A dynamic approach to voluntary environmental contributions in tourism

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

[a, b, c] *Department of Applied Economics, University of the Balearic Islands, Ctra Valldemossa 07122*
Palma de Mallorca, Spain
* *corresponding author: Javier.lozano@uib.es, Tel. +34 971172786, Fax. +34 971172389*

Abstract

In an evolutionary game-theoretical model of tourism firms that use an endogenous natural Common Pool Resource (CPR) we show that stable equilibria with voluntary environmental initiatives may coexist with other equilibria where voluntary abatement is absent. The basins of attraction of the equilibria are identified and a bifurcation analysis is carried out producing two results with policy implications. First, there is a highly non-linear relationship between the cost of abatement required to be green and the share of green firms. Second, increases in the number of the CPR's users will ultimately dissipate the incentives to make abatement beyond regulation.

Keywords: Common-pool resource; Voluntary environmental contributions; Evolutionary framework; Sustainable management; Tourism

Abbreviations:

CPR: common-pool resource

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1. Introduction

Voluntary approaches are increasingly considered as relevant policy instruments to complement traditional command-and-control regulation (Segerson and Miceli, 1998; Khanna, 2001; Lyon and Maxwell, 2002; Sasidharan et al., 2002; Anton et al., 2004; Brau and Carraro, 2004; Delmas and Keller, 2005; Glachant, 2007; Dawson and Segerson, 2008). Voluntary environmental initiatives are defended as institutional changes in corporate culture towards self-regulation which incorporate environmental concerns in production decisions (Anton et al., 2004). Non-mandatory approaches to environmental protection include a diverse set of efforts that can be classified into three broad categories according to the degree of involvement of regulators or other third parties: unilateral commitments, negotiated agreements, and certified voluntary programs (Khanna, 2001; Delmas and Keller, 2005). Some examples are respectively, participation codes of environmental management (such as the Responsible Care program of the American Chemical Council), agreements between regulators and individual firms on environmental targets (such as the Project XL in the United States or the agreements under the Dutch National Environmental Policy Plan), and adoption of international certification standards for environmental management (such as the ISO 14001) (Anton et al., 2004; Dawson and Segerson, 2008). All these are considered voluntary initiatives since they have two basic characteristics: promoters of the initiatives are not obliged by law to launch the scheme, and target groups are not obliged to apply or join (WTO, 2002).

Given their non-mandatory nature, the economics literature generally holds the view that voluntary programs must generate short-term economic gains to promote compliance (Khanna, 2001; Alberini and Segerson, 2002; Dawson and Segerson, 2008). Consequently, it is suggested that voluntary programs connect private benefits to voluntary environmental action (Delmas and Keller, 2005). According to the literature, some motives behind a firm's decision to adopt a voluntary agreement are regulatory gains, demand effects, cost efficiency, and technical assistance (Arora and Gangopadhyay, 1995; Vidreras and Alberini, 2000; Khanna, 2001; Lyon and Maxwell, 2002; Amacher et al., 2004; Anton et al., 2004; Brau and Carraro, 2004; Vidovic and Khanna, 2007; Lyon and Maxwell, 2008; Portney, 2008).

Regulatory gains and demand effects have been the center of research attention in the past. The former suggests that firms may strategically adhere to a voluntary program to postpone or avoid the regulatory behavior of public agencies (Segerson and Miceli, 1998; Manzini and Mariotti, 2003; Glachant, 2007; Dawson and Segerson, 2008). The latter analyzes the market implications of product differentiation when consumers are concerned about environmental aspects of goods and services (Arora and Gangopadhyay, 1995; Moraga-González and Padrón-Fumero, 2002; Sedjo and Swallow, 2002; Amacher et al., 2004; Conrad, 2005; Ibanez and Grolleau, 2008).

In this paper, we build on some of the theoretical foundations of the latter to develop a model of voluntary environmental initiatives by tourism users of a natural common-pool resource (CPR), which are an increasingly relevant reality, according to empirical studies (UNEP, 1998; Mihalic, 2000; Buckley, 2002; Font, 2002; Sasidharan et al., 2002; WTO, 2002; Ayuso, 2006, 2007; Blanco et al., 2009). Tourism-related uses of natural resources are an increasingly relevant type of use of natural common-pool resources. Empirical evidence has shown that traditional recreational uses, such as visits to national parks, hunting and fishing, camping, backpacking and hiking have been declining in the US and Japan over the last 20 years (Pergams and Zaradic, 2008). On the other hand, nature-based tourism has turned out to be the fastest growing segment of the global tourism market (Sirakaya and Uysal, 1997; Huybers and Bennett, 2003).

Despite this relevancy, limited efforts have been made to bring attention to the benefits that could be gained by a broader and deeper voluntary commitment to the environment by service organizations (Davis, 1991; Grove et al., 1996; Foster et al., 2000). Given that the objective of voluntary initiatives is to complement regulatory frameworks (WTO, 2002), voluntary initiatives have to improve performance above legal compliance to achieve relevant improvements in the main problems of tourism (Buckley, 2002). This is particularly relevant since tourism is not very regulated by public authorities compared to other sectors (Ayuso, 2007).

We focus on one type of voluntary environmental initiative, namely unilateral commitments. We develop a model with two available strategies consisting on undertaking or not undertaking unilateral commitments. The model is presented for exogenous and endogenous levels of natural capital. 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.

To do so, we adopt evolutionary game theory to build our model. The origins of such an approach are in evolutionary biology, but the approach is increasingly being used in economic and social sciences (Nowak and Sigmund, 2004). Under evolutionary game theory, payoffs depend on players' actions and the actions of the co-players in the population. Strategies with high payoffs spread through learning, imitation, or other forms of cultural evolution (Friedman, 1991, 1998; Hofbauer and Sigmund, 2003). This shift in strategy has some inertia, which can be attributed to adjustment costs, information imperfections, or bounded rationality (Friedman, 1998). Furthermore, players do not systematically attempt to influence future play of others (Friedman, 1998), nor do they take into consideration the possibility that others adjust their behavior strategically (Mailath, 1998). One justification for this is the existence of a large number of players (Friedman, 1998; Mailath, 1998). This naïve behavior is one crucial difference between evolutionary games and repeated games in orthodox game theory (Friedman, 1998). A second major difference is that the focus of study of evolutionary game theory is the dynamic behavior of the system (Mailath, 1998), extending classical game theory away from the static doctrine of the Nash solution concept (Friedman, 1991; Hofbauer and Sigmund, 2003; Nowak and Sigmund, 2004)

The main advantage of using evolutionary game theory is that it enables the researcher to discriminate between different equilibria (Sethi and Somanathan, 1996; Mailath, 1998; Nowak and Sigmund, 2004). It is possible to distinguish stable from unstable equilibria and to identify the regions of initial conditions that eventually lead to a given equilibrium (i.e., basins of attraction) (Friedman, 1991, 1998). In addition, it is preferable in our analysis since it better considers the role of resources dynamics on the long run behavior of players (Tarui et al., 2008).

Evolutionary game theory has already been applied to analyze voluntary environmental behavior in non-tourism settings (Sethi and Somanathan, 1996; Osés and Viladrich, 2007). However, our paper is original in at least two general aspects. First, unlike these previous studies, voluntary environmental contributions hinge on market motivations. Second, although perfect information (Blanco et al., 2009) and Bayesian (Bimonte, 2008) non-cooperative game-theory models have already been used to analyze voluntary environmental contributions in tourism settings, this is, to our knowledge, the first attempt to apply evolutionary game theory for that purpose.

The rest of the paper is organized as follows. The next section presents some stylized facts for unilateral commitments in tourism. Section 3 develops the model. We first present the population dynamics, then the natural CPR dynamics, and finally the dynamics of the combined system. The model gives place to multiple equilibria consisting of heterogeneous population compositions, where voluntary initiatives coexists with dirtier firms, and homogeneous populations with only "dirty" firms. We end this section with a sensitivity analysis that allows drawing several policy implication. Section 4 concludes.

2. Unilateral commitments in tourism

We define unilateral commitments as those initiatives individually undertaken by firms that are not subject to external assessment of participants' behavior. This can include the internal development of firms' own environmental policies, adherence to codes of good practices, and other uncertified environmental practices. Some well known international unilateral commitments are the International Hotels Environment Initiative and the Tour Operators Initiative for Sustainable Tourism (WTO, 2002).

To model the environmental decisions of tourism firms regarding to unilateral commitments, we assume that consumers' individual decisions are based on utility-maximizing behavior and that part of the society includes in these decisions a trade-off between the environmental attributes of the good and other desired characteristics (Conrad, 2005). We further assume that consumer preference to purchase from green firms is well established and often revealed through increased willingness to pay for products viewed as "clean" (Sedjo and Swallow, 2002; Amacher et al., 2004). Empirical evidence supports this assumption in tourism, especially in nature-based destinations. Most conservative estimates show that up to 5 percent of the overall travel market would pay a premium for sustainable packages (Dodds and Joppe, 2005), and some regional results show that up to 52 percent of visitors would be prepared to pay an extra 10 percent for environmentally-friendly tourism products (PATA, 2007). In North Tropical Queensland, the lower boundary estimate for the willingness to pay by origin markets for an increase in the environmental quality from somewhat spoiled to unspoiled is more than US $480 for a fortnight's holiday (Huybers and Bennett, 2003).

We separately consider two price premiums which might result from this demand effect: a premium from green differentiation, and a premium from increased environmental quality of the common-pool resource.

First, we hold that firms that preserve the natural environment beyond the level that is legally mandated can obtain a premium from green differentiation (as supported by empirical evidence in Álvarez et al., 2001; Kassinis and Soteriou, 2003; Carmona-Moreno et al., 2004; Claver-Cortés et al., 2007). That is to say, firms can stand out among their competitors by following environmentally sensitive strategies to fill a green market niche (Alberini and Segerson, 2002). Environmental attributes of tourism services are partially observable by consumers (are not pure credence attributes), since there is a high interaction between production and consumption, which can have environmental management implications (Stoeckl, 2004; Ayuso, 2006). Marketing has been effective at taking advantage of this differentiation premium and moving the demand towards environmentally friendly firms (WTO, 2002).

Second, we consider the existence of a price premium resulting from increased environmental quality in the region. Hamilton (2006) and Rigall-i-Torrent and Flufià (2007) shows evidence that environmental attributes affect willingness to pay by visitors. The tourism literature considers environmental investments for improving environmental quality as non-excludable goods. Then, consistent with empirical evidence, environmentally-friendly strategies positively affect the profits of all firms (Huybers and Bennett, 2002). The strategic consequences of the existence of this premium in tourism have been previously analyzed, mostly in models of environmental competition between destinations (Calveras, 2003; Calveras and Vera-Hernández, 2005; Candela and Cellini, 2006; González et al., 2006; Calveras, 2007; Pintassilgo and Albino, 2007).

3. The unilateral commitment model

We consider a model where a fixed population of firms $N = \{1,...,n\}$, $n \geq 2$, make use of a common pool renewable natural resource for the recreational enjoyment of their customers. Some examples of what the resource might be are a lake, a piece of shoreline, diving areas, fresh and salt ponds, rivers, caves, forest land, wildlife areas and ski areas (Healy, 1994; Imperial, 1999). Recreational activities have a negative impact on the quality of the resource, but firms can undertake voluntary abatements of their environmental pressures beyond those required by regulation. To exercise this potential, tourism firms can voluntarily undertake either activities to reduce environmental pressures (as more efficient use of raw materials, reduction of pollution emissions, greener purchasing, etc.) or investments for improving the status of an already degraded environment (being some examples a hotel improving the quality of a beach next to it or a coral reef excursions company cleaning its diving area) (Mihalic, 2000)

Similar to Sethi and Somanathan (1996) and Osés and Viladrich (2007), we represent the abatement efforts of each firm $i \in N$ with a binary variable $a_i \in \{a_{ng}, a_g\}$, where a_g corresponds to firms voluntarily undertaking abatement efforts beyond compliance and a_{ng} to firms only complying with regulation ($a_g > a_{ng}$). We refer to agents choosing a_g as “green” firms, which have undertaken unilateral commitments, and to agents choosing a_{ng} as “non-green” firms. For simplicity in notation we normalize $a_{ng}=0$. The level of a_g is treated as exogenous and could result from the uncoordinated decision of symmetric green firms or be determined by a code of good practices developed by an industry association. The abatement profile of firms, $\vec{a} = (a_1, ..., a_n)$, determines the proportion of green firms s_g and that of non-green firms s_{ng} in the population, where $s_{ng}=1-s_g$.

Consistent with empirical evidence in the tourism literature firms’ payoffs differ depending on their environmental strategies (Álvarez et al., 2001; Kassinis and Soteriou, 2003; Carmona-Moreno et al., 2004; Claver-Cortés et al., 2007). Specifically, some empirical literature (Huybers and Bennett, 2002; Rivera, 2002; Kassinis and Soteriou, 2003; PATA, 2007) suggests that this difference can be motivated by a demand effect that generates a competitive/comparative advantage for firms that undertake voluntary environmental actions, and it is usually reflected in the capacity of green firms to charge higher prices. Following this evidence, as first presented in Blanco et al.(2009), we assume that the price at which player *i* sells its tourism product is equal to:

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

where *x* is a part of the price independent of environmental actions and $g(a_i) = \{0,1\}$ is a dummy variable equal to 1 for firms undertaking abatement efforts beyond of those legally required ($0<a_i<1$) and equal to 0 for non-green firms. Attributes defining $\delta(s_{ng},K)$ and $\gamma(K)$ are,

$$\delta(s_{ng}, K) = \begin{cases} z_i \geq 0 & if\ s_{ng} = 1 \\ 0 \leq \delta(\cdot) \leq z_i & if\ 0 < s_{ng} < 1 \\ 0 & if\ s_{ng} = 0 \end{cases}$$

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

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

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

These establish that when player *i* undertakes voluntary environmental actions, it is capable of charging a price premium $\delta(\cdot)$, thanks to its environmental differentiation. Differentiation is higher when the proportion of non-green firms (green firms) is higher (lower) in a region. Furthermore, the price premium $\delta(\cdot)$ only takes positive values for positive levels of natural capital in the region and is increasing with the environmental quality of the natural CPR of which firms make use. This positive relationship can be justified either by a higher concentration of more environmentally aware visitors in regions highly-endowed with natural resources or by tourists being more concerned for their environmental pressures in areas with high environmental quality.

In addition, we consider a second price premium $\gamma(\cdot)$ that positively depends on environmental quality and that is common to all firms regardless of their individual environmental behavior. This premium reflects both the non-excludable character of the resource, which is a property of common pool resources, and the fact that environmental amenities constitute a component of the tourism product in nature-based destinations. Some empirical evidence shows that tourists are ready to pay higher prices for higher levels of environmental quality at a tourism destination (Huybers and Bennett, 2003; Alegre and Cladera, 2006; Alegre and Juaneda, 2006).

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

$$\pi_i = q_i[x + \delta(s_{ng}, K) \cdot g(a_i) + \gamma(K)] - c(a_i) - co \qquad (2)$$

where q_i is the quantity produced by the i-th firm, which, for simplicity, is assumed to be 1; co are costs independent of environmental behavior and $c(a_i)$ is the cost of abatement activities. We assume $c(0)=0$, $c'(a_l)>0$, $\lim_{a_i \to 1} c(a_i) = \infty$. Thus, only green firms incur abatement costs.

For a given level of capital endowment, payoffs for firms following each strategy depend on the composition of the population. According to evolutionary game theory, payoff differentials exert evolutionary pressures on the population composition to evolve in favor of those groups earning the highest payoff. That is to say, firms respond to differences in payoffs by modifying their strategies. This behavioral pattern does not change instantaneously. This is modeled using the replicator dynamics, which is the simplest evolutionary dynamic one can use to investigate dynamic properties of evolutionary stable strategies (Sethi and Somanathan, 1996; Mailath, 1998):

$$\dot{s}_{ng} = s_{ng}\left(\pi_{ng} - \bar{\pi}\right) \tag{3}$$

where $\bar{\pi}$ is the average payoff in the population as a whole, $\bar{\pi} = s_{ng}\pi_{ng} + (1 - s_g)\pi_g$. Combining equations 2 and 3 the replicator dynamics can be specified as:

$$\dot{s}_{ng} = s_{ng}(1 - s_{ng})[c(a_g) - \delta(s_{ng}, K)] \tag{4}$$

Note that since all firms benefit from premiums from increased environmental quality, $\gamma(\cdot)$ does not influence the evolution of the composition of the population.

To model the renewable natural resource**,** we assume that environmental quality varies over time according to the following motion function:

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

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

We consider a differentiable replenishment function, $F(K)$, satisfying the usual assumptions for describing the dynamics of renewable resources, as represented in figure 1. There is a finite carrying capacity $\bar{K}$ of the resource and a minimum level of natural capital $\underline{K}$ $(0 < \underline{K} < \bar{K})$ so that $F(\bar{K}) = 0$ and $F(\underline{K}) = 0$. Between $\bar{K}$ and $\underline{K}$, the resource grows at a positive rate, and it grows at a negative rate otherwise. This describes the fact that the resource reaches a maximum size $\bar{K}$ and that below $\underline{K}$ replenishment via natural reproduction is impossible even in the absence of environmental damage. For stock levels between $\underline{K}$ and $\bar{K}$ $F''(K)>0$, with $F(K)$ reaching its maximum at K^M.

[insert figure 1]

Figure 1. Replenishment function of the natural CPR.

Regarding environmental damage, we attribute a uniform environmental damage d to each firm, which can be reduced by abatement efforts. Each firm's strategy selection determines its environmental damage, net of abatement, which is d for non-green firms, and $d(1\text{-}a_g)$ for green firms. Given our specifications, abatement is open to two different interpretations, either reduction in the environmental pressures (more efficient use of natural inputs or reductions in pollution emissions) or direct investments toward improving the quality of the natural resource. Total environmental damage is then $D(s_{ng}, s_g) = n{\cdot}d[s_{ng} + s_g(1 - a_g)]$ and after some transformations we end up with $D(s_{ng}) = n[1 - a_g(1 - s_{ng})]$, where d is normalized to one without loss of generality.

3.1. Population Dynamics

Let us now present the population dynamics when endowment of natural capital in the region is exogenous. Apart from the usefulness of this exercise for later sections, this case could be empirically relevant for those contexts where, due to scale properties, the activity of the model's population as a whole has no noticeable effect on the quality of the resource.

[insert figure 2]

Figure 2. Population dynamics of the unilateral commitment model.

With exogenous natural capital, the dynamics of the system is fully described by equation 4. It is easy to verify that there are three steady states: (i) no firms engage in voluntary environmental action, $s_{ng}=1$; (ii) all firms undertake voluntary abatements, $s_{ng}=0$; and (iii) firms are indifferent between being green or non-green, that is, when $\delta(s_{ng},K)=c(a_g)$.

Lemma 1: *For a given level of natural capital, a heterogeneous equilibrium of the population composed of non-green and green firms exists if there is a* $s_{ng} \in (0,1)$*, such that* $\delta(s_{ng},K)=c(a_g)$*. Given that this equilibrium exists it is always asymptotically locally stable. A stable homogeneous all-non-green firms equilibrium exists when* $\delta(1,K) < c(a_g)$*. Any homogeneous all-green equilibrium is unstable.*

In figure 2.b, $\widehat{S}_I$ (for which $\dot{s}_{ng} = 0$) represents the steady state levels of s_{ng} for different levels of K. Given the properties of $\delta(\cdot)$this curve shows asymptotic convergence to the vertical axis. As it is shown, there is a level of environmental capital K^{MIN} below which price premiums for green differentiation are lower than extra abatement costs for any population composition, that is, $\delta(1,K^{MIN})=c(a_g)$. Then, below K^{MIN} (area A in figure 2.b), $\dot{s}_{ng} < 0$ and, therefore, only homogeneous equilibria with all-non-green populations can be stable.

For natural endowments above K^{MIN}, only heterogeneous equilibria are stable. In Area B in figure 2 the proportion of green firms is small enough to make being green profitable, and the dynamics imply a shift of the population toward an increase in this strategy (a fall in s_{ng}). However, when the proportion of green firms is high (area C in figure 1), premiums from green differentiation are too low to make this strategy profitable and convergence to the steady state implies a fall in the proportion of green firms (an increase in the proportion of non-green firms).

Some empirical evidence (Álvarez et al., 2001; Rivera, 2002; Kassinis and Soteriou, 2003; Claver-Cortés et al., 2007) shows that green firms obtain statistically significant better economic results than other firms at nature-based destinations. In the context of our model, the cases analyzed by this literature would be located in area B and therefore would reflect incomplete adjustment to the steady state.

3.2. Resource Dynamics

Let us now analyze the dynamics of the natural resource when the composition of the population is exogenous. According to equation 5, the condition for constant capital is $D(s_{ng})=F(K)$. This defines a relationship between the composition of the population and the stock of natural capital as shown in the forth quadrant of figure 3, where curves $\tilde{K}(s_{ng})$ and $\hat{K}(s_{ng})$ represent the isoclines of the resource ($\dot{K}=0$). This relationship is obtained using the steady state relationship between environmental damage and natural capital (first quadrant) and that between total damage and the composition of population (third quadrant), and it is drawn for the special case when the natural capital in the steady state is positive even in the more polluting scenario (that is, when $s_{ng}=1$).

When analyzing the dynamics of the resource for an exogenous s_{ng}, it has to be first noted that the replenishment function is defined such that there is a threshold, $\underline{K}$ below which the resource is doomed to exhaustion regardless of the environmental pressures (area A). Moreover, if natural capital reaches a level between $\underline{K}$ and $\tilde{K}(s_{ng})$, exhaustion is not inevitable but it is not possible to achieve levels of damage low enough to avoid exhaustion with only voluntary environmental behavior as defined in the model. When natural capital is between $\tilde{K}(0)$ and $\hat{K}(0)$, it is possible to avoid exhaustion through voluntary environmental behavior by at least a proportion of the firms. For levels of natural capital above $\hat{K}(0)$, disregarding the composition of the population, environmental damage is higher than the replenishment capacity of the resource, and thus K converges to the isocline $\hat{K}(s_{ng})$.

Lemma 2: *$\hat{K}(s_{ng})$ and $\tilde{K}(s_{ng})$ represent curves of equilibria of the resource dynamics. $\hat{K}(s_{ng})$ determines asymptotically locally stable equilibria, for which there is a negative relationship between environmental damage and steady state natural capital, while $\tilde{K}(s_{ng})$ represents unstable equilibria, characterized by a positive relationship between environmental damage and steady state natural capital.*

[insert figure 3]

Figure 3. Resource dynamics of the unilateral commitment model.

3.3. Dynamics of the combined system

In this section both natural capital and the composition of the population are endogenous, and, therefore, dynamics are determined by the system formed by equations 4 and 5. As usual, we first explore the steady states (s_{ng},K) of our dynamic system. It is shown that in this system, as in Osés and Viladrich (2007), and opposite to Sethi and Somanathan (1996), the resource dynamic play a key role in determining the population composition in the steady state.

Superimposing figure 2.b and the fourth quadrant of figure 3 yields figure 4, where different scenarios are represented in terms of the number and stability of the steady states. Existence and stability of different types of equilibria for the combined system are formalized in a series of propositions (proofs can be found in appendix A).

[insert figure 4]

Figure 4. Dynamics of the combined system of the unilateral commitment model.

Proposition 1: *Whenever there exists a value of* $s_{ng} \in (0,1)$ *such that the isocline of the population shares at least one point with any of the isoclines of the natural capital, a mixed equilibrium of the combined system exists. Given that a heterogeneous equilibrium exists, conditions for that equilibrium to be asymptotically locally stable are F'(K)<0 and*

$$\frac{\partial \delta(s_{ng}, K)}{\partial s_{ng}} + \frac{n \cdot a_g}{F'(K)} \frac{\partial \delta(s_{ng}, K)}{\partial K} > 0$$

Therefore, as in Osés and Viladrich (2007), and contrary to Sethi and Somanathan (1996), heterogeneous populations composed of green and non-green firms can exist in the long run. Figures 4.a-e represent scenarios where at least one heterogeneous equilibrium exists, whereas in figure 4.f no heterogeneous equilibrium exists. Stable (unstable) equilibria are represented by a solid dot (a cross). Condition *F'(K)<0* says that stable heterogeneous equilibriums must belong to the isocline $\hat{K}(s_{ng})$, whereas the second condition in proposition 1 implies that a marginal increase in the proportion of non-green firms has a negative effect on these firms' profits compared to the green firms' profits ($\partial(\pi_{ng} - \pi_g)/\partial s_{ng} < 0$). It also implies that $\hat{K}(s_{ng})$ must be flatter than the isocline of the population at the intersection point.

Whenever a stable heterogeneous equilibrium exists, areas A to D in figures 4.a-d represent the set of initial situations for which convergence towards the stable heterogeneous equilibrium is guaranteed, i.e., these areas belong to its basin of attraction. Area A describes values of the system for which the natural resource is abundant and the number of firms undertaking voluntary environmental abatement is small. Therefore, firms can charge high price premiums for green differentiation when undertaking voluntary environmental initiatives, *δ(·)*, which are higher than abatement costs to becoming green. As a result, the number of green firms increases. In addition, given that area A is above $\hat{K}(s_{ng})$, total damage exercised by users exceeds the replenishment capacity of the resource, $D(s_{ng})>F(K)$, and, consequently, the stock of natural capital diminishes. The initial scenarios in area B are similar to those in are A, but in B the stock of natural capital is lower, thus the replenishment capacity of the resource is higher and the resulting dynamic is an increasing stock of natural capital. In area C, as in B, environmental damage is below the replenishment capacity of the resource but, in this case, the combination of the stock of natural capital and the proportion of green firms in the population does not create sufficiently high price premiums for green differentiation. Thus, green firms have incentives to abandon their environmental efforts and become non-green. Area D presents an extreme situation in which both environmental quality and the proportion of green firms are very high. For values in area D, there are too many green firms in the system for green differentiation to be profitable, and hence the number of green firms diminishes. Further, the high stock of natural capital in D determines a small replenishment capacity of the resource which is actually smaller than damage derived from recreational uses. Therefore, environmental quality is reduced.

For initial values in areas *E* and *F*, the qualitative analysis does not allow us to unambiguously determine the equilibrium towards which trajectories converge. In any other areas, the system inevitably converges to a stable all-non-green equilibrium. Existence and stability of all-non-green homogeneous equilibria are presented in proposition 2.

Proposition 2: *The point* $(s_{ng},K)=(1,0)$ *is an asymptotically locally stable equilibrium with all-non-green firms. There exist homogeneous equilibria with all-non-green firms and positive natural capital whenever the isocline of the population shares one point with any of the isoclines of the natural capital for* $s_{ng}=1$*. Given that an homogeneous equilibrium with all non-green firms and positive natural capital exists, it is a necessary and sufficient condition for the equilibrium to be asymptotically locally stable that* $F'(K)<0$ *and* $\delta(1,K)<c(a_g)$*.*

This implies stronger conditions than in Osés and Viladrich (2007) where all-non-green equilibria are always stable except in the special case when $\widetilde{K}(1) = \hat{K}(1)$. In our case, for these equilibria to be stable it is necessary that the slope of the resource replenishment function is negative ($F'(K)<0$) and that a shift to the green option is not profitable even when the potential premium is the highest for a given level of capital ($\delta(1,K)<c(a_g)$).

Therefore, there are two relevant thresholds of natural capital, which affects the stability of equilibria for all-non-green populations. First, below $\underline{K}$, the natural capital is inevitably depleted regardless of the damage exercised by users. The existence of this threshold guarantees that (1,0) is always asymptotically locally stable. Areas H and J in figure 4 determine values of the system for which the system necessarily evolves towards the equilibrium (1,0). The second relevant threshold for stability is K^{MIN}. Recall that the value of natural capital K^{MIN} is the threshold above which users of the natural resource start to find it worth becoming green when starting from an all-non-green situation. It is necessary that $K^{MIN} > \hat{K}(1)$ for an asymptotically locally stable equilibrium with all-non-green firms and positive natural capital to exist. Figures 4.d to f represent situations in which these equilibria are stable. In these figures, areas L to O determine the areas of convergence to this equilibrium.

Lastly, opposite to Osés and Viladrich (2007) and as stated in lemma 1, all-green homogeneous equilibria are not stable. This is because $\widehat{S}_I$ approximates asymptotically to the vertical axis. This asymptotic behavior is independent of the dynamics of natural capital.

Proposition 3. *Endogenizing natural capital does not change the stability conditions for all-green equilibria. These are always unstable.*

In sum, in the combined system, there always exists an asymptotically locally stable all-non-green equilibrium in which the resource is depleted, (1,0). In addition to this equilibrium: (i) an asymptotically locally stable all-non-green homogeneous equilibrium can exist when $\hat{K}(1) < K^{MIN,}$ for which the resource is not depleted, $(1, \hat{K}(1))$; (ii) an asymptotically locally stable heterogeneous equilibrium can exist when there exists a $s_{ng} \in (0,1)$, for which $\hat{S}_I = \hat{K}(s_{ng})$ and the slope of $\hat{S}_I$ is higher than the slope of $\hat{K}(s_{ng})$ in absolute terms.

The existence of a basis of attraction to the heterogeneous green-non-green equilibrium only under certain situations is consistent with the observation that firms making use of some natural CPRs engage in voluntary initiatives whereas firms using other CPRs do not. The historical evolution of tourism destinations shows that, initially, the tourism industry had no particular concern for its environmental impacts, thus being in an all-non-green equilibrium. Tourism expansion has generally been described as accompanied by congestion, degradation of natural assets, weak management of wastes and effluents and other negative impacts (Morgan, 1991; for some examples, see Knowles and Curtis, 1999; Tisdell, 2001). The homogeneous all-non-green firms equilibrium has shown itself to be a stable equilibrium of the system in some destinations where environmental concerns have not been introduced, whereas in other destinations the population has evolved to include a certain proportion of green firms. When the all-non-green equilibrium is unstable, the introduction of a green strategy by a single firm entails a trajectory that converges to the equilibrium with a heterogeneous composition of the population. This conforms to the increasing environmental concerns shown in some destinations, in spite of the fact that such concerns are embraced only by a certain share of its tourism firms (UNEP, 1998; WTO, 2002).

3.4. Sensitivity and bifurcation analysis

As 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, namely a_g and n. It turns out that bifurcation values of these parameters can be identified that imply dramatic changes in the characteristics of the set of equilibria (Lorenz, 1989; Gandolfo, 1996, pp. 469-502).

[insert figure 5]

Figure 5. Sensitivity analysis of the population to a_g and bifurcation diagram.

Let us first consider the consequences of variations in the abatement levels associated to the unilateral commitment, a_g. As we have not modeled explicitly the choice of a_g, let us just assume in this section that it stems from a code of good environmental practices whose adoption is what characterize green firms. The code can be more or less stringent, implying different degrees of abatement effort. We start from a situation in which a_g is low enough for both the stable and unstable heterogeneous equilibria to exist, as represented in figure 4.d. As shown in figure 5, moderate increases in a_g shift both $\hat{S}_I$ and $\hat{K}(\cdot)$ upwards, having an ambiguous effect on the population composition and natural capital level associated with the heterogeneous stable equilibrium. This is so because changes in a_g can have two opposite effects on the relative attractiveness of the available strategies: An increase in a_g increases costs of being green, but the premium associated with green differentiation $\delta(\cdot)$ may also go up if eventually natural capital increases. The direction of change of the equilibrium composition of the population depends on the relative strength of both effects. Regarding the equilibrium level of natural capital, it tends to go up due to the increase of individual abatement by green firms. This effect may be reinforced or dampened by the change of the equilibrium share of green firms depending on whether this increases or diminishes, respectively. In the latter case the equilibrium level of natural capital may fall down.

Independently of the effect of a_g on the share of green firms and natural capital, what is clear is that subsequent increases in a_g will lead to a value of required abatements for which the curves $\hat{S}_I$ and $\hat{K}(\cdot)$ are tangent. As explained in appendix B, this occurs when $\frac{\partial\delta(s_{ng},K)}{\partial s_{ng}}+\frac{n\cdot a_g}{F'(K)}\frac{\partial\delta(s_{ng},K)}{\partial K}=0$. This is a bifurcation value of a_g since for that value both heterogeneous equilibria collapse into a single non-hyperbolic heterogeneous equilibrium, that is to say, as shown in appendix B, for this parameter value, the determinant of the Jacobian becomes zero. For larger values of the parameter, there is no equilibrium with green and non-green firms, and therefore, unilateral commitments cannot prosper. This then constitutes a saddle-node or fold bifurcation (Gandolfo, 1996, pp. 472-473).

The main result of this analysis is that the design of codes of environmental good practice becomes quite complex. A more demanding design may increase or decrease both participation and environmental quality. Moreover, changes of the stringency of the code around a critical value (the bifurcation value) imply dramatic changes of the impact of the initiative in environmental behavior.

Regarding the effect of the population on the existence of voluntary environmental initiatives, let us again start from the situation depicted in figure 4.d. As shown in figure 6, increases in n shift $\hat{K}(\cdot)$ downwards (and $\tilde{K}(\cdot)$ upwards), whereas $\hat{S}_I$ remains now unaffected. A first effect that should be noticed is that these shifts reduce the basin of attraction of the stable heterogeneous equilibrium. Therefore, in an out-of-the-equilibrium situation the population increase may undermine a trajectory of incipient adoption of unilateral commitments.

[insert figure 6]

Figure 6. Sensitivity analysis of the population to *n*. Bifurcation diagram.

As to the effects of the population size on the configuration of equilibria, appendix B shows that there is a bifurcation value, n_1^b, that implies the tangency of $\hat{K}(\cdot)$ and $\hat{S}_I$, and therefore gives rise to the same fold bifurcation as explained before. Higher values of *n* imply the impossibility of stable equilibrium with voluntary environmental initiatives, but at least there exists an all-non-green stable equilibrium with positive endowment of natural capital. If *n* increases further, it will reach a new bifurcation value n_2^b for which isoclines $\hat{K}(\cdot)$ and $\tilde{K}(\cdot)$ join for s_{ng}=1, which implies that both homogeneous equilibria where no firm makes environmental contributions collapse into a single non-hyperbolic homogeneous equilibrium. As shown in appendix B, this is another fold bifurcation since for higher population levels these homogeneous equilibria disappear. The practical consequence is that the only stable equilibrium that remains implies the exhaustion of the CPR.

A more dramatic scenario as the one described results from $n_1^b > n_2^b$. In this case, and assuming that initially the system is in the basin of attraction of the heterogeneous equilibrium, a population increase beyond n_2^b will have a small effect. However, in the vicinity of n_1^b, a marginal population increase will make the system pass from a situation with stable voluntary contributions that guarantee a sustainable management of the CPR to a dynamic that leads to the irreversible exhaustion of the CPR.

Again, in both scenarios the effects of population increases on the equilibrium levels of natural capital and population composition are smooth except for certain thresholds, the bifurcation values. If these thresholds are exceeded, the system enters in a dynamic that implies a dramatic fall in natural capital and the disappearance of green firms[1], with irreversible effects if natural capital falls below $\underline{K}$.

This result has important implications for environmental policy, as shows that the existence of limits to the number of the CPR users is a necessary condition for voluntary initiatives to arise. This result does not derive from previously analyzed lack of capacity of coordination in large groups (Ostrom, 1990; Ostrom et al., 1994; Ostrom, 2005) but from a weakening effect on the incentives towards green differentiation due to the deterioration of the CPR that stems from the increase in the number of users. Therefore, even in contexts where we observe voluntary environmental initiatives (and therefore compulsory policy seems unnecessary), the incentives for sustainable management of CPRs may ultimately hinge on mandatory approaches aimed at maintaining the number of users at moderate levels through licenses to operate, controls to access, building restrictions and so on.

5. Conclusions

Tourism firms may have chrematistic reasons, based on differentiation, for engaging in voluntary environmental initiatives beyond legal mandate. In an evolutionary game-theoretical model of a population of tourism firms making use of an endogenously determined natural CPR we have shown that those incentives can be enough to sustain stable equilibria where voluntary environmental initiatives exist. This result complements previous literature which shows voluntary

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[1] Although there is a jump at the bifurcation in terms of equilibrium levels, in reality the actual values of the variables evolve smoothly following the transitional path to the corresponding stable equilibrium.

initiatives being the result of either potential punishments (Sethi and Somanathan, 1996) or rewards (Osés and Viladrich, 2007) between different players in a community.

The model provides an explanation for situations in which voluntary initiatives are partially adopted or do not emerge at all. When demand effects are strong enough, abatement activities are cheap and effective and/or the number of the CPR's users is small enough, stable equilibria with unilateral commitments can emerge. However, when this is not the case, undertaking voluntary initiatives might not be a stable strategy. This latter scenario conforms to findings from empirical examinations on characteristics of social-ecological systems that are capable to avoid tragedy outcomes of their use of natural resources (Ostrom, 1990; Ostrom et al., 1994; Ostrom, 2005). Moreover, even in those contexts where a stable equilibrium with voluntary initiatives can be achieved, this is not a necessary outcome since heterogeneous equilibria with green firms coexist with other equilibria where all firms just comply with regulation. Thus, initial conditions also play a role when determining the steady-state behavior of the system.

The assumption of endogenous natural capital becomes essential for some of the results of the model. First, the level of the CPR is crucial in determining the basin of attraction of the different equilibria. Second, the comparison of the population dynamics (section 3.1) with the combined system (section 3.3) reveals that an endogenous natural capital is necessary to obtain multiple equilibria. Finally, an endogenous natural capital is needed for the population composition to be sensitive to the scale of that population.

The model shows that, in certain bifurcation situations, the survival of unilateral commitments may be very fragile, in the sense that slight changes in contextual factors may set the system in dynamics that lead to disappearance of unilateral commitments and to lower levels of natural capital, including the possibility of the irreversible exhaustion of the CPR. This result is obtained in a sensitivity analysis carried out with the level of abatement of green firms and the size of firms' population. In the former case the analysis reveals a highly nonlinear relationship between abatement requirements to be considered a "green" firm and the equilibrium shares of green firma and resulting natural capital. When unilateral commitments are interpreted as adherence to codes of good practice, this result reveals the difficulty in designing those codes to obtain the desired outcomes in terms of participation and environmental quality improvements. The latter analysis shows that an unbounded increase in the number of the CPR's users is incompatible with the presence of unilateral commitments, not due to increasing coordination problems between firms (which have not been considered in this paper) but to dissipation of the economic incentives fostering firms to differentiate under green attributes. It therefore results that voluntary initiatives may ultimately hinge on mandatory policy aimed to controlling the number of users if market conditions are such that new firms want to make use of the CPR.

This research could be extended in at least three ways. First, in addition to the diffusion mechanism of strategies (which we have modeled by means of replicator dynamics), we could introduce a network of social interaction to the system. 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). Second, we could analyze the effect on price premiums of competition between destinations for an international green niche of tourists. Consequently, differentiation premiums might not totally disappear when all firms using a particular CPR are green. Firms would then cooperate to attract tourists to the destination and later compete at the destination level, as noted in the concept of competition in the tourism literature (Edgell and Haenisch, 1995). Finally, the model could be extended to expand the set of available strategies, considering the existence of certified voluntary programs beside the option of unilateral commitments.

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7. References

Alberini, A., and Segerson, K., 2002. Assessing voluntary programs to improve environmental quality. Environ. Resour. Econ., 22: 157-184.

Alegre, J., and Cladera, M., 2006. Repeat visitation in mature sun and sand holiday destinations. Journal of Travel Research, 44: 288-297.

Alegre, J., and Juaneda, C., 2006. Destination loyalty: Consumers' economic behavior. Ann. Tourism Res., 33: 648-706.

Álvarez, M., Burgos, J., and Céspedes, J., 2001. An analysis of environmental management, organizational context and performance of Spanish hotels. Omega, 29: 457-471.

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.

Bimonte, S., 2008. The "tragedy of tourism resources" as the outcome of a strategic game: A new analytical framework. Ecol. Econ., 67: 457-464.

Blanco, E., Rey-Maquieira, J., and Lozano, J., 2009. Economic Incentives for Tourism Firms to Undertake Voluntary Environmental Management. Tourism Manage., 30: 112-122.

Buckley, R., 2002. Tourism ecolabels. Ann. Tourism Res., 29: 183-208.

Calveras, A., 2003. Incentives of international and local hotel chains to invest in environmental quality. Tourism Economics, 9: 297-306.

Calveras, A., 2007. Expansion of a hotel chain and environmental quality. Invest. Econ.-Spain, XXXI: 263-295.

Calveras, A., and Vera-Hernández, M., 2005. Quality externalities among hotel establishments: what is the impact of tour operators? Tourism Economics, 11: 571-593.

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.

Conrad, K., 2005. Price competition and product differentiation when consumers care for the environment. Environ. Resour. Econ., 31: 1-19.

Davis, J. J., 1991. A blueprint for green marketing. Journal of Business Strategy, 12(4): 14-17.

Dawson, N. L., and Segerson, K., 2008. Voluntary agreements with industries: Participation incentives with industry-wide targets. Land Econ., 84: 97-114.

Delmas, M., and Keller, A., 2005. Free riding in voluntary environmental programs: The case of the U.S. EPA WasteWise program. Policy Sci., 38: 91-106.

Edgell, D. L., and Haenisch, R. (Editors), 1995. Coopetition: Global Tourism Beyond The Millennium. International Policy Publishing, Kansas City, 148 pp.

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.

Friedman, D., 1998. On economic applications of evolutionary game theory. J. Evol. Econ., 8: 15-43.

Gandolfo, G. (Editors), 1996. Economic dynamics. Springer-Verlag, Berlin, 610 pp.

Glachant, M., 2007. Non-binding voluntary agreements. J. Environ.Econ.Manag., 54: 32-48.

González, M., León, C., and Padrón, N., 2006. Obsolescencia y políticas de renovación medioambiental en el sector turístico. Cuadernos Económicos del ICE, 71: 153-176.

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.

Hamilton, J. M., 2006. Coastal landscape and the hedonic price of accomodation. Ecol. Econ., 62: 594-602.

Healy, R., 1994. The "common pool" problem in tourism landscapes. Ann. Tourism Res., 21: 596-611.

Hofbauer, J., and Sigmund, K., 2003. Evolutionary game dynamics. B. Am. Math. Soc., 40: 479-519.

Huybers, T., and Bennett, F. (Editors), 2002. Environmental management and the competitiveness of nature-based tourism destinations. Edward Elgar Publishing, Cheltenham, 192 pp.

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.

Knowles, T., and Curtis, S., 1999. The market viability of European mass tourist destinations. A post-stagnation life-cycle analysis. International Journal of Tourism Research, 1: 87-96.

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).

Lyon, T., and Maxwell, J., 2002. "Voluntary" approaches to environmental regulation. In: M. Franzini & A. Nicita (Editors), Economics Institutions and Environmental Policy. Ashgate Publishing, Brookfield, Vermont, pp. 75-120).

Lyon, T., and Maxwell, J., 2008. Corporate social responsibility and the environment: A theoretical perspective. Review of Environmental Economics and Policy, 2: 240-260.

Mailath, G., 1998. Do people play Nash equilibrium? Lessons from evolutionary game theory. J. Econ. Lit., XXXVI(September): 1347-1374.

Manzini, P., and Mariotti, M., 2003. A bargaining model of voluntary environmental agreements. J. Public Econ., 87: 2725-2736.

Mihalic, T., 2000. Environmental management of a tourist destination. A factor of tourism competitiveness. Tourism Manage., 21: 65-78.

Moraga-González, J. L., and Padrón-Fumero, N., 2002. Environmental policy in a green market. Environ. Resour. Econ., 22: 419-447.

Morgan, M., 1991. Dressing up to survive: Marketing Majorca anew. Tourism Manage., 12: 15-20.

Nowak, M. A., and Sigmund, K., 2004. Evolutionary dynamics of biological games. Science, 303: 793-799.

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, 280 pp.

Ostrom, E. (Editors), 2005. Understanding institutional diversity. Woodstock: Princeton University Press, Princeton, N.J., 355 pp.

Ostrom, E., Gardner, R., and Walker, J. (Editors), 1994. Rules, games and common pool resources. The University of Michigan Press, Ann Arbor, 369 pp.

Pergams, O., and Zaradic, P., 2008. Evidence for a fundamental and pervasive shift away from nature-based recreation. PNAS, 105: 2295-2300.

Pintassilgo, P., and Albino, J., 2007. "Tragedy of the commons" in the tourism accommodation industry. Tourism Economics, 13: 209-224.

Portney, P. R., 2008. The (not so) new corporate social responsibility: An empirical perspective. Review of Environmental Economics and Policy, 2: 261-275.

Rigall-i-Torrent, R., and Fluvià, M., 2007. Public goods in toursim municipalities: formal analysis, empirical evidence and implications for sustainable development. Tourism Economics*,* 13: 361-378.

Rivera, J., 2002. Assessing a voluntary environmental initiative in the developing world: The Costa Rican Certification for Sustainable Tourism. Policy Sci.*,* 35: 333-360.

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.

Stoeckl, N., 2004. The private costs and benefits of environmental self-regulation: which firms have most to gain? Business Strategy and the Environment*,* 13: 135-155.

Tarui, N., Mason, C., Polansky, S., and Ellis, G., 2008. Cooperation in the commons with unobservable actions. J. Environ.Econ.Manag.*,* 55: 37-51.

Tisdell, C., 2001. National gains from international tourism in the light of environmental factors: Further considerations. In: C. Tisdell (Editors), Tourism economics, the environment and development: Analysis and policy. Edward Elgar, pp. 55-67).

UNEP (Editors), 1998. Ecolabels in the tourism industry. United Nations Environment Programme, Paris, 52 pp.

Vidovic, M., and Khanna, N., 2007. Can voluntary pollution prevention programs fulfill their promises? Further evidence from EPA's 33/50 Program. J. Environ.Econ.Manag.*,* 53: 180-195.

Vidreras, J., and Alberini, A., 2000. The appeal of voluntary environmental programs: which firms participate and why? Contemp Econ Policy*,* 18: 449-461.

WTO (Editors), 2002. Voluntary initiatives for sustainable tourism: Worldwide inventory and comparative analysis of 104 eco-labels, awards and self-commitments. WTO, Madrid, Spain, 160 pp.

Appendix A: Stability of equilibria

A steady state of a two-dimensional system is locally asymptotically stable when the determinant of the Jacobian evaluated at that point has a positive value while the trace is negative. It is locally asymptotically unstable when both the determinant and the trace are positive, whereas it is a saddle-point when the determinant is negative.

This model is comprised of equations 4 and 5. Linearization of these equations results in a system whose Jacobian is:

$$J = \begin{pmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{pmatrix}$$

where $J_{11} = F'(K)$

$$J_{12} = -n \cdot a_g$$

$$J_{21} = -s_{ng}(1 - s_{ng})\sigma$$

$$J_{22} = -\alpha + 2s_{ng}\alpha - s_{ng}(1 - s_{ng})\lambda$$

where we have defined $\alpha = \delta(s_{ng}, K) - c(a_g)$

$$\lambda = \frac{\partial \delta(\cdot)}{\partial s_{ng}}$$

$$\sigma = \frac{\partial \delta(\cdot)}{\partial K}$$

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

Proof of proposition 1

In a heterogeneous equilibrium, according to lemma 1, α=0 and consequently,

$$|J| = F'(K)\left[-s_{ng}(1-s_{ng})\lambda\right] - n{\cdot}a_g s_{ng}(1-s_{ng})\sigma$$

$$\text{trace}J = F'(K) - s_{ng}(1-s_{ng})\lambda$$

For this equilibrium to be locally asymptotically stable it is necessary that $F'(K)<0$ and $\lambda + \frac{n{\cdot}a_g}{F'(K)}\sigma > 0$. $F'(K)<0$ is necessary for the determinant not being negative, and given that $F'(K)<0$, condition $\lambda + \frac{n{\cdot}a_g}{F'(K)}\sigma > 0$ guarantees that it is positive. $F'(K)<0$ also makes the trace negative.

Proof of proposition 2

In a homogeneous all-non-green equilibrium, s_{ng}=1. Thus,

$$|J| = F'(K)\alpha$$

$$\text{trace}J = F'(K)$$

For the trace to be negative it is necessary that $F'(K)<0$. Given that $F'(K)<0$, it is necessary that α<0 for the determinant to be positive.

Appendix B: Bifurcation analysis

Changes in a_{gapp}

Curves $\hat{S}_I$ and $\hat{K}(\cdot)$ are the steady state versions of equations 4 and 5. Their slopes are, respectively:

$$\frac{dK}{ds_{ng}} = -\frac{\partial\delta/\partial s_{ng}}{\partial\delta/\partial K}$$

$$\frac{dK}{ds_{ng}} = \frac{n \cdot a_g}{F'(K)}$$

Therefore, both curves are tangent for that value of a_g such that

$$\frac{\partial\delta(s_{ng}, K)}{\partial s_{ng}} + \frac{n \cdot a_g}{F'(K)} \frac{\partial\delta(s_{ng}, K)}{\partial K} = 0$$

The existence of this value is guaranteed by the continuity of functions and the fact that $\hat{K}(\cdot)$ has an upper bound determined by carrying capacity, whereas $\hat{s}_I$ has not, given our assumption that $\lim_{a_i \to 1} c(a_i) = \infty$.

Simple inspection of the determinant of the Jacobian associated to the heterogeneous equilibrium in appendix A reveals that this is also the condition for it to be null.

Changes in population size

As to the first bifurcation value, it is referring to the same equilibrium as in the previous section. Therefore, this bifurcation value is such that condition

$$\frac{\partial\delta(s_{ng}, K)}{\partial s_{ng}} + \frac{n_1^b \cdot a_g}{F'(K)} \frac{\partial\delta(s_{ng}, K)}{\partial K} = 0 \text{ is satisfied.}$$

Bifurcation value n_2^b refers to the homogeneous equilibria. Notice that $\hat{K}(\cdot)$ $\tilde{K}(\cdot)$ corresponds to expression $F(K) = n[1 - a_g(1 - s_{ng})]$ obtained from (5). This, evaluated at the homogeneous equilibria results in $F(K) = n$. Given the properties of the replenishment function, *F*(*K*), there is only one value of *n*, n_2^b, for which *F*(*K*) gives a single value (that, is, for which $\hat{K}(\cdot)$ $\tilde{K}(\cdot)$ join). Moreover, at this specific point it results that $F'(K)=0$. Finally, the determinant of the jacobian associated with the homogeneous equilibria (see appendix A) is null when $F'(K)=0$.