrow changing strategy today as in Markov strategies. The same result has been found by Driskill and McCafferty (1989) and Jun and Vives (2001) using different models but it differs from the one in Fershtman and Kamien (1987) and Cellini and Lambertini (2001.a), since in their models, the open-loop solution implies higher output than the static solution, and they coincide only when the price level can adjust instantaneously. This difference is mainly due to the different specification of the transition law attached to the costate variables in the Hamiltonian system. In our model, as in Driskill and McCafferty(1989) and Jun and Vives (2001), this transition law is simply the definition of first difference in prices,²⁷ while in Fershtman and Kamien (1987) and Cellini and Lambertini (2001.a), this transition law is the difference between current price level and the price on the demand function for each level of output. Finally, from a regulation point of view, if it could be possible to force firms to behave according to open-loop strategies it would be possible to increase the level of competition in equilibrium also with the presence of positive adjustment costs.

5 Conclusion

In this paper we have developed a dynamic duopoly model of price competition over an infinite horizon, with symmetric and convex price adjustment costs and spatially differentiated products. We have concentrated our analysis on the strategic interaction between firms in a linear quadratic difference game using two different equilibrium concepts: Markov perfect equilibrium, that has the property of being subgame perfect, and the open-loop equilibrium, that is normally not subgame perfect. Given the existence of adjustment costs in prices, in the steady state Markov perfect equilibrium there is a strategic incentive for firms to deviate from the repeated static Nash solution even if no adjustment costs are paid in equilibrium. In particular, we have shown that the equilibrium prices in steady state are higher in the stationary Markov equilibrium than in the counterpart static Nash solution without adjustment costs.

The economic force behind this result is the presence of intertemporal strategic complementarity. A firm by pricing high today will induce high prices from the rival

²⁷Obviously, in Driskill and McCafferty (1989) and Jun and Vives (2001) the transition law is the time derivative of prices.

tomorrow. Moreover, the presence of adjustment costs leads to credibility in strategies that imply higher prices in equilibrium, for each firm, than in the case of static Nash equilibrium. This implies that firms are always better off when adjustment costs are positive and they behave according to Markov strategies and that the presence of these adjustment costs can sustain tacit collusive behaviour. However, this is true only if products are not homogeneous. If products are perfect substitutes, the steady state Markov perfect equilibrium always coincide with the static Nash equilibrium of the repeated game without adjustment costs and we fall into the classical "Bertrand paradox". The incentive to deviate from the static equilibrium is absent once we consider open-loop strategies. Indeed, the stationary open-loop equilibrium of our model is always in correspondence one-to-one with the Nash equilibrium of the static game. In addition, we have shown that when adjustment costs tend to zero or to infinity, the limit of our Markov perfect equilibrium converges to the static Nash equilibrium. The former result, confirmed by Lapham and Ware (1994), seems to be peculiar of discrete time models, since in continuous time models there is a discontinuity in the limit of the Markov perfect equilibrium as adjustment costs tend to zero. A number of extensions can be made in our analysis. Linear quadratic games do not perform well when uncertainty is considered. These particular models allow for specific shocks in the transition equation but they cannot deal, for instance, with shocks to the demand function. A natural extension of our analysis could be to relax the hypothesis of linearity of the strategies to allow for demand uncertainty. Another possible extension could be the analysis of the effects of asymmetric adjustment costs between firms, since this could give rise to a possible set of asymmetric steady state outcomes.

Appendix

In this section we derive the equations for the unknown parameters of the value functions b_i, c_i, d_i, e_i and f_i that are to be solved to compute a Markov perfect equilibrium in our model. We start with the solution of the two first-order conditions given by 5) in the paper. Using the derivatives of the value functions 7.1) and 7.2) into 5) and calculating the relevant derivatives of the payoff functions, we obtain the following system of equations:

$$p_{it} = A_i + B_i p_{jt} + C_i p_{it-1}, \quad \text{for } i, j = 1, 2 \text{ and } i \neq j. \quad (\text{A1})$$

where the coefficients A_i, B_i and C_i have the following functional form:

$$A_i = \frac{\frac{1}{2} + \beta b_i}{(2s + \lambda - \beta d_i)}; \quad B_i = \frac{(s + \beta e_i)}{(2s + \lambda - \beta d_i)}; \quad C_i = \frac{\lambda}{(2s + \lambda - \beta d_i)}$$

and where we assume that $2s + \lambda \neq \beta d_i$.

We can solve the system A.1) for p_{it} as a function of the state variables p_{it-1} and p_{jt-1} , for $i, j = 1, 2$ and $i \neq j$. The solution is the pair of linear Markov strategies given by 8) in the paper that we report here for simplicity of exposition:

$$\tilde{p}_{it} = F_i + R_i p_{jt-1} + M_i p_{it-1} \quad \text{for } i, j = 1, 2 \text{ and } i \neq j$$

where

$$F_i = \frac{A_i}{1 - B_i}; \quad R_i = \frac{B_i C_i}{(1 - B_i^2)}; \quad M_i = \frac{C_i}{(1 - B_i^2)}; \quad \text{for } i, j = 1, 2 \text{ and } i \neq j \quad (\text{A2})$$

and where we assume $B_i \neq 1$, that implies that $(2s + \lambda - \beta d) \neq (s + \beta e)$.

Using 7) into the Euler equations 9), and then using 8), we can obtain four equations that depend only on the state variables, p_{it-1} , with $i = 1, 2$. Rearranging and matching the coefficients associated with the state variables as well as for the various constant terms, we obtain the following non-linear system of ten implicit equations in ten unknowns, b_i, c_i, d_i, e_i and f_i :

$$0 = s(R_j - M_i)F_i - b_i + M_j \left[\frac{1}{2} - s(F_i - F_j) \right] - \lambda(M_i - 1)F_i + \beta R_j [F_i(s + e_i + f_i) + c_i]$$

$$0 = s(M_j - R_i)F_i - c_i + \frac{1}{2}R_j - \lambda(F_j \Omega_j) + \beta R_i \left[\frac{1}{2} - F_i(2s + \lambda + d_i) + F_j(s + e_i) + b_i \right]$$

$$0 = s(R_j - M_i)M_i - d_i - sM_j [M_j - R_j] - \lambda (M_i - 1)^2 + \beta R_j [M_i (s + e_i) + f_i R_j]$$

$$0 = s(R_j - M_i)R_i - e_i - sM_j [R_i - M_j] - \lambda (M_i - 1) R_i + \beta R_j [R_j (s + e_i) + f_i M_i]$$

$$0 = s(R_i - M_j)R_i - f_i - sR_i (R_i - M_j) - \lambda R_i^2 + \beta R_i [M_j (s + e_i) - R_i (2s + \lambda - d_1)] \quad (\text{A3})$$

where for all the equations we have that $i, j = 1, 2$ and $i \neq j$. Imposing symmetry, that is $b_1 = b_2 = b$, $c_1 = c_2 = c$, $d_1 = d_2 = d$, $e_1 = e_2 = e$, $f_1 = f_2 = f$, $F_1 = F_2 = F$, $R_1 = R_2 = R$ and $M_1 = M_2 = M$, implies that the steady state associated with the system 8) in the paper is given by:

$$p_i^{mpe} = \frac{F}{1 - (M + R)} \quad (\text{A4})$$

and substituting the definitions for the coefficients F , R and M given above, we find equation 10) in the paper.

We use numerical techniques to solve the system A3). To solve system A3), we first define different set of values for the structural parameters of the model, (s , λ and β). We evaluate the system A3) for these values and then we look for the corresponding solution for the parameters b, c, d, e and f using the Newton algorithm. Using the restrictions described in the paper we are able to obtain a unique solution for any set of values of the structural parameters. In our analysis the value of β is fixed to 0.95 as in Karp and Perloff (1993). The parameters s and λ varies from 0 to 1000 with different length of variation. A sample of the results is reported in the following tables:

Table A1). Solution for the parameters b, c, d, e and f given values for s, λ and β

$s = 0.5, \beta = 0.95$						$s = 1, \beta = 0.95$				
λ	b	c	d	e	f	b	c	d	e	f
0.1	0.129	0.049	-0.084	0.006	0.0024	0.072	0.02	-0.09	0.004	0.001
0.5	0.373	0.125	-0.286	0.062	0.0162	0.252	0.09	-0.35	0.052	0.016
1	0.488	0.146	-0.423	0.127	0.0248	0.373	0.12	-0.57	0.125	0.032
2	0.552	0.139	-0.567	0.219	0.028	0.486	0.13	-0.84	0.255	0.049
5	0.554	0.097	-0.740	0.341	0.019	0.556	0.10	-1.22	0.501	0.054
10	0.535	0.063	-0.842	0.409	0.010	0.551	0.07	-1.48	0.683	0.038
25	0.516	0.031	-0.927	0.461	0.003	0.528	0.04	-1.73	0.851	0.016

Table A2). Solution for the parameters b, c, d, e and f given values for s, λ and β

$s = 10, \beta = 0.95$						$s = 100, \beta = 0.95$				
λ	b	c	d	e	f	b	c	d	e	f
0.1	0.008	0.003	-0.09	0.0005	0.0002	0.0008	0.0003	-0.09	0.00005	0.00002
0.5	0.038	0.015	-0.47	0.0118	0.0046	0.0041	0.0016	-0.49	0.0013	0.0005
1	0.072	0.027	-0.90	0.0416	0.0159	0.0081	0.0032	-0.98	0.0053	0.0021
2	0.12	0.045	-1.68	0.134	0.0487	0.016	0.0063	-1.95	0.0206	0.0082
5	0.24	0.028	-3.53	0.526	0.165	0.0383	0.0118	-4.75	0.118	0.0465
10	0.33	-0.19	-5.72	1.254	0.325	0.071	-0.014	-9.09	0.416	0.159
25	0.30	-1.45	-8.28	3.100	0.536	0.104	-0.816	-20.3	1.913	0.676

Proof of Proposition 4. First of all, we impose symmetry in the system A3). Then, we consider the case in which $\lambda \rightarrow 0$. Evaluating the term C at $\lambda = 0$ we clearly obtain that $C_{(\lambda=0)} = 0$, and using this fact into the definitions of R and M , we have that $R_{(\lambda=0)} = 0$; $M_{(\lambda=0)} = 0$. Thus, irrespective of the value of F , using $R_{(\lambda=0)} = 0$; $M_{(\lambda=0)} = 0$ into system A3) we have: $b^* = c^* = d^* = e^* = f^* = 0$. Furthermore, as in Lapham and Ware (1994), the Jacobian matrix associated with that system is an identity matrix, and thus, non singular. This implies, that at λ close to zero, the solution for the unknown parameters is a continuous function of λ . Substituting $b^* = d^* = e^* = 0$ into 10) in the paper, we see that the Markov perfect equilibrium becomes equal to $\frac{1}{2s}$, that is the static Nash equilibrium given by 11). Now consider the case in which $\lambda \rightarrow \infty$. Taking the limit for $\lambda \rightarrow \infty$ of the coefficients A, B and C , we obtain $\lim_{\lambda \rightarrow \infty} A = 0$, $\lim_{\lambda \rightarrow \infty} B = 0$ and $\lim_{\lambda \rightarrow \infty} C = 1$. Applying the well known rules for limits, we have that $\lim_{\lambda \rightarrow \infty} F = 0$, $\lim_{\lambda \rightarrow \infty} R = 0$ and $\lim_{\lambda \rightarrow \infty} M = 1$. Thus, taking the limit for $\lambda \rightarrow \infty$ of the implicit functions in the system A3) gives the following results for the unknown parameters: $b^* = 1/2$, $c^* = 0$, $d^* = -2s$, $e^* = s$ and $f^* = 0$. Again, substituting this fact into the Markov perfect equilibrium given by 10) we can see that it coincides with the static Nash equilibrium 11). Obviously, we can obtain the same limit result for the Markov perfect equilibrium, taking the limit for $\lambda \rightarrow \infty$ of A4) and applying the Hospital's rule.

References

- [1] Akerlof, G. and J. Yellen (1985), "Can Small Deviations from Rationality Make Significant Differences to Economic Equilibria?", *American Economic Review* 75, pp. 708-721.
- [2] Amir, R. (2001), "Stochastic Games in Economics and Related Fields: an Overview", *CORE Discussion Paper* 2001/60.

- [3] Basar, T. and G.J. Olsder (1995), *Dynamic Noncooperative Game Theory*, Academic Press: New York.
- [4] Cellini, R. and L. Lambertini (2001.a), “Dynamic Oligopoly with Sticky Prices: Closed-Loop, Feedback and Open-Loop Solutions”, Working Paper, Dipartimento di Scienze Economiche, Universita’ degli Studi di Bologna.
- [5] Cellini, R. and L. Lambertini (2001.b), “Differential oligopoly Games where the Closed-Loop Memoryless and the Open-Loop Equilibria Coincide”, Working Paper, Dipartimento di Scienze Economiche, Universita’ degli Studi di Bologna.
- [6] Cheney W. and D. Kincaid (1999), *Numerical Mathematics and Computing*, Brooks/Cole Publishing, Pacific Grove, CA.
- [7] Doganoughlu, T. (1999), “Dynamic Price Competition with Persistent Consumer Tastes”, University of Bonn, mimeo.
- [8] Driskill R.A. and S. McCafferty (1989), “Dynamic Duopoly with Adjustment Costs: A Differential Game Approach”, *Journal of Economic Theory*, vol. 49, pp. 324-338.
- [9] Fershtman, C. and M. Kamien (1987), “Dynamic Duopolistic Competition with Sticky Prices”, *Econometrica*, vol. 55, no. 5, pp. 1151-1164.
- [10] Fudenberg, D. and J. Tirole (1984), “The Fat-Cat Effect, the Puppy-Dog ploy, and the Lean and Hungry Look”, *American Economic Review, Papers and Proceedings* 74, pp. 361-389.
- [11] Fudenberg, D. and J. Tirole (1991), *Game Theory*, The MIT Press: Cambridge, MA.
- [12] Jensen, H. and B. Lokwood (1998), “A Note on Discontinuous Value Functions and Strategies in Affine-Quadratic Differential Games”, *Economic Letters* 61, pp. 301-306.
- [13] Judd, K.L. (1989), “Cournot vs. Bertrand: A Dynamic Resolution”, University of Stanford, mimeo.
- [14] Jun, B. and X. Vives (2001), “Incentives in Dynamic Duopoly”, *CEPR Discussion Paper*, n. 2899 .
- [15] Karp, L. and J. Perloff (1993), “Open-loop and Feedback Models of Dynamic Oligopoly”, *International Journal of Industrial Organization*, vol. 11, pp. 369-389.

- [16] Kreps, D. and J. Scheinkman (1983), “Quantity Precommitment and Bertrand Competition Yield Cournot Outcomes”, *Bell Journal of Economics*, vol.14, pp.326-337.
- [17] Lapham, B. and R. Ware (1994), “Markov Puppy Dogs and Related Animals”, *International Journal of Industrial Organization*, vol. 12, pp. 569-593.
- [18] Leonard D. and N. Van Long (1998), *Optimal Control Theory and Static Optimization in Economics*, Cambridge University Press: Cambridge, UK.
- [19] Lockwood, B. (1996), “Uniqueness of Markov Perfect Equilibrium in Infinite Time Affine-Quadratic Differential Games”, *Journal of Economics Dynamics and Control*, vol.20, pp. 751-765.
- [20] Mankiw, G. (1985), “Small Menu Costs and Large Business Cycles: Macroeconomic Model of Monopoly”, *Quarterly Journal of Economics* 100, pp. 529-539.
- [21] Maskin, E. and J. Tirole (1987), “A Theory of Dynamic Oligopoly III”, *European Economic Review* 31, pp. 947-968.
- [22] Maskin, E. and J. Tirole (1988), “A Theory of Dynamic Oligopoly, II: Price Competition, Kinked Demand Curves, and Edgeworth Cycles”, *Econometrica*, vol.56, no. 3, pp. 571-599.
- [23] Maskin, E. and J. Tirole (2001), “Markov Perfect Equilibrium: I. Observable Actions”, *Journal of Economic Theory*, vol.100, pp. 191-219.
- [24] Papavassilopoulos G.P., J.V. Medanic, and J.B. Cruz (1979), “On the Existence of Nash Strategies and Solutions to Coupled Riccati Equations in Linear-Quadratic Games”, *Journal of Optimization Theory and Applications*, vol.28, no. 1, pp.49-76.
- [25] Piga, C. (2000), “Competition in a Duopoly with Sticky Prices and Advertising”, *International Journal of Industrial Organization* 18, pp. 595-614.
- [26] Reinganum, J. and N. Stokey (1985), “Olygopoly Extraction of a Common Property Natural Resource: The Importance of the Period of Commitment in Dynamic Games”, *International Economic Review*, vol. 26, pp. 161-173.
- [27] Reynolds, S.S. (1991), “Dynamic Oligopoly with capacity Adjustment Costs”, *Journal of Economic Dynamics and Control*, vol. 15, no. 3, pp. 491-514.
- [28] Rotemberg, J.J. (1982), “Sticky Prices in the United States”, *Journal of Political Economy*, vol. 90, no. 6, pp. 1187-1211.

- [29] Slade, M.E. (1999), “Sticky Prices in a Dynamic Oligopoly: An Investigation of (s, S) Thresholds”, *International Journal of Industrial Organization*, vol. 17, pp. 477-511.
- [30] Tirole, J. (1988), *The Theory of Industrial Organization*, MIT Press: Cambridge, MA.
- [31] Zeeuw, A. and J. Van der Ploeg (1991), “Difference Games and Policy Evaluation: A Conceptual Framework”, *Oxford Economic Papers*, vol. 43, pp. 612-636.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

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

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

<http://papers.ssrn.com>

SUST	1.2002	<i>K. TANO, M.D. FAMINOW, M. KAMUANGA and B. SWALLOW:</i> <u>Using Conjoint Analysis to Estimate Farmers' Preferences for Cattle Traits in West Africa</u>
ETA	2.2002	<i>Efrem CASTELNUOVO and Paolo SURICO:</i> <u>What Does Monetary Policy Reveal about Central Bank's Preferences?</u>
WAT	3.2002	<i>Duncan KNOWLER and Edward BARBIER:</i> <u>The Economics of a "Mixed Blessing" Effect: A Case Study of the Black Sea</u>
CLIM	4.2002	<i>Andreas LÖSCHEL:</i> <u>Technological Change in Economic Models of Environmental Policy: A Survey</u>
VOL	5.2002	<i>Carlo CARRARO and Carmen MARCHIORI:</i> <u>Stable Coalitions</u>
CLIM	6.2002	<i>Marzio GALEOTTI, Alessandro LANZA and Matteo MANERA:</i> <u>Rockets and Feathers Revisited: An International Comparison on European Gasoline Markets</u>
ETA	7.2002	<i>Effrosyni DIAMANTOUDI and Efthios S. SARTZETAKIS:</i> <u>Stable International Environmental Agreements: An Analytical Approach</u>
KNOW	8.2002	<i>Alain DESDOIGTS:</i> <u>Neoclassical Convergence Versus Technological Catch-up: A Contribution for Reaching a Consensus</u>
NRM	9.2002	<i>Giuseppe DI VITA:</i> <u>Renewable Resources and Waste Recycling</u>
KNOW	10.2002	<i>Giorgio BRUNELLO:</i> <u>Is Training More Frequent when Wage Compression is Higher? Evidence from 11 European Countries</u>
ETA	11.2002	<i>Mordecai KURZ, Hehui JIN and Maurizio MOTOLESE:</i> <u>Endogenous Fluctuations and the Role of Monetary Policy</u>
KNOW	12.2002	<i>Reyer GERLAGH and Marjan W. HOFKES:</i> <u>Escaping Lock-in: The Scope for a Transition towards Sustainable Growth?</u>
NRM	13.2002	<i>Michele MORETTO and Paolo ROSATO:</i> <u>The Use of Common Property Resources: A Dynamic Model</u>
CLIM	14.2002	<i>Philippe QUIRION:</i> <u>Macroeconomic Effects of an Energy Saving Policy in the Public Sector</u>
CLIM	15.2002	<i>Roberto ROSON:</i> <u>Dynamic and Distributional Effects of Environmental Revenue Recycling Schemes: Simulations with a General Equilibrium Model of the Italian Economy</u>
CLIM	16.2002	<i>Francesco RICCI (I):</i> <u>Environmental Policy Growth when Inputs are Differentiated in Pollution Intensity</u>
ETA	17.2002	<i>Alberto PETRUCCI:</i> <u>Devaluation (Levels versus Rates) and Balance of Payments in a Cash-in-Advance Economy</u>
Coalition Theory Network	18.2002	<i>László Á. KÓCZY (liv):</i> <u>The Core in the Presence of Externalities</u>
Coalition Theory Network	19.2002	<i>Steven J. BRAMS, Michael A. JONES and D. Marc KILGOUR (liv):</i> <u>Single-Peakedness and Disconnected Coalitions</u>
Coalition Theory Network	20.2002	<i>Guillaume HAERINGER (liv):</i> <u>On the Stability of Cooperation Structures</u>
NRM	21.2002	<i>Fausto CAVALLARO and Luigi CIRAOLO:</i> <u>Economic and Environmental Sustainability: A Dynamic Approach in Insular Systems</u>
CLIM	22.2002	<i>Barbara BUCHNER, Carlo CARRARO, Igor CERSOSIMO and Carmen MARCHIORI:</i> <u>Back to Kyoto? US Participation and the Linkage between R&D and Climate Cooperation</u>
CLIM	23.2002	<i>Andreas LÖSCHEL and ZhongXIANG ZHANG:</i> <u>The Economic and Environmental Implications of the US Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech</u>
ETA	24.2002	<i>Marzio GALEOTTI, Louis J. MACCINI and Fabio SCHIANTARELLI:</i> <u>Inventories, Employment and Hours</u>
CLIM	25.2002	<i>Hannes EGLI:</i> <u>Are Cross-Country Studies of the Environmental Kuznets Curve Misleading? New Evidence from Time Series Data for Germany</u>
ETA	26.2002	<i>Adam B. JAFFE, Richard G. NEWELL and Robert N. STAVINS:</i> <u>Environmental Policy and Technological Change</u>
SUST	27.2002	<i>Joseph C. COOPER and Giovanni SIGNORELLO:</i> <u>Farmer Premiums for the Voluntary Adoption of Conservation Plans</u>
SUST	28.2002	<i>The ANSEA Network:</i> <u>Towards An Analytical Strategic Environmental Assessment</u>
KNOW	29.2002	<i>Paolo SURICO:</i> <u>Geographic Concentration and Increasing Returns: a Survey of Evidence</u>
ETA	30.2002	<i>Robert N. STAVINS:</i> <u>Lessons from the American Experiment with Market-Based Environmental Policies</u>

NRM	31.2002	<i>Carlo GIUPPONI and Paolo ROSATO: <u>Multi-Criteria Analysis and Decision-Support for Water Management at the Catchment Scale: An Application to Diffuse Pollution Control in the Venice Lagoon</u></i>
NRM	32.2002	<i>Robert N. STAVINS: <u>National Environmental Policy During the Clinton Years</u></i>
KNOW	33.2002	<i>A. SOUBEYRAN and H. STAHN : <u>Do Investments in Specialized Knowledge Lead to Composite Good Industries?</u></i>
KNOW	34.2002	<i>G. BRUNELLO, M.L. PARISI and Daniela SONEDDA: <u>Labor Taxes, Wage Setting and the Relative Wage Effect</u></i>
CLIM	35.2002	<i>C. BOEMARE and P. QUIRION (lv): <u>Implementing Greenhouse Gas Trading in Europe: Lessons from Economic Theory and International Experiences</u></i>
CLIM	36.2002	<i>T. TIETENBERG (lv): <u>The Tradable Permits Approach to Protecting the Commons: What Have We Learned?</u></i>
CLIM	37.2002	<i>K. REHDANZ and R.J.S. TOL (lv): <u>On National and International Trade in Greenhouse Gas Emission Permits</u></i>
CLIM	38.2002	<i>C. FISCHER (lv): <u>Multinational Taxation and International Emissions Trading</u></i>
SUST	39.2002	<i>G. SIGNORELLO and G. PAPPALARDO: <u>Farm Animal Biodiversity Conservation Activities in Europe under the Framework of Agenda 2000</u></i>
NRM	40.2002	<i>S.M. CAVANAGH, W. M. HANEMANN and R. N. STAVINS: <u>Muffled Price Signals: Household Water Demand under Increasing-Block Prices</u></i>
NRM	41.2002	<i>A. J. PLANTINGA, R. N. LUBOWSKI and R. N. STAVINS: <u>The Effects of Potential Land Development on Agricultural Land Prices</u></i>
CLIM	42.2002	<i>C. OHL (lvi): <u>Inducing Environmental Co-operation by the Design of Emission Permits</u></i>
CLIM	43.2002	<i>J. EYCKMANS, D. VAN REGEMORTER and V. VAN STEENBERGHE (lvi): <u>Is Kyoto Fatally Flawed? An Analysis with MacGEM</u></i>
CLIM	44.2002	<i>A. ANTOCI and S. BORGHESI (lvi): <u>Working Too Much in a Polluted World: A North-South Evolutionary Model</u></i>
ETA	45.2002	<i>P. G. FREDRIKSSON, Johan A. LIST and Daniel MILLIMET (lvi): <u>Chasing the Smokestack: Strategic Policymaking with Multiple Instruments</u></i>
ETA	46.2002	<i>Z. YU (lvi): <u>A Theory of Strategic Vertical DFI and the Missing Pollution-Haven Effect</u></i>
SUST	47.2002	<i>Y. H. FARZIN: <u>Can an Exhaustible Resource Economy Be Sustainable?</u></i>
SUST	48.2002	<i>Y. H. FARZIN: <u>Sustainability and Hamiltonian Value</u></i>
KNOW	49.2002	<i>C. PIGA and M. VIVARELLI: <u>Cooperation in R&D and Sample Selection</u></i>
Coalition Theory Network Coalition Theory Network	50.2002	<i>M. SERTEL and A. SLINKO (liv): <u>Ranking Committees, Words or Multisets</u></i>
ETA	51.2002	<i>Sergio CURRARINI (liv): <u>Stable Organizations with Externalities</u></i>
ETA	52.2002	<i>Robert N. STAVINS: <u>Experience with Market-Based Policy Instruments</u></i>
ETA	53.2002	<i>C.C. JAEGER, M. LEIMBACH, C. CARRARO, K. HASSELMANN, J.C. HOURCADE, A. KEELER and R. KLEIN (liii): <u>Integrated Assessment Modeling: Modules for Cooperation</u></i>
CLIM	54.2002	<i>Scott BARRETT (liii): <u>Towards a Better Climate Treaty</u></i>
ETA	55.2002	<i>Richard G. NEWELL and Robert N. STAVINS: <u>Cost Heterogeneity and the Potential Savings from Market-Based Policies</u></i>
SUST	56.2002	<i>Paolo ROSATO and Edi DEFRANCESCO: <u>Individual Travel Cost Method and Flow Fixed Costs</u></i>
SUST	57.2002	<i>Vladimir KOTOV and Elena NIKITINA (lvii): <u>Reorganisation of Environmental Policy in Russia: The Decade of Success and Failures in Implementation of Perspective Quests</u></i>
SUST	58.2002	<i>Vladimir KOTOV (lvii): <u>Policy in Transition: New Framework for Russia's Climate Policy</u></i>
SUST	59.2002	<i>Fanny MISSFELDT and Arturo VILLAVICENCO (lvii): <u>How Can Economies in Transition Pursue Emissions Trading or Joint Implementation?</u></i>
VOL	60.2002	<i>Giovanni DI BARTOLOMEO, Jacob ENGWERDA, Joseph PLASMANS and Bas VAN AARLE: <u>Staying Together or Breaking Apart: Policy-Makers' Endogenous Coalitions Formation in the European Economic and Monetary Union</u></i>
ETA	61.2002	<i>Robert N. STAVINS, Alexander F. WAGNER and Gernot WAGNER: <u>Interpreting Sustainability in Economic Terms: Dynamic Efficiency Plus Intergenerational Equity</u></i>
PRIV	62.2002	<i>Carlo CAPUANO: <u>Demand Growth, Entry and Collusion Sustainability</u></i>
PRIV	63.2002	<i>Federico MUNARI and Raffaele ORIANI: <u>Privatization and R&D Performance: An Empirical Analysis Based on Tobin's Q</u></i>
PRIV	64.2002	<i>Federico MUNARI and Maurizio SOBRERO: <u>The Effects of Privatization on R&D Investments and Patent Productivity</u></i>
SUST	65.2002	<i>Orley ASHENFELTER and Michael GREENSTONE: <u>Using Mandated Speed Limits to Measure the Value of a Statistical Life</u></i>
ETA	66.2002	<i>Paolo SURICO: <u>US Monetary Policy Rules: the Case for Asymmetric Preferences</u></i>
PRIV	67.2002	<i>Rinaldo BRAU and Massimo FLORIO: <u>Privatisations as Price Reforms: Evaluating Consumers' Welfare Changes in the U.K.</u></i>
CLIM	68.2002	<i>Barbara K. BUCHNER and Roberto ROSON: <u>Conflicting Perspectives in Trade and Environmental Negotiations</u></i>
CLIM	69.2002	<i>Philippe QUIRION: <u>Complying with the Kyoto Protocol under Uncertainty: Taxes or Tradable Permits?</u></i>
SUST	70.2002	<i>Anna ALBERINI, Patrizia RIGANTI and Alberto LONGO: <u>Can People Value the Aesthetic and Use Services of Urban Sites? Evidence from a Survey of Belfast Residents</u></i>
SUST	71.2002	<i>Marco PERCOCO: <u>Discounting Environmental Effects in Project Appraisal</u></i>

NRM	72.2002	<i>Philippe BONTEMS and Pascal FAVARD: <u>Input Use and Capacity Constraint under Uncertainty: The Case of Irrigation</u></i>
PRIV	73.2002	<i>Mohammed OMRAN: <u>The Performance of State-Owned Enterprises and Newly Privatized Firms: Empirical Evidence from Egypt</u></i>
PRIV	74.2002	<i>Mike BURKART, Fausto PANUNZI and Andrei SHLEIFER: <u>Family Firms</u></i>
PRIV	75.2002	<i>Emmanuelle AURIOL, Pierre M. PICARD: <u>Privatizations in Developing Countries and the Government Budget Constraint</u></i>
PRIV	76.2002	<i>Nichole M. CASTATER: <u>Privatization as a Means to Societal Transformation: An Empirical Study of Privatization in Central and Eastern Europe and the Former Soviet Union</u></i>
PRIV	77.2002	<i>Christoph LÜLSFESMANN: <u>Benevolent Government, Managerial Incentives, and the Virtues of Privatization</u></i>
PRIV	78.2002	<i>Kate BISHOP, Igor FILATOTCHEV and Tomasz MICKIEWICZ: <u>Endogenous Ownership Structure: Factors Affecting the Post-Privatisation Equity in Largest Hungarian Firms</u></i>
PRIV	79.2002	<i>Theodora WELCH and Rick MOLZ: <u>How Does Trade Sale Privatization Work? Evidence from the Fixed-Line Telecommunications Sector in Developing Economies</u></i>
PRIV	80.2002	<i>Alberto R. PETRUCCI: <u>Government Debt, Agent Heterogeneity and Wealth Displacement in a Small Open Economy</u></i>
CLIM	81.2002	<i>Timothy SWANSON and Robin MASON (Ivi): <u>The Impact of International Environmental Agreements: The Case of the Montreal Protocol</u></i>
PRIV	82.2002	<i>George R.G. CLARKE and Lixin Colin XU: <u>Privatization, Competition and Corruption: How Characteristics of Bribe Takers and Payers Affect Bribe Payments to Utilities</u></i>
PRIV	83.2002	<i>Massimo FLORIO and Katuscia MANZONI: <u>The Abnormal Returns of UK Privatisations: From Underpricing to Outperformance</u></i>
NRM	84.2002	<i>Nelson LOURENÇO, Carlos RUSSO MACHADO, Maria do ROSÁRIO JORGE and Luis RODRIGUES: <u>An Integrated Approach to Understand Territory Dynamics. The Coastal Alentejo (Portugal)</u></i>
CLIM	85.2002	<i>Peter ZAPFEL and Matti VAINIO (Iv): <u>Pathways to European Greenhouse Gas Emissions Trading History and Misconceptions</u></i>
CLIM	86.2002	<i>Pierre COURTOIS: <u>Influence Processes in Climate Change Negotiations: Modelling the Rounds</u></i>
ETA	87.2002	<i>Vito FRAGNELLI and Maria Erminia MARINA (Iviii): <u>Environmental Pollution Risk and Insurance</u></i>
ETA	88.2002	<i>Laurent FRANCKX (Iviii): <u>Environmental Enforcement with Endogenous Ambient Monitoring</u></i>
ETA	89.2002	<i>Timo GOESCHL and Timothy M. SWANSON (Iviii): <u>Lost Horizons. The noncooperative management of an evolutionary biological system.</u></i>
ETA	90.2002	<i>Hans KEIDING (Iviii): <u>Environmental Effects of Consumption: An Approach Using DEA and Cost Sharing</u></i>
ETA	91.2002	<i>Wietze LISE (Iviii): <u>A Game Model of People's Participation in Forest Management in Northern India</u></i>
CLIM	92.2002	<i>Jens HORBACH: <u>Structural Change and Environmental Kuznets Curves</u></i>
ETA	93.2002	<i>Martin P. GROSSKOPF: <u>Towards a More Appropriate Method for Determining the Optimal Scale of Production Units</u></i>
VOL	94.2002	<i>Scott BARRETT and Robert STAVINS: <u>Increasing Participation and Compliance in International Climate Change Agreements</u></i>
CLIM	95.2002	<i>Banu BAYRAMOGLU LISE and Wietze LISE: <u>Climate Change, Environmental NGOs and Public Awareness in the Netherlands: Perceptions and Reality</u></i>
CLIM	96.2002	<i>Matthieu GLACHANT: <u>The Political Economy of Emission Tax Design in Environmental Policy</u></i>
KNOW	97.2002	<i>Kenn ARIGA and Giorgio BRUNELLO: <u>Are the More Educated Receiving More Training? Evidence from Thailand</u></i>
ETA	98.2002	<i>Gianfranco FORTE and Matteo MANERA: <u>Forecasting Volatility in European Stock Markets with Non-linear GARCH Models</u></i>
ETA	99.2002	<i>Geoffrey HEAL: <u>Bundling Biodiversity</u></i>
ETA	100.2002	<i>Geoffrey HEAL, Brian WALKER, Simon LEVIN, Kenneth ARROW, Partha DASGUPTA, Gretchen DAILY, Paul EHRlich, Karl-Goran MALER, Nils KAUTSKY, Jane LUBCHENCO, Steve SCHNEIDER and David STARRETT: <u>Genetic Diversity and Interdependent Crop Choices in Agriculture</u></i>
ETA	101.2002	<i>Geoffrey HEAL: <u>Biodiversity and Globalization</u></i>
VOL	102.2002	<i>Andreas LANGE: <u>Heterogeneous International Agreements – If per capita emission levels matter</u></i>
ETA	103.2002	<i>Pierre-André JOUVET and Walid OUESLATI: <u>Tax Reform and Public Spending Trade-offs in an Endogenous Growth Model with Environmental Externality</u></i>
ETA	104.2002	<i>Anna BOTTASSO and Alessandro SEMBENELLI: <u>Does Ownership Affect Firms' Efficiency? Panel Data Evidence on Italy</u></i>
PRIV	105.2002	<i>Bernardo BORTOLOTTI, Frank DE JONG, Giovanna NICODANO and Ibolya SCHINDELE: <u>Privatization and Stock Market Liquidity</u></i>
ETA	106.2002	<i>Haruo IMAI and Mayumi HORIE (Iviii): <u>Pre-Negotiation for an International Emission Reduction Game</u></i>
PRIV	107.2002	<i>Sudeshna GHOSH BANERJEE and Michael C. MUNGER: <u>Move to Markets? An Empirical Analysis of Privatisation in Developing Countries</u></i>
PRIV	108.2002	<i>Guillaume GIRMENS and Michel GUILLARD: <u>Privatization and Investment: Crowding-Out Effect vs Financial Diversification</u></i>
PRIV	109.2002	<i>Alberto CHONG and Florencio LÓPEZ-DE-SILANES: <u>Privatization and Labor Force Restructuring Around the World</u></i>
PRIV	110.2002	<i>Nandini GUPTA: <u>Partial Privatization and Firm Performance</u></i>
PRIV	111.2002	<i>François DEGEORGE, Dirk JENTER, Alberto MOEL and Peter TUFANO: <u>Selling Company Shares to Reluctant Employees: France Telecom's Experience</u></i>

PRIV	112.2002	<i>Isaac OTCHERE</i> : <u>Intra-Industry Effects of Privatization Announcements: Evidence from Developed and Developing Countries</u>
PRIV	113.2002	<i>Yannis KATSOULAKOS and Elissavet LIKOYANNI</i> : <u>Fiscal and Other Macroeconomic Effects of Privatization</u>
PRIV	114.2002	<i>Guillaume GIRMENS</i> : <u>Privatization, International Asset Trade and Financial Markets</u>
PRIV	115.2002	<i>D. Teja FLOTHO</i> : <u>A Note on Consumption Correlations and European Financial Integration</u>
PRIV	116.2002	<i>Ibolya SCHINDELE and Enrico C. PEROTTI</i> : <u>Pricing Initial Public Offerings in Premature Capital Markets: The Case of Hungary</u>
PRIV	1.2003	<i>Gabriella CHIESA and Giovanna NICODANO</i> : <u>Privatization and Financial Market Development: Theoretical Issues</u>
PRIV	2.2003	<i>Ibolya SCHINDELE</i> : <u>Theory of Privatization in Eastern Europe: Literature Review</u>
PRIV	3.2003	<i>Wietze LISE, Claudia KEMFERT and Richard S.J. TOL</i> : <u>Strategic Action in the Liberalised German Electricity Market</u>
CLIM	4.2003	<i>Laura MARSILIANI and Thomas I. RENSTRÖM</i> : <u>Environmental Policy and Capital Movements: The Role of Government Commitment</u>
KNOW	5.2003	<i>Reyer GERLAGH</i> : <u>Induced Technological Change under Technological Competition</u>
ETA	6.2003	<i>Efrem CASTELNUOVO</i> : <u>Squeezing the Interest Rate Smoothing Weight with a Hybrid Expectations Model</u>
SIEV	7.2003	<i>Anna ALBERINI, Alberto LONGO, Stefania TONIN, Francesco TROMBETTA and Margherita TURVANI</i> : <u>The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers</u>
NRM	8.2003	<i>Elissaios POPYRAKIS and Reyer GERLAGH</i> : <u>Natural Resources: A Blessing or a Curse?</u>
CLIM	9.2003	<i>A. CAPARRÓS, J.-C. PEREAU and T. TAZDAÏT</i> : <u>North-South Climate Change Negotiations: a Sequential Game with Asymmetric Information</u>
KNOW	10.2003	<i>Giorgio BRUNELLO and Daniele CHECCHI</i> : <u>School Quality and Family Background in Italy</u>
CLIM	11.2003	<i>Efrem CASTELNUOVO and Marzio GALEOTTI</i> : <u>Learning By Doing vs Learning By Researching in a Model of Climate Change Policy Analysis</u>
KNOW	12.2003	<i>Carole MAIGNAN, Gianmarco OTTAVIANO and Dino PINELLI (eds.)</i> : <u>Economic Growth, Innovation, Cultural Diversity: What are we all talking about? A critical survey of the state-of-the-art</u>
KNOW	13.2003	<i>Carole MAIGNAN, Gianmarco OTTAVIANO, Dino PINELLI and Francesco RULLANI (lix)</i> : <u>Bio-Ecological Diversity vs. Socio-Economic Diversity. A Comparison of Existing Measures</u>
KNOW	14.2003	<i>Maddy JANSENS and Chris STEYAERT (lix)</i> : <u>Theories of Diversity within Organisation Studies: Debates and Future Trajectories</u>
KNOW	15.2003	<i>Tuzin BAYCAN LEVENT, Enno MASUREL and Peter NIJKAMP (lix)</i> : <u>Diversity in Entrepreneurship: Ethnic and Female Roles in Urban Economic Life</u>
KNOW	16.2003	<i>Alexandra BITUSIKOVA (lix)</i> : <u>Post-Communist City on its Way from Grey to Colourful: The Case Study from Slovakia</u>
KNOW	17.2003	<i>Billy E. VAUGHN and Katarina MLEKOV (lix)</i> : <u>A Stage Model of Developing an Inclusive Community</u>
KNOW	18.2003	<i>Selma van LONDEN and Arie de RUIJTER (lix)</i> : <u>Managing Diversity in a Globalizing World</u>
Coalition Theory Network	19.2003	<i>Sergio CURRARINI</i> : <u>On the Stability of Hierarchies in Games with Externalities</u>
PRIV	20.2003	<i>Giacomo CALZOLARI and Alessandro PAVAN (lx)</i> : <u>Monopoly with Resale</u>
PRIV	21.2003	<i>Claudio MEZZETTI (lx)</i> : <u>Auction Design with Interdependent Valuations: The Generalized Revelation Principle, Efficiency, Full Surplus Extraction and Information Acquisition</u>
PRIV	22.2003	<i>Marco LiCalzi and Alessandro PAVAN (lx)</i> : <u>Tilting the Supply Schedule to Enhance Competition in Uniform-Price Auctions</u>
PRIV	23.2003	<i>David ETTINGER (lx)</i> : <u>Bidding among Friends and Enemies</u>
PRIV	24.2003	<i>Hannu VARTAINEN (lx)</i> : <u>Auction Design without Commitment</u>
PRIV	25.2003	<i>Matti KELOHARJU, Kjell G. NYBORG and Kristian RYDQVIST (lx)</i> : <u>Strategic Behavior and Underpricing in Uniform Price Auctions: Evidence from Finnish Treasury Auctions</u>
PRIV	26.2003	<i>Christine A. PARLOUR and Uday RAJAN (lx)</i> : <u>Rationing in IPOs</u>
PRIV	27.2003	<i>Kjell G. NYBORG and Ilya A. STREBULAEV (lx)</i> : <u>Multiple Unit Auctions and Short Squeezes</u>
PRIV	28.2003	<i>Anders LUNANDER and Jan-Eric NILSSON (lx)</i> : <u>Taking the Lab to the Field: Experimental Tests of Alternative Mechanisms to Procure Multiple Contracts</u>
PRIV	29.2003	<i>TangaMcDANIEL and Karsten NEUHOFF (lx)</i> : <u>Use of Long-term Auctions for Network Investment</u>
PRIV	30.2003	<i>Emiel MAASLAND and Sander ONDERSTAL (lx)</i> : <u>Auctions with Financial Externalities</u>
ETA	31.2003	<i>Michael FINUS and Bianca RUNDSHAGEN</i> : <u>A Non-cooperative Foundation of Core-Stability in Positive Externality NTU-Coalition Games</u>
KNOW	32.2003	<i>Michele MORETTO</i> : <u>Competition and Irreversible Investments under Uncertainty</u>
PRIV	33.2003	<i>Philippe QUIRION</i> : <u>Relative Quotas: Correct Answer to Uncertainty or Case of Regulatory Capture?</u>
KNOW	34.2003	<i>Giuseppe MEDA, Claudio PIGA and Donald SIEGEL</i> : <u>On the Relationship between R&D and Productivity: A Treatment Effect Analysis</u>
ETA	35.2003	<i>Alessandra DEL BOCA, Marzio GALEOTTI and Paola ROTA</i> : <u>Non-convexities in the Adjustment of Different Capital Inputs: A Firm-level Investigation</u>
GG	36.2003	<i>Mathieu 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 (Ixi)</i> : <u>The Minimal Dominant Set is a Non-Empty Core-Extension</u>
CTN	51.2003	<i>Matthew O. JACKSON (Ixi)</i> : <u>Allocation Rules for Network Games</u>
CTN	52.2003	<i>Ana MAULEON and Vincent VANNETELBOSCH (Ixi)</i> : <u>Farsightedness and Cautiousness in Coalition Formation</u>
CTN	53.2003	<i>Fernando VEGA-REDONDO (Ixi)</i> : <u>Building Up Social Capital in a Changing World: a network approach</u>
CTN	54.2003	<i>Matthew HAAG and Roger LAGUNOFF (Ixi)</i> : <u>On the Size and Structure of Group Cooperation</u>
CTN	55.2003	<i>Taiji FURUSAWA and Hideo KONISHI (Ixi)</i> : <u>Free Trade Networks</u>
CTN	56.2003	<i>Halis Murat YILDIZ (Ixi)</i> : <u>National Versus International Mergers and Trade Liberalization</u>
CTN	57.2003	<i>Santiago RUBIO and Alistair ULPH (Ixi)</i> : <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 (Iix)</i> : <u>Lorenzo Market between Diversity and Mutation</u>
KNOW	70.2003	<i>Ercole SORI (Iix)</i> : <u>Mapping Diversity in Social History</u>
KNOW	71.2003	<i>Ljiljana DERU SIMIC (Iixii)</i> : <u>What is Specific about Art/Cultural Projects?</u>
KNOW	72.2003	<i>Natalya V. TARANOVA (Iixii)</i> : <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 (Iixii)</i> : <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 (Iixii)</i> : <u>Glocal Dialogue- Transformation through Transcultural Communication</u>
KNOW	75.2003	<i>Catarina REIS OLIVEIRA (Iixii)</i> : <u>Immigrants' Entrepreneurial Opportunities: The Case of the Chinese in Portugal</u>
KNOW	76.2003	<i>Sandra WALLMAN (Iixii)</i> : <u>The Diversity of Diversity - towards a typology of urban systems</u>
KNOW	77.2003	<i>Richard PEARCE (Iixii)</i> : <u>A Biologist's View of Individual Cultural Identity for the Study of Cities</u>
KNOW	78.2003	<i>Vincent MERK (Iixii)</i> : <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</i> : <u>Oil and Product Dynamics in International Petroleum Markets</u>
CLIM	82.2003	<i>Y. Hossein FARZIN and Jinhua ZHAO</i> : <u>Pollution Abatement Investment When Firms Lobby Against Environmental Regulation</u>

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

- (l) This paper was presented at the Workshop “Growth, Environmental Policies and Sustainability” organised by the Fondazione Eni Enrico Mattei, Venice, June 1, 2001
- (li) This paper was presented at the Fourth Toulouse Conference on Environment and Resource Economics on “Property Rights, Institutions and Management of Environmental and Natural Resources”, organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE, Toulouse, May 3-4, 2001
- (lii) This paper was presented at the International Conference on “Economic Valuation of Environmental Goods”, organised by Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001
- (liii) This paper was circulated at the International Conference on “Climate Policy – Do We Need a New Approach?”, jointly organised by Fondazione Eni Enrico Mattei, Stanford University and Venice International University, Isola di San Servolo, Venice, September 6-8, 2001
- (liv) This paper was presented at the Seventh Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Venice, Italy, January 11-12, 2002
- (lv) This paper was presented at the First Workshop of the Concerted Action on Tradable Emission Permits (CATEP) organised by the Fondazione Eni Enrico Mattei, Venice, Italy, December 3-4, 2001
- (lvi) This paper was presented at the ESF EURESCO Conference on Environmental Policy in a Global Economy “The International Dimension of Environmental Policy”, organised with the collaboration of the Fondazione Eni Enrico Mattei, Acquafredda di Maratea, October 6-11, 2001
- (lvii) This paper was presented at the First Workshop of “CFEWE – Carbon Flows between Eastern and Western Europe”, organised by the Fondazione Eni Enrico Mattei and Zentrum für Europäische Integrationsforschung (ZEI), Milan, July 5-6, 2001
- (lviii) This paper was presented at the Workshop on “Game Practice and the Environment”, jointly organised by Università del Piemonte Orientale and Fondazione Eni Enrico Mattei, Alessandria, April 12-13, 2002
- (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

2002 SERIES

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

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>