Interactions between voluntary environmental initiatives with endogenous natural capital: a case for tourism evolutionary dynamics

Esther Blanco[a], Javier Lozano[b], Javier Rey-Maquieira[c]

[a] University of Innsbruck, Institute of Public Finance, Universitaetsstrasse 15/4, 6020 Innsbruck, Austria; Telephone: +43(0)512-5077160; Fax: +43(0)512-5072970; e-mail: esther.blanco@uibk.ac.at

[c] *University of the Balearic Islands, Ctra. Valldemossa km. 7.5, 07122 Palma de Mallorca, Spain.* Telephone: 971172786; Fax: 971172389. *E-mail address: javier.lozano@uib.es,*

[b] *University of the Balearic Islands, Ctra. Valldemossa km. 7.5, 07122 Palma de Mallorca, Spain.* Telephone: 971173309; Fax: 971172389. *E-mail address: javier.rey@uib.es*

Abstract

We analyze environmental management decisions by a population of tourism firms making use of a natural common-pool resource (CPR) when they can opt for two abatement strategies (certified and uncertified abatement) in addition to the no-abatement option. The behavior of the system is modeled through three replicator dynamics and one resource dynamics equations. The model builds on the demand effect literature and three price premiums for firms' voluntary abatement are assumed to be relevant. Endogenous natural capital affects firms' strategy selection through interacting effects with these price premiums. We show that contrary to previous literature, heterogeneous compositions of the population with voluntary abatement can be sustained in the long-run without assuming punishments or rewards by other users of the natural common-pool resource. However, no stable co-existence between the ecolabel and the uncertified green initiatives in the long-run is supported by this model. A bifurcation analysis reveals, first, that there are critical (bifurcation) values around which small changes in ecolabel's abatement requirements imply dramatic changes in ecolabel participation and, second, that incentives for voluntary environmental initiatives may ultimately hinge on public control on the number of the CPR's users.

JEL Classification: Q - Agricultural and Natural Resource Economics; Environmental and Ecological Economics

Interactions between voluntary environmental initiatives with endogenous natural capital: a case for tourism evolutionary dynamics

1. Introduction

It is common to argue that unregulated contexts lead to overexploitation and exhaustion of common-pool resources (CPR) due to free-riding behavior of agents. Under this assumption, there is no scope for voluntary environmental initiatives, and public intervention is considered essential to avoid overexploitation of natural resources. However, there is a body of literature on the management of natural CPRs that shows that voluntary environmental initiatives that avoid tragedy outcomes are a theoretical possibility and an empirical reality (Agrawal, 2001; McGinnis, 2000; Ostrom, 1990; Ostrom et al., 1999). Voluntary environmental initiatives are receiving increasing attention among business leaders, academics, investors, and governments as a relevant policy alternative (Anton et al., 2004; Glachant, 2007; Khanna, 2001; Segerson and Miceli, 1998). This rising recognition is fostered by the desire to find cost-effective solutions to environmental problems, adopt a cooperative approach between industry and governments, and help prevent the negative legal and political consequences associated with regulatory failure.

In this paper we build a model for voluntary actions by tourism users of natural resources. International tourism accounts for US$944 billion tourism receipts and 922 millions of tourism arrivals, accounting for 30% of the world's exports of commercial services and 6% of overall exports of goods and services (WTO, 2009). Nature-based tourism has been one of the fastest growing segments of the global tourism market for years (Huybers and Bennett, 2003; Sirakaya and Uysal, 1997). As a result, empirical studies show that tourism-related uses of natural resources are increasingly relevant (Ayuso, 2006, 2007; Buckley, 2002; Font, 2002; Mihalic, 2000; Sasidharan et al., 2002; UNEP, 1998; WTO, 2002). These uses include land, water and energy consumption, pollution releases in form of garbage or sewage, as well as many recreational activities as hiking, sailing, fishing, hunting, etc. The resources of which tourism firms make use have different degree of excludability and rivalry, some of them being CPR (Healy, 1994). Examples may include mountain areas as forest land, wildlife areas or rivers, and also coastal environments as a piece of shoreline, diving areas, coral reefs, or fresh and salt ponds (Healy, 1994; Imperial, 1999). These resources are nonexcludable and, therefore, it is too costly, physically impossible, or socially unacceptable to preclude tourism firms to use them as a source of resources or as a sink for waste disposal and by tourists for recreation and enjoyment. Often, these resources are also rival as tourism-uses degrade them in pure ecological terms and/or in appeal for tourists (Buckley, 1996). For example, the European Union Environment Agency reports environmental impacts derived from tourism ranging from habitat fragmentation and biodiversity loss to over use of water, and impacts derived from inadequate waste and wastewater disposal (EEA, 2007). Other impacts elsewhere have also been extensively documented (Garcia and Servera, 2003; Hawkins and Roberts, 1994; Hillery et al., 2001)

Despite the relevancy of tourism uses of natural resources, research on the benefits that could be gained by a broader and deeper voluntary commitment to the environment by service organizations is still limited (Blanco et al., 2009; Davis, 1991; Foster et al., 2000; Grove et al., 1996).

In this paper, we develop an evolutionary game-theory model for voluntary environmental initiatives by tourism users of a natural CPR. Building in the demand effects literature, we analyze the market implications of voluntary abatement as a form of product differentiation in markets where there is a concern by consumers about environmental aspects of goods and services[1] (Ibanez and Grolleau, 2008; Sedjo and Swallow, 2002). Our primary interest is to model the incentives to undertake voluntary environmental contributions when two different environmental strategies are available and the state of natural capital affects endogenously firms' profits. Specifically, we create a model with three strategies, namely, no-environmental action, uncertified voluntary action, and adherence to an ecolabel. We analyze the interacting incentives resulting from the two environmental strategies and identify the circumstances under which voluntary initiatives can be stable in the long run. By integrating the dynamics of the resource stock, as suggested by Sethi and Somanathan (1996), the stability of population configurations is considered together with the sustainability of resource use.

As already stressed by van der Bergh (2007), there are few papers that combine evolutionary economics and CPR dynamics. With the exception of Noally et al. (2003), these papers focus on the incentives for voluntary responsible management of the CPR. Compared with this literature, our paper makes some distinctive contributions. First, unlike Sethi and Somanathan (1996) and Osés and Viladrich (2007), our model builds on market motivations to undertake voluntary environmental contributions. Second, our model explicitly addresses

[1] Other sources of economic incentives that can trigger implementation of voluntary initiatives considered by previous literature, include regulatory gains, cost efficiency, and technical assistance (Amacher et al., 2004; Anton et al., 2004; Khanna, 2001).

environmental decision of firms endogenously affected by the state of natural capital when they are presented with two different environmental strategies in addition to the option of not engaging in greener behavior. Previous literature has addressed scenarios where firms either undertake one form of environmental action or do no abatement, and natural capital is exogenous to firms' decisions.

The consideration of an ecolabel strategy besides the uncertified green one is the main difference of this paper compared to Blanco et al. (2009), which also analyzes voluntary environmental contributions of tourism firms that are users of a CPR. This paper is more realistic, as in many real settings firms choose between more than one possible voluntary environmental course of action. Adding this complexity reveals new results. Thus, we show that the two environmental strategies cannot coexist in the long-run, but heterogeneous compositions of the populations with either of the environmental strategies and firms not undertaking any abatement are possible. In addition we show that it is possible that in the long-run all firms become members of an ecolabel of voluntary adherence, whereas we confirm the result obtained in Blanco et al. (2009) that uncertified environmental practices, which are only supported by environmental differentiation between tourism firms, cannot attract the whole population. Finally, as in Blanco et al. (2009) homogeneous compositions where no firm engages in green strategies can be stable.

The rest of the paper is organized as follows. Section 2 presents some stylized facts in tourism that inspire the main assumptions of the model presented in section 3. This latter section develops the structure of the model, presenting first the equilibrium populations, next the equilibrium levels of the resource, and finally the dynamics of the combined system. In section 4 we conduct a sensitivity and bifurcation analysis of the model. Lastly, section 5 presents some conclusions.

2. Uncertified and certified voluntary environmental initiatives in tourism

In this paper we distinguish between two kind of voluntary environmental initiatives, namely uncertified and certified (ecolabels). Firms that internally develop their own environmental policies, and those that adhere to uncertified codes of good practices would be included in the first category. Ecolabels, by contrast, imply the certification of a particular level of environmental performance in the production of a tradable product or service (Buckley, 1992), requiring the assessment of participants (Font, 2002). Some international examples in tourism are the Blue Flag Campaign and the Green Globe (WTO, 2002).

To model the environmental decisions of tourism firms regarding the implementation of voluntary environmental initiatives, we build on some of the theoretical foundations of the literature on demand effects as motivators of voluntary action. We consider imperfectly informed consumers with green preferences (Arora and Gangopadhyay, 1995; Ibanez and Grolleau, 2008; Sedjo and Swallow, 2002) revealed through their willingness to pay for greener products or services (Amacher et al., 2004). This assumption is supported by empirical evidence in tourism showing that up to 5 percent of the overall travel market would pay a premium for sustainable packages (Dodds and Joppe, 2005), or other regional findings estimating that up to 52 percent of visitors would be prepared to pay an extra 10 percent for environmentally-friendly tourism products (PATA, 2007). For instance, estimates in North Tropical Queensland (Australia) show a lower boundary estimate for the willingness to pay for an increase in the environmental quality from "somewhat spoiled" to "unspoiled" of more than US $480 for a fortnight's holiday (Huybers and Bennett, 2003). We also assume that, given the high interaction between production and consumption in tourism, greener behavior by tourism firms is not a pure credence attribute. However, consumers are neither perfectly able to asses the environmental performance of tourism firms and, therefore, credibility, reputation and marketing play an important role to determine the demand response to environmental behavior (WTO, 2002). Finally, we also assume that private tourism services are consumed in a bundle jointly with unpriced common-pool resources.

Given these assumptions, we separately consider three price premiums which might result from demand effects[2]: a premium from green differentiation, a certification premium, and a premium that depends on the state of the common-pool resource.

First, we hold that firms which undertake voluntary environmental initiatives can obtain a premium from green differentiation (Carmona-Moreno et al., 2004; Claver-Cortés et al., 2007; Kassinis and Soteriou, 2003). This is the case since firms which abate their environmental impacts beyond those legally mandated can stand out among their competitors to fill a green market niche (Alberini and Segerson, 2002).

Second, tourism firms which belong to an ecolabel can obtain a certification premium from their environmental efforts (Buckley, 2002; Font, 2002; WTO, 2002), since ecolabeling can provide relevant information for imperfectly informed consumers to gauge the environmental sensitivity of tourism firms (Buckley, 2002; Font, 2002; Sasidharan et al., 2002; UNEP, 1998; WTO, 2002). The high level of tourist response to ecolabeled products

[2] See Sedjo and Swallow (2002) for a discussion on the circumstances under which a willingness to pay for environmental attributes of goods by a significant proportion of consumers results in price differentials for environmentally-friendly firms.

has been upheld as one of the most telling indicators of the strength of environmental concern of the tourism demand (Buckley, 2002). Empirical findings show that, among hotels, being enrolled in certification programs with higher levels of environmental performance is significantly related to higher room prices (Rivera, 2002) and higher occupation rates (Font, 2002) relative to hotels which are not members of an ecolabel.

The strength of this certification premium might depend on the credibility and diffusion of information released by ecolabels. Credibility of the information released by ecolabels is crucial, since ecolabeling is in danger of being considered a green wash (Font, 2002). Credibility results from several factors. First, the higher abatement required for qualification. Thus, according to the international standard for ecolabels (ISO 14024), these voluntary initiatives should include the precondition of the applicant's compliance with environmental legislation and show measurable and significant differences in environmental impact compared to non-certified licensees (WTO, 2002). Second, the existence of a procedure to assess the performance of applicants (preferably undertaken by independent third parties). Third, the existence of a monitoring system to ensure that the label is only used by those firms who have earned it and that it is withdrawn if no longer applicable. Fourth, participation of multiple stakeholders in the design and management of ecolabels. And, finally, the public image of the promoting institution (Buckley, 2002; Mihalic, 2000; UNEP, 1998; WTO, 2002).

Overall, to be successful an ecolabel has to provide services to its members in order to raise credibility and spread information. These services are costly, and thus, obtaining enough funding is one of the threats which ecolabels must face. Funding usually comes from the promoting institution, public or private foundations, and fees from applicants (WTO, 2002). The literature on ecolabeling in tourism recognizes the relevance of fees as a source of financial resources, but it also highly recommends keeping fees as low as possible (Font, 2002; UNEP, 1998; WTO, 2002). This is because it has been widely reported that administrative fees might deter adherence (Sasidharan et al., 2002; WTO, 2002). Among others, one criticism of tourism ecolabels is that they are expensive in terms of both money and time (Font, 2002). Given these arguments, a general concern in this literature is the ability of ecolabels to obtain enough members as this becomes crucial for the ecolabel scheme to provide the aforementioned services. An ecolabels' ability to do this is highly related to the technical assistance and guidelines that it can provide to firms in order to improve their environmental behavior and to facilitate adherence (Font, 2002; UNEP, 1998; WTO, 2002). The higher the number of adherents, the higher the financial resources of the initiative, and thus, the higher the level of services it provides, which increase the reputation of the scheme.

Finally, tourist satisfaction stems from the joint consumption of different goods and services, some of them private and some of them, as those provided by CPRs, with public attributes (Gómez et al., 2008). Therefore, as it is common in the tourism literature of strategic interaction (e.g. Candela and Cellini, 2006), we consider a price premium that depends on environmental conditions, specifically, on the level of the CPR. This implies that, insofar as a firm's abatement activities has an impact on the CPR enjoyed by tourists, it will affect the profits of all firms making use of that CPR, as it is confirmed by some empirical evidence (Huybers and Bennett, 2003).

3. The model

We extend the model in Blanco et al. (2009), where firms which profits are affected by the quality of a CPR have the possibility to voluntarily reduce their environmental impact with uncertified initiatives, by introducing a second available environmentally-friendly strategy: an ecolabel. The model considers a fixed population of firms, $N = \{1,...,n\}$, that provide tourism services linked to the use of a renewable natural CPR by tourists. The recreational use of the CPR by these N users has a negative environmental impact that can be mitigated aside of regulations with these two voluntary environmental initiatives.

Similar to Sethi and Somanathan (1996), Osés and Viladrich (2007) and Blanco et al. (2009), we represent the abatement efforts of each firm $i \in N$ with a discrete variable $a_i \in \{a_{ng}, a_c, a_l\}$, $0 \le a_i \le 1$, where a_l is the abatement level required by ecolabel rules, a_c the one carried out by firms that implement uncertified voluntary environmental initiatives (uncertified initiatives henceforth), and a_{ng} to firms only complying with regulation. [3]. We refer to agents choosing a_l as "ecolabel" firms, agents choosing a_c as "uncertified green", and to agents choosing a_{ng} as "non-green" firms. Consistently with the stylized facts commented in section 2, we assume (a_l>a_c>a_{ng}). Moreover, for simplicity in notation, we normalize a_{ng}=0. The abatement profile of firms, $\vec{a} = (a_1,...,a_n)$, determines the proportion of firms following each strategy, $s_i \in \{s_{ng}, s_c, s_l\}$, $\sum s_i = 1$.

[3] Arguably, firms may be able to choose among several ecolabel schemes and implement different uncertified initiatives. However, the choice of replicator dynamics limits the degree of heterogeneity to guarantee analytical tractability. Heterogeneity could be enlarged using other

Consistently with previous section, we assume that the price at which firm i sells its tourism product can be described using equation 1.

$$P_i = x + \delta(s_{ng}, K)\cdot g(a_i) + \rho(s_l, K)\cdot l(a_i) + \gamma(K) \text{, for } \forall s_{ng} \geq 0 \qquad (1)$$

where x is a part of the price independent of environmental actions; $g(a_i) = \{0,1\}$ is a dummy variable equal to 1 for firms undertaking abatement efforts ($0<a_i<1$) and equal to 0 for non-green firms; and $l(a_i) = \{0,1\}$ is a dummy variable taking the value 1 for ecolabel firms and 0 otherwise. Attributes defining $\delta(s_{ng},K)$, $\rho(s_l,K)$ and $\gamma(K)$ are,

$$\delta(0,K) > 0 \quad \text{and} \frac{\partial\delta(\cdot)}{\partial s_{ng}} > 0, \ \frac{\partial^2\delta(\cdot)}{\partial s_{ng}^2} < 0, \ \lim_{s_{ng}\to 0}\delta(\cdot) = 0$$

$$\delta(s_{ng},0) = 0, \quad \text{and} \frac{\partial\delta(\cdot)}{\partial K} > 0, \ \frac{\partial^2\delta(\cdot)}{\partial K^2} < 0$$

$$\gamma(0) = 0, \quad \text{and} \frac{\partial\gamma(\cdot)}{\partial K} > 0, \ \frac{\partial^2\gamma(\cdot)}{\partial K^2} < 0$$

$$\rho(0,K) > 0, \quad \text{and} \frac{\partial\rho(\cdot)}{\partial s_l} > 0, \ \frac{\partial^2\rho(\cdot)}{\partial s_l^2} < 0$$

$$\rho(s_l,0) = 0, \quad \text{and} \frac{\partial\rho(\cdot)}{\partial K} > 0, \ \frac{\partial^2\rho(\cdot)}{\partial K^2} < 0$$

Where K is the level of natural capital of the renewable CPR of which firms make use. $\delta(\cdot)$ is the price premium for environmental differentiation. The size of this premium is contingent on the environmental behavior of other firms using the CPR: the higher (lower) the proportion of non-green firms (environmentally sensitive firms), the higher (lower) the differentiation premium for a firm becoming greener. In addition, the size of the premium is contingent on the level of natural capital: it only takes positive values for positive levels of natural capital and is increasing with it[4].

Price premium $\rho(\cdot)$ is reaped by ecolabel firms. We assume that this certification premium depends on the credibility of the certification procedure, but also on the number of firms adhered to the initiative and on the environmental level of the CPR. As explained in section 2, as more firms adhere to the ecolabel, the ecolabel gains greater funding capacity to

---

evolutionary approaches as agent-based models, but again at the expenses of analytical tractability (Safryńska and Van der Berg, 2009).

[4] See Blanco et al. (2009) for some reasons that justify these assumptions and an explanation for why dependency of price premiums on K makes the model specially applicable to nature-based tourism.

provide the services that support the ecolabel's credibility and marketing activities which increase willingness to pay. As to the positive dependence on the level of the CPR, the arguments are the same as those put forward for $\delta(\cdot)$. We also reasonably assume that the certification premium is zero when the natural resource is exhausted.

Finally, price premium $\gamma(\cdot)$ is common to all firms regardless of their individual environmental behavior since it captures the effect on willingness to pay for the state of the CPR which is, by definition, non-excludable.

Building on equation 1, the following payoff function can be constructed:

$$\pi_i = q_i[x + \delta(s_{ng}, K)\cdot g(a_i) + \rho(s_l, K)\cdot l(a_i) + \gamma(K)] - C(a_i) - Co\,,\; i = ng, c, l \qquad (2)$$

where $C(0)=0$, $C'(a_i)>0$, $\lim_{a_i \to 1} C(a_i) = \infty$,

and where q_i is the quantity produced by the i-th firm, assumed to be 1 for simplicity; Co are costs independent of environmental strategies; and $C(a_i)$ is the cost of abatement activities. Since the ecolabel scheme requires higher abatement efforts than uncertified initiatives, it also implies higher costs[5].

When addressed under evolutionary game theory, the payoff differentials between the different strategies exert evolutionary pressures on the population favoring groups earning higher payoffs. These modifications of strategies are not instantaneous. To capture these behavioral patterns we make use of a replicator dynamics as presented in equation 3, which is the most common evolutionary tool to investigate dynamic properties of evolutionary stable strategies (Friedman, 1991; Mailath, 1998; Sethi and Somanathan, 1996):

$$\dot{s}_i = s_i\left(\pi_i - \overline{\pi}\right),\; i=l,ng \qquad (3)$$

where $\overline{\pi} = s_{ng}\pi_{ng} + s_l\pi_l + (1 - s_{ng} - s_l)\pi_g$ is the average payoff in the population as a whole. The population dynamics determined by a two-dimensional dynamic system in the variables s_{ng} and s_l are shown in equations 4:

$$\left.\begin{aligned} \dot{s}_{ng} &= s_{ng}[-s_l\left(\rho(s_l, K) - \left(C(a_l) - C(a_g)\right)\right) - (1 - s_{ng})\left(\delta(s_{ng}, K) - C(a_g)\right)] \\ \dot{s}_l &= s_l[s_{ng}\left(\delta(s_{ng}, K) - C(a_g)\right) + (1 - s_l)\left(\rho(s_l, K) - \left(C(a_l) - C(a_g)\right)\right)] \end{aligned}\right\} \quad (4)$$

---

[5] Apart from this, there are other costs associated with ecolabel membership, such as certification and licensing fees to be paid to the ecolabelling agency for awarding the ecolabel to firms, and greater coordination activities or employee training and product and process improvement (Anton et al., 2004). To consider explicitly these other costs would only reinforce our assumption that the ecolabel implies higher costs than the other alternatives.

From the system of equations in 4 it is noteworthy that since all firms benefit from premiums from increased environmental capital, this premium does not influence the evolution of the composition of the population.

The strategic dynamic system for environmental decisions of firms is also determined by the dynamic behavior of the renewable natural CPR, as presented in equation 5.

$$\dot{K} = F(K) - D(s_{ng}, s_l) \qquad (5)$$

where $F(K)$ is a replenishment function, capturing the renewable nature of the CPR, and $D(s_{ng}, s_l)$ is the total environmental damage by the population of firms.

As in previous literature (Blanco et al., 2009; Osés and Viladrich, 2007; Sethi and Somanathan, 1996) we consider a differentiable replenishment function, *F(K)* that exhibits critical depensation and satisfies the usual assumptions for describing the dynamics of renewable resources, as represented in figure 1. There is a level of natural capital $\underline{K}$ and a finite carrying capacity $\overline{K}$ of the resource $(0 < \underline{K} < \overline{K})$ so that $F(\underline{K}) = 0$ and $F(\overline{K}) = 0$. Between these two thresholds, *K* grows at a positive rate, whereas it grows at a negative when the stock is below $\underline{K}$. Accordingly, the resource reaches a maximum size given by its carrying capacity, and below $\underline{K}$ the natural replenishment of the resource is impossible even in the absence of environmental damage. For stock levels between $\underline{K}$ and $\overline{K}$ $F''(K)<0$, with the replenishment function reaching the maximum yield at K^M.

Insert figure 1 about here

The dynamics of the natural resource are negatively affected by the environmental damage derived from the pressures generated by the population of firms. We assume a uniform environmental damage *d* to each firm, which can be reduced by abatement efforts[6]. Accordingly, firms' environmental damage, net of abatement, is *d* for non-green firms, $d(1-a_c)$ for uncertified green firms, and $d(1-a_l)$ for ecolabel firms. Then, after some straightforward transformations, total environmental damage is

[6] In the model, environmental damage *d* bundles both tourism firms' and tourists' impacts insofar as the latter are made possible by the provision of accommodation and other tourism services by the tourism firms. However, abatement is only attributed to the tourism firm and it can result from reduction in the firm's environmental pressures (more efficient use of natural inputs or reductions in pollution emissions) and/or direct investments toward improving the quality of the natural resource. For instance, firms that provide boat excursions for scuba-diving in a coral reef may improve its operative processes to reduce waste-water discharges. It can also clean its diving area.

$D(s_{ng}, s_l) = N[(1-a_c) + s_{ng}a_c - s_l(a_l - a_c)]$, where for simplicity d is normalized to one without loss of generality.

3.1. Population dynamics

Figure 2 presents the feasible region as a prism in the s_{ng}, s_l, K space. This figure also contains isoclines of the population, that is, those loci where the strategy shares are constant. These isoclines include $\widehat{S}_I, \widehat{S}_{II}$ and $\widehat{S}_{III}$ as well as those edges of the feasible region where all the population chooses the same strategy. The figure is drawn for a case where at least some part of each isocline is inside the feasible region.

Insert figure 2 about here

Isocline $\widehat{S}_I$ is drawn on the plane (s_{ng},K) and represents, for each level of natural capital, equilibrium populations composed of uncertified green and non-green firms. That is, in this locus there are no ecolabel firms and π_c=π_{ng}. As it is drawn, it has a straight part at s_{ng}=1, which implies that the level of the CPR is so low that it does not pay to carry out uncertified voluntary environmental initiatives. The shape of the curve part is determined by the fact that, as K is higher, the differentiation premium is larger and, therefore, this equilibrium population contains a higher share of uncertified green firms.

Isocline $\widehat{S}_{II}$ is drawn on the sloping plane of the prism defining the feasible region. Thus, it is composed of equilibrium populations where there are just ecolabel and non-green firms with equal profits. As it is drawn, for low levels of K this kind of equilibrium cannot exist. The reason is that price premiums for ecolabel firms are so low that do not compensate for the extra costs whatever the strategies shares are. However, for higher levels of K, there are two equilibrium populations, which implies that for both population compositions profits of ecolabel firms are the same. The reason is the presence of two price premiums in the profit function of an ecolabel firms. Thus, when there are few ecolabel firms, the certification premium is low but the differentiation premium is large. The contrary happens when the share of ecolabel firms is large.

Finally, isocline $\widehat{S}_{III}$ is drawn inside the feasible region and it is composed of equilibrium populations where the three strategies are present and are equally profitable. As it is drawn, the solid part of $\widehat{S}_{III}$ is inside the feasible region whereas the dashed part is outside it (and, therefore, it is irrelevant). The point of $\widehat{S}_{III}$ on the sloping plane of the prism also belongs to $\widehat{S}_{II}$, as it represents a population with just ecolabel and non-green firms with equal profits.

3.2. Resource dynamics

We now identify equilibrium levels of natural capital considering the composition of the population exogenous. The steady state condition, $D(s_{ng},s_l)=F(K)$, defines a relationship between the composition of the population and the stock of natural capital represented by isoclines $\breve{K}(s_{ng},s_l)$ and $\hat{K}(s_{ng},s_l)$ in figure 3.

Insert figure 3 about here

The edges of the isoclines represent equilibrium values of the resource for different combinations of two out of the three possible strategies. Thus, the edges in the plane (s_{ng},K) only consider uncertified green and non-green strategies, the edges at the plane (s_l,K) only consider uncertified green and ecolabel strategies, and, finally, the edge belonging to the sloping plane of the prism defining the feasible region only consider non-green and ecolabel strategies. Points within the interior of the feasible set represent equilibrium values of natural capital when the composition of the population comprises the three strategies.

Dynamics of the CPR for an exogenous population are simple. For high (above $\hat{K}(\cdot)$) and low (below $\breve{K}(\cdot)$) values of K, natural capital is decreasing, whereas it is increasing for intermediate values of K (between $\hat{K}(\cdot)$ and $\breve{K}(\cdot)$). Therefore, points belonging to $\hat{K}(\cdot)$ are stable equilibria, whereas those belonging to $\breve{K}(\cdot)$ are unstable.

Figure 3 is drawn under the simplifying assumption that total damage is below the maximum sustainable yield. However, the development of the model below is not restricted to this special case.

3.3. Existence and stability of steady states of the combined system

In the combined system, both natural capital and the composition of the population are endogenous and, therefore, the model is governed by equations 4 and 5. In this section we explore the steady states of the combined system, whereas in next section the sensitivity of the model to changes in key parameters is analyzed.

We start with the definition of the combined system's steady states:

Definition: A steady state of the combined system is any point that belongs both to an isocline of the population and to an isocline of the CPR.

Figure 4 presents a situation where all possible steady states exist. These are fourteen equilibria, labeled with lower case letters, with different levels of the CPR and population compositions. Stable equilibria are identified with a dot, whereas unstable equilibria are identified with a cross. Other configurations of equilibria are also possible, as shown in figure 5. Still, there are several equilibria that are always present, as is stated in the following proposition (proofs to all propositions are included in the appendix).

Insert figure 4 about here

Proposition 1: A homogeneous all-ecolabel equilibrium always exist. All-uncertified green and all-non-green firms equilibria exist if and only if total damage of these homogeneous populations does not exceed maximum sustainable yield. An all-ecolabel equilibrium is asymptotically locally stable if and only if $\rho(1,K) > C(a_l)$ and $F'(K)<0$; an all-uncertified green equilibrium is always unstable; an all-non-green is asymptotically locally stable if and only if $\delta(1,K) < C(a_c)$, $\rho(0,K) + \delta(1,K) < C(a_l)$ and $F'(K)<0$.

If voluntary environmental contributions by all the population, either as uncertified initiatives or as an ecolabel, are not enough to reduce resource depletion below the maximum sustainable yield, then all-ecolabel or all-uncertified green equilibria (equilibria d, d', g and g') cannot exist. Existence of an all-non green equilibrium with positive stock of the CPR (equilibria h and h') also requires that maximum yield is not surpassed when there is no voluntary environmental action. Nevertheless, an all-non green equilibrium with exhausted CPR always exists. Moreover, this equilibrium is always stable since price premiums for voluntary environmental action are zero when the CPR is exhausted and critical depensation prevents natural recovery of the CPR. Regarding the rest of homogeneous equilibria, stability conditions require both that the surviving strategy yields higher profits than the others and that the CPR level corresponds to the downward sloping part of the replenishment function.

Homogeneous equilibria are points h, h', g, g', d and d' of figure 4 and 5. Proposition 1 implies that homogenous equilibria are only stable at the edges of $\hat{K}(\cdot)$. In figure 4 all homogeneous equilibria with positive level of the CPR are unstable, whereas figure 5 contains cases with homogeneous stable equilibria. Thus, figures 5.a and d represent respectively very optimistic[7] and very pessimistic cases in terms of the success of voluntary

[7] We loosely evaluate the different cases as as optimistic or pessimistic in terms of stable participation in the green strategies. However, it must be noted that evaluating a voluntary program on the basis of participation alone is incomplete. Even with very high participation

environmental initiatives. In 5.a it is possible that, in the long run, the whole population is made up of members of an ecolabel, whereas in 5.d it is a stable equilibrium that none of the firms engages in any voluntary environmental initiative.

The relevance of all-ecolabel equilibrium should be cautiously considered since there is no evidence supporting full adherence to ecolabels in tourism. This may imply that an all-ecolabel stable equilibrium is not realistic. However, it may also be due to the systems being in early stages of dynamic evolutions that eventually would reach a stable point *d*. The former hypothesis could be supported by more than half of the ecolabels that were identified in WTO (2002) as operating for less than four years. This is a rather short time period for the diffusion of a new strategy. Thus, it could be the case that some tourism ecolabels could eventually embrace all firms of their target population. It has been defended that the end point in the evolution of a tourism ecolabel is when it becomes a routine part of normal business relations between firms and customers so that connotations of a label are lost and the criteria of the ecolabel are perceived as a requirement (Buckley, 2002).

Insert figure 5 about here

Moving to heterogeneous equilibria, propositions 2 and 3 present, respectively, the stability conditions for heterogeneous equilibria where two and three strategies coexist.

Proposition 2: A population composed of ecolabel and uncertified green firms is always unstable. A population composed of ecolabel and non-green firms it is locally asymptotically stable if and only if $F'(K)<0$, $\delta(s_{ng},K) < C(a_c)$, and

$$\left(\frac{\partial\delta(s_{ng},K)}{\partial s_{ng}} - \frac{\partial\rho(s_l,K)}{\partial s_l}\right) + \frac{N\cdot a_l}{F'(K)}\left(\frac{\partial\delta(s_{ng},K)}{\partial K} + \frac{\partial\rho(s_l,K)}{\partial K}\right) > 0$$

. A population composed of uncertified green and non-green firms is locally asymptotically stable if and only if $F'(K)<0$, $\rho(s_l,K) < C(a_l) - C(a_c)$ and $\frac{\partial\delta(s_{ng},K)}{\partial s_{ng}} + \frac{N\cdot a_c}{F'(K)}\frac{\partial\delta(s_{ng},K)}{\partial K} > 0$.

Proposition 2 determines three kind of conditions for the stability of heterogeneous equilibria with two strategies. First, only those equilibria that belong to $\hat{K}(\cdot)$ can be stable. Second, profits of the absent strategy must be strictly lower than profits of the surviving ones. Third, for those equilibria to be stable, a change in the composition of the population must be detrimental for the payoff of the strategy that increases adherence as compared with the other

rates, aggregate abatement can be very low if abatement by each participating firm is low (Alberini and Segerson, 2002).

existing strategy in the equilibrium, that is, $\partial(\pi_c - \pi_{ng})/\partial s_{ng} > 0$ in the uncertified green and non-green equilibrium and $\partial(\pi_l - \pi_{ng})/\partial s_{ng} > 0$ in the ecolabel and non-green equilibrium.

Points *f* in figures 5.a-c represent stable uncertified green and non-green equilibria. In figures 5.b and c, this is the only stable equilibrium. In the first case, equilibria containing a positive proportion of ecolabel firms exist, but they are not stable and, therefore, the ecolabel cannot survive in the long run. Specifically, *a* cannot be stable as in *a* payoffs of both non-green and ecolabel strategies are lower than those of the uncertified green strategy, that is, $\delta(s_{ng},K)>C(a_c)$ and $\rho(s_l,K)<C(a_l)-C(a_c)$.[8] In figure 5.c, no equilibrium exists in which a proportion of firms are members of the ecolabel, since the minimum level of natural capital that is required for being worth becoming a member of the ecolabel is higher than the level of natural capital that the resource can steadily provide.

In figures 5 and 5.d there exists heterogeneous stable equilibria with positive ecolabel membership, *a*. In *a*, *K* is the highest among its class of equilibria. What is more, it can be shown that always $K_a > K_f$ This is due to two effects that work in the same direction: first, the ecolabel requires higher abatement efforts than the uncertified initiatives and, second, the heterogeneous equilibrium with ecolabel has a lower share of non-green firms that the corresponding equilibrium with uncertified green firms. Therefore, when successful, the ecolabel triggers an improvement in the state of the CPR when compared to uncertified initiatives, and this happens even if there is only partial participation. This result is consistent with previous literature defending that even though an industry-wide voluntary approach is not likely to induce full participation, it can still be a viable means of achieving relevant environmental objectives in aggregate terms for that industry (Alberini and Segerson, 2002).

Proposition 3: An equilibrium where all strategies co-exist is always conditionally stable.

In figures 5 and 6, the intersection of the isocline $\widehat{S}_{III}$ with the isoclines of natural capital determines equilibria with the three strategies, *c* and *c'*. Associated with each one, there may be a stable arm (if there are two positive and one negative eigenvalues) or a set of convergent paths that lie on a two-dimensional manifold (if there are one positive and two negative eigenvalues). The conditional stability characteristics of *c* and *c'* imply that the system can follow paths that converge to long run situations where the three strategies coexist. It is also interesting to note that one of these situations is characterized by a low level

[8] Graphically, this always happens when $\widehat{S}_{III}$ crosses $\widehat{S}_{II}$ above *a*.

of natural capital, $\tilde{K}(\cdot)$. Nevertheless, these equilibria are not locally asymptotically stable and any marginal deviation from either *c* or *c'* out of the stable arm or the stable two-dimensional manifold places the system in a divergent path. Nevertheless, equilibria *c* and *c'* play the important role of dividing the feasible region into the basin of attraction associated to the existing stable equilibria.

4. Sensitivity and bifurcation analysis

As it has been shown, the model admits a wide variety of scenarios in terms of number and stability of equilibria. A sensitivity analysis is therefore necessary to determine how the dynamic behavior of the system depends upon the value of critical parameters of the model. Specifically, we focus on two parameters relevant for institutional design and policy implications. First, we focus our attention on bifurcations resulting from changes in abatement requirements by the ecolabel, a_l. Second, we consider changes in the size of the population of users of the natural CPR. In all cases we assume that the relation between $\hat{S}_{II}$ and $\hat{S}_{III}$ is such that, when they exist, *a* and *d* are stable unless otherwise stated. It turns out that bifurcation values of these parameters can be identified that imply dramatic changes in the characteristics of the set of equilibria (Gandolfo, 1996, pp. 469-502; Lorenz, 1989). All proofs are presented in the appendix.

Let us start by considering the consequences of variations in abatement levels required to join the ecolabel, a_l,[9] something that is displayed in figures 7 and 8, which represent the sloping plane of the prism defining the feasible region. As it is shown in figure 6, higher values of a_l shift $\hat{S}_{II}$ and $\hat{K}$ downwards. Given this, the following proposition can be stated

Proposition 4: If $C(a_l) = \rho(1, \hat{K})$, *d* is a non-hyperbolic equilibrium. The value of a_l that satisfies this expression is a transcritical bifurcation value.

The value of a_l of proposition 4 gives place to the solid lines of figure 6. This is a bifurcation value since marginal changes from this value imply dramatic changes in the equilibria. Thus, in figure 6 it is shown that for lower values of a_l, *d* is a stable equilibrium of the system, whereas for higher values of a_l, *d* becomes unstable and a new stable equilibrium , *a*, appears.

Insert figure 6 about here

Further, there exists a value of a_l that determines whether the ecolabel can be viable in the long run.

Proposition 5: Equilibrium *a* is non-hyperbolic if

$$\left(\frac{\partial\delta(s_{ng},K)}{\partial s_{ng}}-\frac{\partial\rho(s_l,K)}{\partial s_l}\right)+\frac{N\cdot a_l}{F'(K)}\left(\frac{\partial\delta(s_{ng},K)}{\partial K}+\frac{\partial\rho(s_l,K)}{\partial K}\right)=0$$

evaluated in that point. The value of a_l that satisfies this expression is a saddle-node bifurcation value.

The non-hiperbolic equilibrium is the tangency point of the solid lines in figure 7. Given the assumption that $\lim_{a_l\to 1} C(a_l)=\infty$, this point always exist if there is a value $a_l \in (0,1)$ such that *a* exists. At this non-hiperbolic equilibrium there is a null marginal effect on the difference of payoffs resulting from changes in the composition of the population between being ecolabel and non-green. The bifurcation is saddle-node (Gandolfo, 1996,pp.472-473) since, for lower values of a_l, there exist a stable (*a*) and an unstable (*b*) equilibria that collapse into the non-hiperbolic equilibrium as a_l is increased. For values of a_l larger than the bifurcation one, equilibria *a* and *b* no longer exist.

Insert figure 7 about here

These two bifurcation analyses coincide with the empirical literature to underline the importance of ecolabels' abatement and other costly requirements for the success of these initiatives. Thus, as it is commented in section 2, the literature stresses the sensitivity of participation with respect to membership fees. Moreover, it has been widely reported that a difficulty for the operation of some ecolabels is that too-stringent criteria are set (Buckley, 2002; Mihalic, 2000; WTO, 2002).. Our sensitivity analysis shows the possibility that lowering abatement criteria required for ecolabel membership may trigger environmental improvements if it creates the conditions for a stable equilibrium with ecolabel firms to exist.

Note that the location of the bifurcation values of a_l depend not only on the costs associated with ecolabel membership, but also on factors affecting the certification price function. This may be negatively affected by the over-launch of green certification programs in tourism, which is alleged to confuse costumers. There is a concern that the presence of a wide array of ecolabels and the different information released by such schemes would prevent visitors from making objective judgments regarding the legitimacy of firms' environmental responsibility claims, lowering the value of all initiatives (Mihalic, 2000;

[9] This analysis can be applied to changes in any determinants of the firm's costs resulting from ecolabel participation, such us, for instance, administrative fees.

Sasidharan et al., 2002). This way the abatement requirements to guarantee the existence of a stable equilibrium with ecolabel firms would be lower, reducing the effectiveness of the program in terms of environmental improvements.

Insert figure 8 about here

Another parameter of the game that has profound implications in the configuration of equilibria is the size of the population of firms that make use of the CPR. Increases in *n* shift $\hat{K}(\cdot)$ downwards and $\breve{K}(\cdot)$ upwards, whereas $\hat{S}_I$ remains unaffected. The result is that the degree of implementation of voluntary initiatives is affected by the size of the population.

As represented in figure 8, it is possible that starting from an initial situation where the long-term population configuration can contain a positive proportion of ecolabel firms (a_{n1}), increases in the population erode the economic incentives to be a member of the ecolabel. Then, uncertified initiatives are the only green option that can survive in the long run (f_{n2}). If the population of firms increases further, it can be the case that any incentive to be green is undermined and no firm in the population develops voluntary environmental initiatives (h_{n3}). Given an all-non-green population composition, it is obvious that further increases in the population will eventually lead to the exhaustion of the resource (as is the case for n_4 in figure 8)[10].

Irrespective of the other factors that affect the incentives to undertake voluntary initiatives, an unlimited increase in the number of users leads to the exhaustion of the CPR. This result has important policy implications and helps to outline the limits of voluntary environmental initiatives as a tool for CPR management. It turns out that, when there is no limit to the number of the CPR's users, voluntary environmental initiatives can not survive unless public policy tools are used to limit the growth in the number of users. Therefore, even if sustainable management of a CPR can be supported by voluntary environmental initiatives, pure *laissez faire* may not be a sustainable option since it can undermine those incentives.

5. Conclusion

This paper analyzes the economic incentives of tourism firms which profits are affected by the state of natural capital, to undertake voluntary environmental initiatives when presented with two kind of environmental strategies, namely uncertified and certified (ecolabel) initiatives. We develop an evolutionary game-theoretical model of a population of tourism

[10] Associated to each of these changes there is a bifurcation value of *n*. For brevity we skip the formal analysis of these bifurcations.

firms making use of a natural CPR whose level is endogenous. The literature on voluntary action has compared one type of voluntary initiative with the no voluntary abatement option, but to the best of our knowledge, no study has simultaneously analyzed different voluntary initiatives with endogenous natural capital.

We show that individual voluntary initiatives can emerge even without the existence of informal rewards or punishment, as opposed to previous results in the related literature (Osés and Viladrich, 2007; Sethi and Somanathan, 1996). In our model, incentives to follow environmentally-friendly strategies depend on profit-seeking motivations raised by demand effects. As in Osés and Viladrich (2007), and opposite to Sethi and Somanathan (1996), heterogeneous populations composed of firms following the uncertified initiative and non-green users of CPRs can exist in the long run. For this to occur, it is necessary that for a positive proportion of uncertified green firms, premiums from green differentiation equal abatement costs of required abatement in the uncertified initiative. The proportion of uncertified green firms in the long run further depends on the steady-state level of natural capital: the higher the natural capital, the larger the green niche the industry can develop. Thus, like Osés and Viladrich (2007) our model reproduces real-world situations, where heterogeneity of agents is obvious to empirical researchers (Ostrom et al., 1999) and contributes to the theoretical work to explain these realities.

The population of firms can also evolve towards a second heterogeneous composition with ecolabel and non-green firms. When the ecolabel prospers, uncertified green firms tend to disappear. Equilibria with the three strategies can exist but just as a knife edge case of conditional stability. It is noteworthy that when an ecolabel prospers, the proportion of non-green firms is lower and the steady-state natural capital of the CPR is higher than that resulting from equilibrium populations with firms following the uncertified initiative. This result would suggest that settings where ecolables and uncertified initiatives coexist in a region, as is the case in Tropical North Queensland (Huybers and Bennett, 2002), constitute a point in the dynamic of the system and that eventually one of the two strategies will collapse.

Further, we also show the possibility of stable equilibria where the ecolabel is generally adopted. This would be consistent with evidence in the manufacturing literature where standards of ecolabels lose their connotations of a label and are perceived as a requirement by consumers (Buckley, 2002). However, given the novelty of ecolabeling in tourism, it is too soon to say whether this kind of equilibria is empirically relevant in the tourism context. Contrary to ecolabels, we show that individual voluntary initiatives based on differentiation for green niches can not extend to the whole population based purely on profit-seeking motivations by firms.

Naturally, the model can also reproduce situations where incentives for voluntary environmental initiatives are too low to prosper. This would be the result of too low demand effects, steady-state level of the CPR not high enough or too high costs associated to voluntary environmental initiatives. An example of an ecolabel that have lacked momentum to survive in the long run is the Environmental Seal program created by the Brandenburg (Germany) tourism association (Hamele, 2002). In our model, an ecolabel can decay and eventually disappear when there is no stable equilibrium with positive ecolabel membership or when, even if this equilibrium exists, initial membership is out of its basin of attraction.

Among the different determinants of the existence of voluntary environmental initiatives that interplay in the model, we explore the role of the costs of ecolabel membership and the population size. Consistently with the empirical literature, we show that the former plays a key role for the success of the ecolabel. Moreover, we find some critical bifurcation values around which marginal changes in those costs imply dramatic changes in the equilibrium configuration. This result should be seriously considered by promoting institutions of ecolabels. Creating a successful certification program requires a careful case-by-case consideration of the parameter values in the particular region of application. Exporting the institutional form of an ecolabel successful elsewhere does not guarantee at all the long-run viability of the initiative in a different region.

As to the population size, we find the important result that no incentive to undertake voluntary environmental initiatives can survive to an unlimited growth in the number of the CPR's users, not due to coordination problems but to dissipation of economic incentives. Therefore, despite being voluntary, environmental initiatives may need public intervention to yield the positive effects on the sustainability of the CPR management.

There are several natural extensions that can be developed from the model presented in this chapter. First, we could endogenously model demand for green attributes by tourism markets, following the industrial economics literature. Second, we could consider other evolutionary dynamic tools in addition to the replicator dynamics and check for the sensitivity of results to this method. Third, we could introduce a network of social interaction to the system to be considered jointly with the diffusion mechanism of strategies. This could determine that interactions do not occur globally in the population, but that there are criteria of preferable interaction (e.g., with close neighbors).

6. References

Agrawal, A., 2001. Common property institutions and sustainable governance of resources. World Development, 29: 1649-1672.
Alberini, A., and Segerson, K., 2002. Assessing voluntary programs to improve environmental quality. Environ. Resour. Econ., 22: 157-184.
Amacher, G., Koskela, E., and Ollikainen, M., 2004. Environmental quality competition and eco-labeling. J. Environ.Econ.Manag., 47: 284-306.
Anton, W., Deltas, G., and Khanna, M., 2004. Incentives for environmental self-regulation and implications for environmental performance. J. Environ.Econ.Manag., 48: 632-654.
Arora, S., and Gangopadhyay, S., 1995. Toward a theoretical model of voluntary overcompliance. J. Econ. Behav. Organ., 28: 289-309.
Ayuso, S., 2006. Adoption of voluntary environmental tools for sustainable tourism: Analysing the experience of Spanish hotels. Corporate Social Responsibility and Environmental Management, 13: 207-220.
Ayuso, S., 2007. Comparing voluntary policy instruments for sustainable tourism: The experience of the Spanish hotel sector. Journal of Sustainable Tourism, 15: 144-159.
Blanco, E., Lozano, J., and Rey-Maquieira, J., 2009. A dynamic approach to voluntary environmental contributions in tourism. Ecol. Econ., 69: 104114.
Buckley, R., 1992. New United States Federal Trade Commission Guidelines for Ecolabelling and Green Advertising. Environmental and Planning Law Journal, 9: 479.
Buckley, R., 1996. Sustainable tourism: Technical issues and information needs. Ann. Tourism Res., 23: 925-928.
Buckley, R., 2002. Tourism ecolabels. Ann. Tourism Res., 29: 183-208.
Candela, G., and Cellini, R., 2006. Investment in tourism market: a dynamic model of differentiated oligopoly. Environ. Resour. Econ., 35: 41-58.
Carmona-Moreno, E., Céspedes-Lorente, J., and de Burgos-Jimenez, J., 2004. Environmental strategies in Spanish Hotels: Contextual factors and performance. The Service Industries Journal, 24: 101-130.
Claver-Cortés, E., Molina-Azoín, J. F., Pereira-Moliner, J., and López-Gamero, M. D., 2007. Environmental strategies and their impact on hotel performance. Journal of Sustainable Tourism, 15: 663-679.
Davis, J. J., 1991. A blueprint for green marketing. Journal of Business Strategy, 12(4): 14-17.
EEA (Editors), 2007. Europe's environment: The fourth assessment. European Environment Agency, Copenhagen.
Font, X., 2002. Environmental certification in tourism and hospitality: progress, process and prospects. Tourism Manage., 23: 197-205.
Foster, T. S. J., Sampson, S. E., and Dunn, S. C., 2000. The impact of customer contact on environmental initiatives for service firms. Int. J. Oper. Prod. Man., 20: 197-203.
Friedman, D., 1991. Evolutionary games in economics. Econometrica, 59: 637-666.
Gandolfo, G. (Editors), 1996. Economic dynamics. Springer-Verlag, Berlin.
Garcia, C., and Servera, J., 2003. Impacts of tourism development on water demand and beach degradation on the island of Mallorca (Spain). Geogr Ann A, 85: 287-300.
Glachant, M., 2007. Non-binding voluntary agreements. J. Environ.Econ.Manag., 54: 32-48.
Gómez, C. M., Lozano, J., and Rey-Maquieira, J., 2008. Environmental policy and long-term welfare in a tourism economy. Span. Econ. Rev., 10: 41-62.
Grove, S. J., Fisk, R. P., Pickett, G. M., and Kangun, N., 1996. Going green in the service sector: Social responsibility issues, implications and implementation. European Journal of Marketing, 30(5): 56-66.

Hamele, H., 2002. Eco-labels for tourism in Europe: Moving the market towards more sustainable practices. In: M. Honey (Editors), Ecotourism & certification: Setting standards in practice. Island Press, Washington).
Hawkins, J. P., and Roberts, C. M., 1994. The Growth of Coastal Tourism in the Red Sea: Present and Future Effects on Coral Reefs. Ambio, 23: 503-508.
Healy, R., 1994. The "common pool" problem in tourism landscapes. Ann. Tourism Res., 21: 596-611.
Hillery, M., Nancarrow, B., Griffin, G., and Syme, G., 2001. Tourism perception of environmental impact. Ann. Tourism Res., 28: 853-867.
Huybers, T., and Bennett, F. (Editors), 2002. Environmental management and the competitiveness of nature-based tourism destinations. Edward Elgar Publishing, Cheltenham.
Huybers, T., and Bennett, F., 2003. Environmental management and the competitiveness of nature-based tourism destinations. Environ. Resour. Econ., 24: 213-233.
Ibanez, L., and Grolleau, G., 2008. Can ecolabelling schemes preserve the environment? Environ. Resour. Econ., 40: 233-249.
Imperial, M., 1999. Institutional analysis and ecosystem-based management: The institutional analysis and development framework. Environ. Manage., 24: 449-465.
Kassinis, G. I., and Soteriou, A. C., 2003. Greening the service profit chain: The impact of environmental management practices. Production and Operations Management, 12: 386-402.
Khanna, M., 2001. Non-mandatory approaches to environmental protection. J. Econ. Surv., 15: 291-324.
Lorenz, H.-W., 1989. Bifurcation theory in dynamical economics. In: M. Beckmann & W. Krelle (Editors), Lecture notes in economics and mathematical systems. Springer-Verlag, Berlin, pp. 64-99).
Mailath, G., 1998. Do people play Nash equilibrium? Lessons from evolutionary game theory. J. Econ. Lit., XXXVI(September): 1347-1374.
McGinnis, M. (Editors), 2000. Polycentric games and institutions: readings from the Workshop in Political Theory and Policy Analysis. University of Michigan Press, Ann Arbor.
Mihalic, T., 2000. Environmental management of a tourist destination. A factor of tourism competitiveness. Tourism Manage., 21: 65-78.
Noally, J., Van der Berg, J. C., and Withagen, C. A., 2003. Evolution of harvesting strategies: replicator and resource dynamics. J. Evol. Econ., 13: 183-200.
Osés, N., and Viladrich, M., 2007. On the sustainability of common property resources. J. Environ.Econ.Manag., 53: 393-410.
Ostrom, E. (Editors), 1990. Governing the commons: The evolution of institutions for collective action. Cambridge University Press, New York.
Ostrom, E., Burger, J., Field, C., Norgaard, R., and Policansky, D., 1999. Revisiting the commons: local lessons, global challenges. Science, 284: 278-282.
Rivera, J., 2002. Assessing a voluntary environmental initiative in the developing world: The Costa Rican Certification for Sustainable Tourism. Policy Sci., 35: 333-360.
Safryńska, K., and Van der Berg, J. C., 2009. Evolutionary models in economics: of methods and building blocks. J. Evol. Econ., DOI 10.1007/s00191-009-0153-9.
Sasidharan, V., Sirakaya, E., and Kerstetter, D., 2002. Developing countries and tourism ecolabels. Tourism Manage., 23: 161-174.
Sedjo, R., and Swallow, S., 2002. Voluntary eco-labeling and the price premium. Land Econ., 78: 272-284.
Segerson, K., and Miceli, T. J., 1998. Voluntary environmental agreements: Good or bad news for environmental protection? J. Environ.Econ.Manag., 36: 109-130.

Sethi, R., and Somanathan, E., 1996. The evolution of social norms in common property resource use. American Economic Review*,* 86: 766-788.
Sirakaya, E., and Uysal, M., 1997. Can sanctions and rewards explain conformance behavior of tour operators with ecotourism guidelines? Journal of Sustainable Tourism*,* 5: 322-332.
UNEP (Editors), 1998. Ecolabels in the tourism industry. United Nations Environment Programme, Paris.
Van der Berg, J. C., 2007. Evolutionary thinking in environmental economics. J. Evol. Econ.*,* 17: 521-549.
WTO (Editors), 2002. Voluntary initiatives for sustainable tourism: Worldwide inventory and comparative analysis of 104 eco-labels, awards and self-commitments. WTO, Madrid, Spain.
WTO (Editors), 2009. Tourism highlights 2009 edition. World Tourism Organization, Madrid.

Appendix: Proofs of propositions

The characteristic equation of the Jacobian of a three-dimensional system is:

$$x^3 - c_1x^2 + c_2x - c_3 = 0$$

where: c_1=TraceJ; c_2=sum of all second-order principal minors of *J;* $c_3=|J|$

According to Descartes' theorem, the number of positive roots of the characteristic equation cannot exceed the number of changes in the sign of the coefficients, whereas the number of positive roots cannot be greater than the number of continuations in the signs of the coefficients (Gandolfo, 1996, p.54). This implies, on the one hand, that there are three negative roots if and only if *traceJ*<0, c_2>0 and $|J|$<0. In this case the steady state is stable. On the other hand, there are three positive roots if and only if *traceJ*>0, c_2>0 and $|J|$>0. In this second case the steady state is unstable. The other possibilities give involve a combination of positive and negative roots that result in a conditionally stable equilibrium, that is, there is a stable manifold or stable arm associated with that equilibrium.

When natural capital is endogenous, the system is defined by expressions 4 and 5. Linearization results in a system whose Jacobian is:

$$J = \begin{pmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{pmatrix}$$

where $J_{11} = F'(K)$; $J_{12} = -N \cdot a_g$; $J_{13} = N(a_l - a_c)$

$J_{21} = -s_{ng}(1-s_{ng})\sigma - s_{ng}s_l\theta$; $J_{22} = -(1-s_{ng})\alpha - s_l\beta + s_{ng}\alpha - s_{ng}(1-s_{ng})\lambda$; $J_{23} = -s_{ng}\beta - s_{ng}s_l\varepsilon$

$J_{31} = s_l(1-s_l)\theta + s_ls_{ng}\sigma$; $J_{32} = s_l\alpha + s_ls_{ng}\lambda$; $J_{33} = (1-s_l)\beta + s_{ng}\alpha - s_l\beta + s_l(1-s_l)\varepsilon$

and where we have defined $\alpha = \delta(s_{ng}, K) - C(a_c)$; $\lambda = \dfrac{\partial \delta(\cdot)}{\partial s_{ng}}$;

$\beta = \rho(s_l, K) - [C(a_l) - C(a_c)]$; $\varepsilon = \dfrac{\partial \rho(\cdot)}{\partial s_l}$; $\Omega = \delta(s_{ng}, K) + \rho(s_l, K) - C(a_l)$; $\sigma = \dfrac{\partial \delta(\cdot)}{\partial K}$;

$\theta = \dfrac{\partial \rho}{\partial K}$

where K, s_l and s_{ng} take different values depending on the specific steady state we consider.

Proof of proposition 1

Homogeneous all-ecolabel equilibrium (s_l=1):

$|J| = F'(K)\beta\Omega$; $\text{trace}J = F'(K) - \beta - \Omega$; $c_2 = -F'(K)\Omega - F'(K)\beta + \beta\Omega$

The determinant and trace are negative and c_2 positive if and only if $F'(K)<0$, $\beta>0$, and $\Omega>0$. This is guaranteed by $F'(K)<0$ and $\rho(1,K)>C(a_l)$. For any other combination, either the determinant is positive, or a positive c_2 and a negative trace cannot coexist.

Homogeneous all-uncertified green equilibrium (s_l=0; s_{ng}=0):

$|J| = -F'(K)\alpha\beta$; $\text{trace}J = F'(K) + \beta - \alpha$; $c_2 = F'(K)\beta - F'(K)\alpha - \beta\alpha$

This equilibrium could be stable if $F'(K)<0$, $\alpha>0$, and $\beta<0$. For any other combination, either the determinant is positive, or a positive c_2 and a negative trace cannot coexist. However, it is impossible that $\alpha>0$ for s_{ng}=0, given that we have assumed $C(a_c)\geq 0$. Thus, homogeneous all-uncertified green equilibria are always unstable.

Homogeneous all-non-green equilibrium (s_{ng}=1):

$|J| = F'(K)\alpha\Omega$; $\text{trace}J = F'(K) + \alpha + \Omega$; $c_2 = F'(K)\Omega + F'(K)\alpha + \alpha\Omega$

The determinant and trace are negative and c_2 positive if and only if $F'(K)<0$, $\alpha<0$, and $\Omega<0$ in the steady state. For any other combination, either the determinant is positive, or a positive c_2 and a negative trace cannot coexist.

Proof of proposition 2

Here we analyze the stability of heterogeneous equilibria where only two strategies exist.

Heterogeneous equilibria composed of non-green and uncertified green firms:

$|J| = -s_{ng}(1 - s_{ng})\beta[F'(K)\lambda + N \cdot a_c \sigma]$; $\text{trace}J = F'(K) - s_{ng}(1 - s_{ng})\lambda + \beta$;

$c_2 = \dfrac{|J|}{\beta} + \beta[F'(K) - s_{ng}(1 - s_{ng})\lambda]$

Let us assume that $\beta>0$. On the one hand, if $F'(K)<0$ then it is impossible for the determinant to be negative and for c_2 to be positive simultaneously, which is a condition for the equilibrium to be stable. On the other hand, if $F'(K)>0$ then the determinant is negative. Therefore, a necessary condition for c_2 to be positive is that $F'(K)>s_{ng}(1-s_{ng})\lambda$. However, this condition prevents the trace to be negative. Therefore, the equilibrium cannot be stable.

Now, suppose that $\beta<0$. Given this, if $F'(K)>0$, then the determinant is positive, which is incompatible with stability. If $F'(K)<0$, the trace is negative, and a necessary and sufficient condition for the determinant to be negative is $\lambda + \frac{N \cdot a_c}{F'(K)}\sigma > 0$, which is also sufficient for c_2 to be positive. Therefore, the steady state is stable if and only if $\beta<0$, $F'(K)<0$ and $\lambda + \frac{N \cdot a_c}{F'(K)}\sigma > 0$.

Heterogeneous equilibria composed of uncertified green and ecolabel firms:

$$|J| = s_l(1-s_l)\alpha[-F'(K)\varepsilon + N(a_l - a_c)\theta];\ \text{trace}J = F'(K) + s_l(1-s_l)\varepsilon - \alpha;$$

$$c_2 = -s_l(1-s_l)[\theta N(a_l - a_c) - \varepsilon F'(K)] - \alpha[F'(K) - s_l(1-s_l)\varepsilon]$$

The assumption $C(a_c)\geq 0$ implies that, in this equilibrium, necessarily $\alpha\leq 0$. Given this, $F'(K)<0$ implies a positive trace, and $F'(K)>0$ implies that a negative trace and positive c_2 cannot coexist. Thus, this equilibrium is always unstable.

Heterogeneous equilibria composed of ecolabel and non-green firms:

$$|J| = -s_l(1-s_l)\alpha[F'(K)(\lambda - \varepsilon) + N \cdot a_l(\sigma + \theta)];\ \text{trace}J = F'(K) + \alpha + s_l(1-s_l)(\varepsilon - \lambda);$$

$$c_2 = \alpha[F'(K) - s_l(1-s_l)(\lambda - \varepsilon)] - s_l(1-s_l)[F'(K)(\lambda - \varepsilon) + N \cdot a_l(\sigma + \theta)]$$

Given these expressions, the equilibrium is stable if and only if $F'(K)<0$, $\alpha<0$, $\varepsilon<\lambda$, and $(\lambda - \varepsilon) + \frac{N \cdot a_l}{F'(K)}(\sigma + \theta) > 0$. Nevertheless, the first and fourth conditions jointly imply the third condition. For other situations, either the determinant is positive, the trace is positive, a positive c_2 and negative determinant cannot coexist, or, finally, a positive c_2 and negative trace cannot coexist.

Proof of proposition 3

Heterogeneous equilibria where the population is composed of ecolabel, uncertified green and non-green firms (s_{ng}, s_l), for $(s_{ng} + s_l) \in (0,1)$:

$$|J| = s_{ng}s_l(1-s_{ng}-s_l)\left[-F'(K)\lambda\varepsilon + N(a_l-a_c)\lambda\theta - N\cdot a_g\sigma\varepsilon\right];$$

$$\text{trace}J = F'(K) - s_{ng}(1-s_{ng})\lambda + s_l(1-s_l)\varepsilon\,;$$

$$c_2 = F'(K)[-s_{ng}(1-s_{ng})\lambda + s_l(1-s_l)\varepsilon] - \lambda\varepsilon s_{ng}s_l(1-s_{ng}-s_l) -$$
$$- N(a_l-a_c)[s_l(1-s_l)\theta + s_l s_{ng}\sigma] - N\cdot a_c[s_{ng}(1-s_{ng})\sigma + s_{ng}s_l\theta]$$

If $F'(K)>0$, it is necessary that $s_l(1-s_l)\varepsilon - s_{ng}(1-s_{ng})\lambda < 0$ for the trace to be negative, but this determines that c_2 is negative. Therefore, there cannot be three positive roots and *c'* is not stable. If $F'(K)<0$, it is necessary that $F'(K)\lambda + Na_c\sigma > 0$ for the determinant to be negative. This is not compatible with c_2 being positive. Thus, there cannot be three positive roots and *c* cannot be stable.

If $F'(K)>0$, it is necessary that $F'(K)\varepsilon - N(a_l - a_c)\theta < 0$ for the determinant to be positive, and this implies a negative c_2. Thus, there cannot be three negative roots and *c'* cannot be unstable. If $F'(K)<0$, it is necessary that $s_l(1-s_l)\varepsilon - s_{ng}(1-s_{ng})\lambda > 0$ for the trace to be positive. This determines that c_2 is necessarily negative. Therefore, there cannot be three negative roots and *c* cannot be unstable.

Thus, the roots of the characteristic equation are always a combination of positive and negative values. This steady state is, consequently, conditionally stable.

Proof of proposition 4

Since the determinant of the homogeneous all-ecolabel equilibrium *d* is $|J|_d = F'(K)\beta\Omega$, this is equal to zero when $\Omega = 0$ evaluated in that point, that is to say, when $\delta(0,\hat{K}) + \rho(1,\hat{K}) = C(a_l)$, or equivalently, $\rho(1,\hat{K}) = C(a_l)$.

Proof of proposition 5

The determinant of a heterogeneous equilibrium composed of ecolabel and non-green firms, $|J|_a = -s_l(1-s_l)\alpha\left[F'(K)(\lambda-\varepsilon) + N\cdot a_l(\sigma+\theta)\right]$, is equal to zero when $F'(K)(\lambda-\varepsilon) + N\cdot a_l(\sigma+\theta) = 0$, or $(\lambda-\varepsilon) + \frac{N\cdot a_l}{F'(K)}(\sigma+\theta) = 0$, evaluated at that point.

Figures

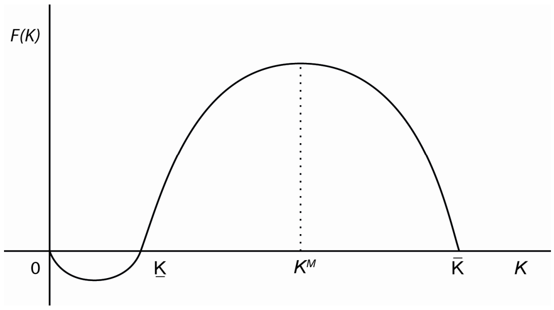

Fig. 1. Replenishment function of the CPR.

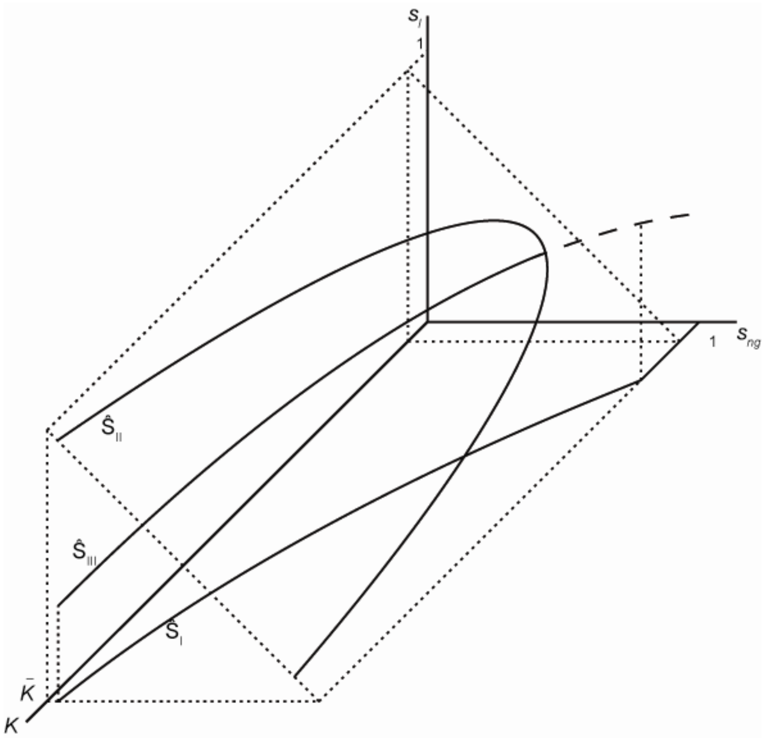

Fig. 2. Feasible region and isoclines of the population.

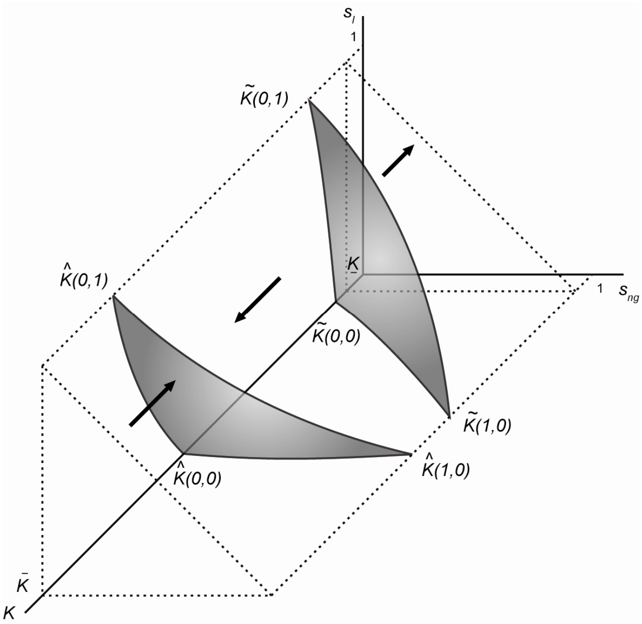

Fig. 3. Isoclines of the CPR.

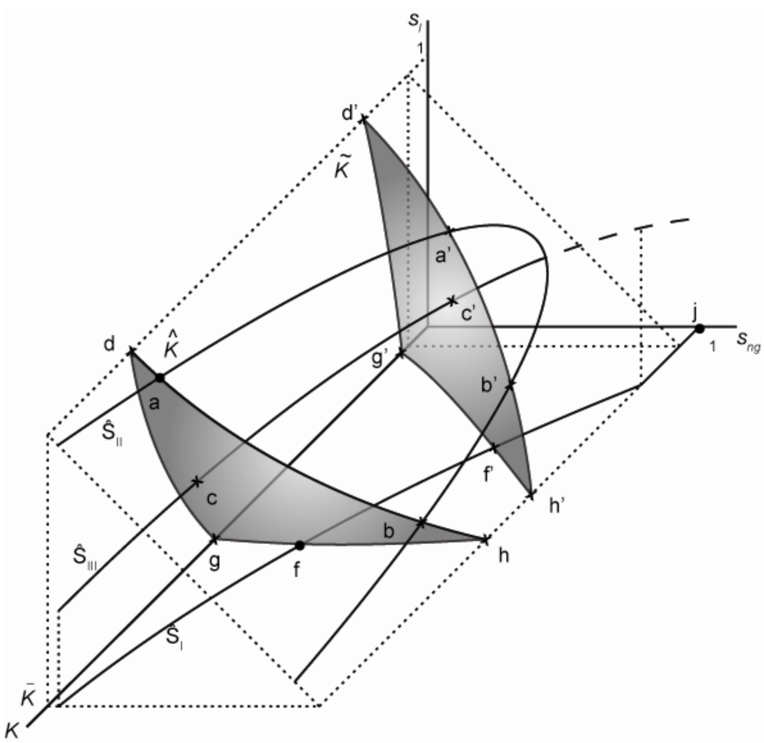

Fig. 4. Equilibrium configuration of the combined system: a case where all possible equilibria exist..

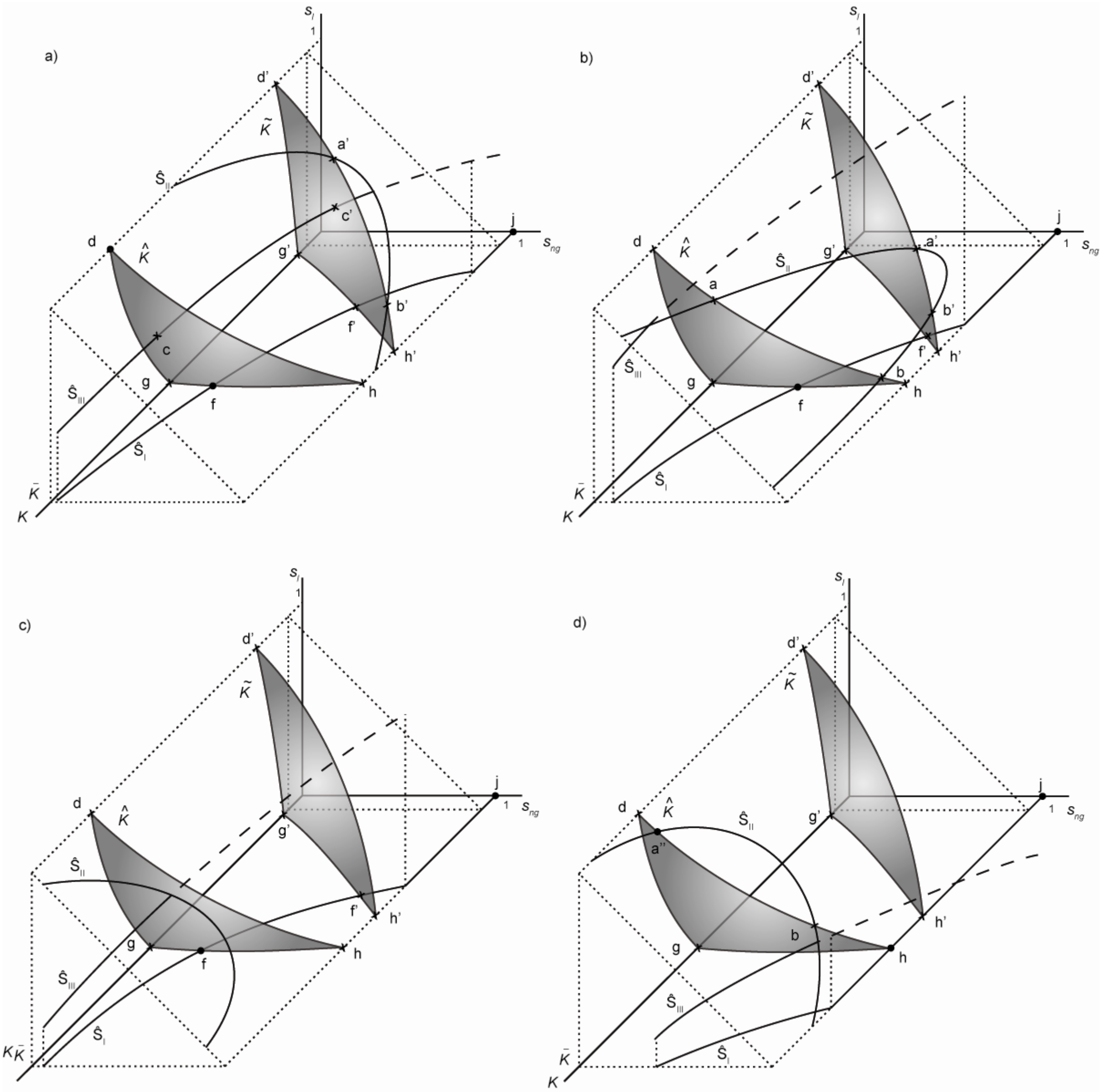

Fig. 5. Other equilibrium configurations of the combined system.

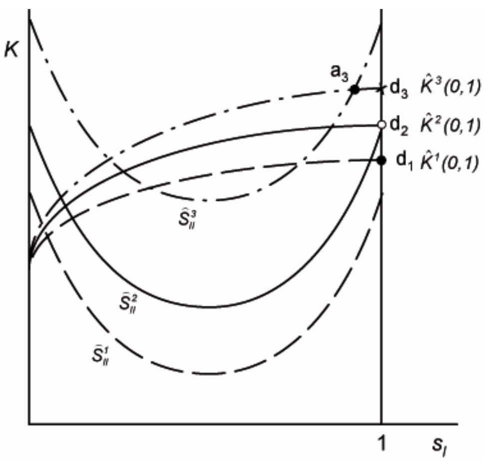

Fig. 6. Sensitivity analysis to a_l. Bifurcation in equilibrium *d*.

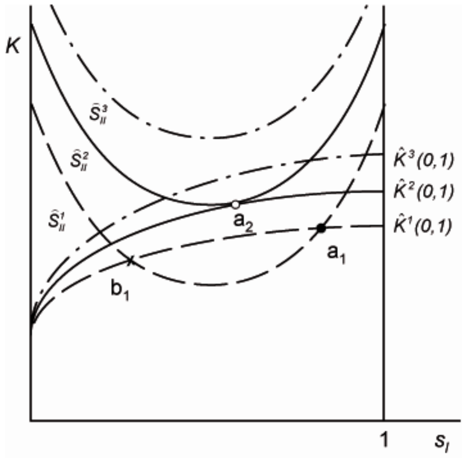

Fig. 7. Sensitivity analysis to a_I. Bifurcation in equilibrium a.

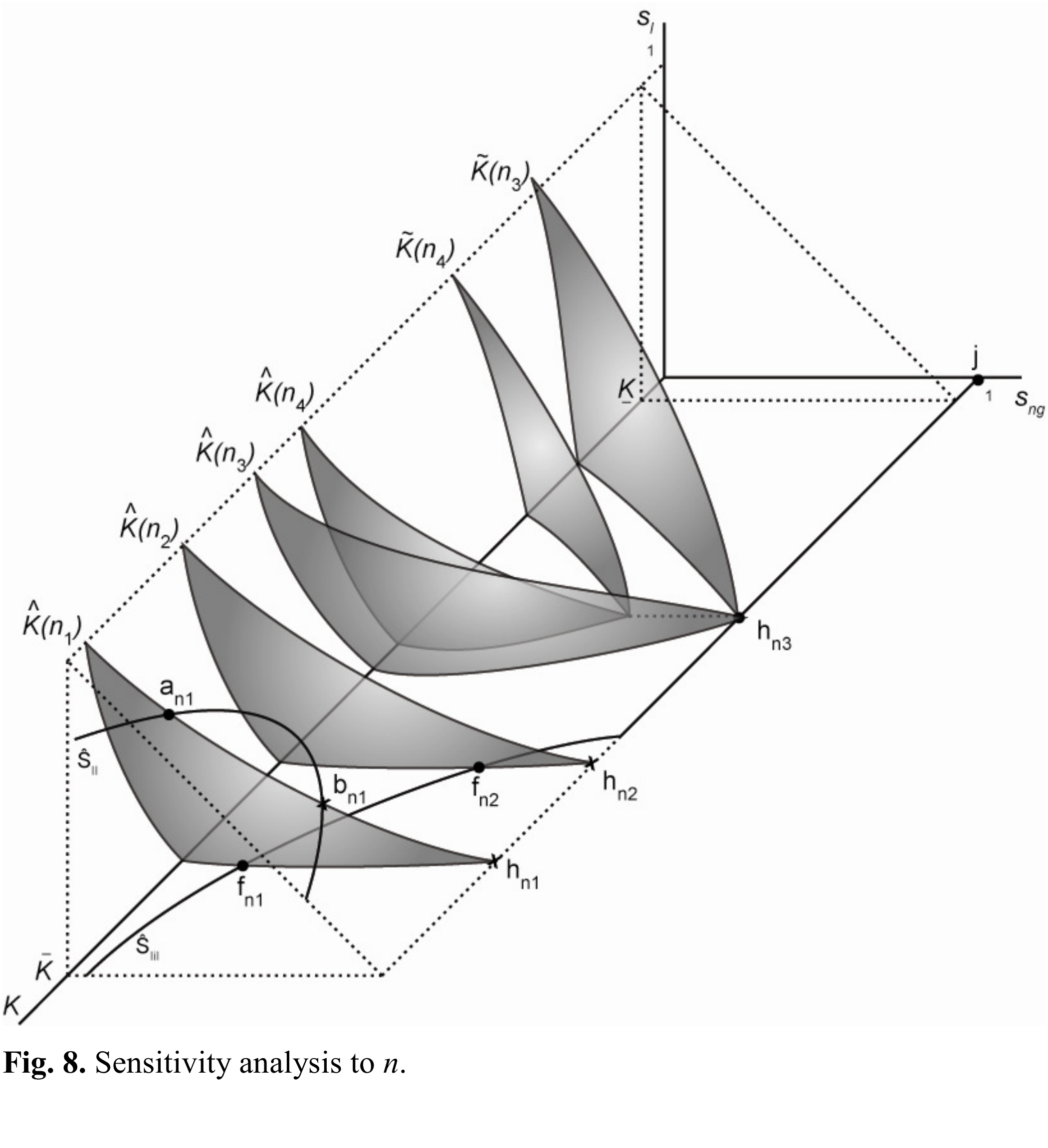

Fig. 8. Sensitivity analysis to n.