Investment in Tourism Market: A Dynamic Model of Differentiated Oligopoly

Guido Candela and Roberto Cellini

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Guido Candela, *Dipartimento di Scienze Economiche, Università di Bologna*
Roberto Cellini, *Dipartimento di Economia e Metodi Quantitativi, Università di Catania*

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Summary

We present a theoretical model in tourism economics, assuming that the market for tourism is an oligopoly with differentiated products. Destinations (i.e., countries, regions, sites or even firms) can invest in order to improve their carrying capacity that can be interpreted as the stock of physical, natural or cultural resources. Tourism flows yield current revenues, but they are usually detrimental for the cultural or natural resource stock over time. We find the solution of the dynamic model, and in particular we find the open-loop Nash equilibrium of the game among the destinations, under alternative settings, depending on whether the arrivals are exogenous or endogenous, and depending on whether the degree of differentiation among destinations is exogenous or endogenous. The model is rather general, and it can provide answers to different specific questions, like the choice between mass- vs. elite-tourism development strategies; the effect of the number of competing products upon profits; the optimal degree of product differentiation.

Keywords: Tourism, Differentiated games, Reservation price

JEL Classification: D43, D92, L83

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Address for correspondence:

Roberto Cellini
Facoltà di Economia
Dipartimento di Economia e Metodi Quantitativi
Università di Catania
Corso Italia 55
95129 Catania
Italy
Phone: +39-095-375344 (ext. 237)
Fax: +39-095-370574
E-mail: cellini@unict.it

1. Introduction

In this paper we take a microeconomic perspective, and in particular an "industrial organization" perspective, in order to study the optimal behavior of destinations, as concerns investment and tourism flow regulation over time. When we use the word "destination" we do not intend to necessarily refer to specific local sites, but countries, or regions, could be the appropriate level of analysis as well.

We assume that the market of tourism is an oligopoly, where differentiated products are supplied. The fact that the tourist goods are differentiated is, to some extent, obvious: not only different types of tourism do exist (e.g., sea-side or mountain resort tourism, cultural tourism, …), but tourist products are clearly differentiated even within the same type: the sea-side resort tourism in Bali is different from the sea-side resort tourism in Italy (and also, the sea-side resorts in Sicily are different from that in Sardinia!). It is more important to discuss why we believe that the market is an oligopoly. Three points are worth stressing: first, the available tourist destinations are a given (though large) number, and the entry of new "suppliers" is costly; second, the number of the organizers of tourism flows (like the tour operators) is limited; third, some interaction among the destinations is present indeed: the choice of Italian firms (or Italian policy-makers) concerning the tourist product clearly affects the optimal behavior of any other firms and policy-makers in that field over the world. For these reasons we believe that the differentiated oligopoly model is the appropriate tool to investigate the behavior in the tourism market. The literature developed by industrial organization about the optimal behavior of firms and policy-makers in market with differentiated products can be useful for tourism economics; to our knowledge, the available literature has overlooked this approach so far.

Of course, the tourism products present some specificity to be taken into account. The tourism flows are necessary to give revenues; however, they usually have detrimental effects on the carrying capacity of the destination, that is, its natural and physical resources, as well as its cultural heritage. The carrying capacity, in turn, affects the consumer reservation price: the higher the carrying capacity is, the higher is the reservation price, ceteris paribus.[1] Moreover, the carrying capacity can be improved through appropriate investments: more precisely, costly appropriate investments can be useful to contrast the depletion entailed by tourism flows over time. For these reasons, we believe that a dynamic approach is necessary.

In particular, we take a differential game approach to study the investment efforts over time, made by tourist destinations, under alternative settings, according to whether tourism flows are choice variables for countries or not, and according to whether the degree of substitutability between different tourism goods is exogenous or it can be influenced by destinations. We find the open-loop Nash equilibrium of the differential game among the destinations, and we focus on the steady-state allocations.

Our model is rather general and it can deal with different points. Three questions are specifically answered within our framework: (i) is it always convenient to develop an *elite*-tourism strategy rather than a *mass*-tourism strategy?; (ii) is it always convenient for a system to introduce new products (provided that its introduction costs are negligible)?; (iii) is it always convenient to increase the product differentiation?

The paper is structured as follows. Section 2 illustrates the basic setup, and in particular the demand side. Section 3 investigates the case where the tourism flows are given, and the only choice variable of a tourism site is the amount of investment aimed at increasing its carrying capacity over time, and thus aimed at increasing consumers' reservation price. In a short digression (Section 3.1) we analyze the case that price is fixed (instead of the tourism flow), so that the possible increase of carrying capacity translates into an increase of the tourism flow instead of an increase of price. The digression allows us to derive some conclusions on whether a tourism development strategy based on fixed-presence is preferable with respect to a fixed-price/mass-tourism strategy. Section 4 takes into account the possibility that the tourist flows over time are one of the choice variables of the sites. In a short digression (Section 4.1) we focus on the effect of the number of competitors upon the individual and aggregate profits. Section 5 briefly discusses the case

[1] This simply derives from the usual properties according to which the "quality" of the tourism product is proportional to the ratio of tourists over the stock of resources, and the price is directly linked with the quality, as suggested, e.g., by Lanza and Pigliaru (1994).

where investments aimed at affecting the degree of substitutability among tourism goods are possible. Section 6 gathers the conclusions.

2. The basics of the model

We consider the tourism market as an oligopoly under full information condition. At any time $t \in (0,+\infty)$, each destination i (i=1,2,…,n) offers a tourism product, which is differentiated with respect to the production of different destinations. Let $x_i(t)$ the tourists' presence in destination i at time t. Correspondingly, the price $P_i(t)$ is given by the inverse demand function:

$$(1) \qquad P_i(t) = A_i(t) - Bx_i(t) - D\sum_{j \neq i} x_j(t).$$

Equation (1), firstly introduced by Bowley (1924), is widely used in industrial organization theory (see, e.g., Spence, 1976, Dixit, 1979, Singh and Vives, 1984). Parameter B>0 captures the sensitivity of the price of variety i to the quantity i. Parameter D, $0 \leq D \leq B$, captures the sensitivity of price of variety i to the quantity of goods of different variety; this means that parameter D captures the degree of substitutability between any pair of varieties: the lower is D, the less substitutable (i.e., more differentiated) are goods; in the limiting case D=B the varieties are perfectly substitutable (i.e., goods are homogeneous), and the homogeneous oligopoly case establishes; in the opposite limiting case, D=0, the differentiation is the largest, products are totally independent, and each supplier behaves as a monopolist.

In the available models, A is parameter capturing the market size or the highest reservation price. In this model we consider $A_i(t)$ as a variable rather than as a parameter.[2] We assume that the highest reservation price (or market size) for variety i is directly linked to the stock of its physical and natural resources, or to the stock of its cultural heritage, in a word, with its carrying capacity. This capacity vary over time, for three reasons: (i) the size of tourism flows, that is, the tourists' presence, x, have an impact on the stocks; (ii) the

[2] This line has been already followed by Cellini and Lambertini (2002), that consider the case that market size can be enlarged through investment in advertising campaigns.

amount of investment aimed at protecting environment (or heritage), *k*, have a positive impact; (iii) a proportional natural depreciation (or even a proportional natural regeneration) may occur at the rate δ. Hence, we assume that the dynamics of variable $A_i(t)$ is described by the following equation:

$$\text{(2)} \qquad \frac{dA_i(t)}{dt} \equiv \dot{A}_i(t) = -\alpha x_i(t) + k_i(t) - \delta A_i(t)\,.$$

Notice that if $\delta > 0$, a depreciation occurs (this could well be the case of cultural heritage); if $\delta < 0$ the stock grows naturally (like in the case of environmental regeneration). In the remainder of the paper, we assume $\delta > 0$, but the model can be easily discussed under the alternative hypothesis. Similarly, the tourism flow x may exert a positive or negative effect on the product quality and hence on the carrying capacity, according to whether $\alpha < 0$, or $\alpha > 0$ respectively. In the remainder of the paper we assume $\alpha = 1$, so that the case of the detrimental effect is posted; however, the model can be easily studied under the opposite case that tourism flow is beneficial to the carrying capacity of destination.

We assume that the investment k_i entails a quadratic cost, captured by function φ:

$$\text{(3)} \qquad \varphi(k_i(t)) = \frac{1}{2} z \cdot [k_i(t)]^2\,, \quad z > 0$$

which means that the marginal productivity of k_i is decreasing. We also assume that the tourists' presence in destination *i*, x_i, entails a production cost, according to the generic function $c(x_i(t))$, $c'(.) > 0$. Hence, the profit for destination *i* at time *t* is:

$$\text{(4)} \qquad \pi_i(t) = P_i(t) \cdot x_i(t) - c(x_i(t)) - z \cdot [k_i(t)]^2 / 2\,.$$

We assume that the objective of each destination is to achieve the maximum present value of the flows of its profits over time:

$$\text{(5)} \qquad Max\Pi_i = \int_0^{+\infty} \pi_i(t) e^{-\rho t} dt$$

where $\rho > 0$ is the discounting rate, assumed to be equal across the destinations' population. The dynamic problem is subject to the constraint (2) and to the initial conditions $\{A_i(0) = A_{i0}\}_{i=1}^{n}$. We solve the problem in three different settings, with increasing complexity.

(i) We assume that the dynamics of tourism flows are exogenous, for any destinations: this means that the dynamics of variables $x_i(t)$, i=1,2,…n, are given, and the control variable for destination i is $k_i(t)$ only; the state variable is $A_i(t)$. In this simple case, analyzed in Section 3, there is no strategic interaction among destinations, and the problem is a straight optimum control problem.

(ii) We assume that each destination can control its tourists' presence in any time. Consequently, the problem faced by destination i has two control variables, $x_i(t)$ and $k_i(t)$, and one state variable, $A_i(t)$; moreover, strategic interaction among destinations is present, since the presence in destination j affect the profit -and hence the optimal choice- of destination i. In this case, a differential game has to be solved. We adopt the open-loop Nash equilibrium as the solution concept, but in this case it coincides with the closed-loop memoryless Nash equilibrium, which is strongly time consistent.

(iii) We assume that the degree of differentiation, D, is a variable rather than a parameter, and it is possible to affect its value through costly investment, h, decided by destinations. In this case, a differential game arises, in which each destination faces a problem with three control variables, $k_i(t)$, $x_i(t)$, $h_i(t)$, and two state variables, $A_i(t)$ and $D_i(t)$. In this case, the open-loop Nash equilibrium differs from the closed-loop equilibrium and it is only weakly time-consistent.

3. Investment in protecting the environment in the presence of exogenous tourism flows

In this section we take into account the simple case that the destinations can not affect the tourism flows, i.e., variables $x_i(t)$ are exogenous; more specifically, we assume that x_i are constant parameters. The problem faced by the destination i summarizes as follows:

$$(6)\qquad Max\Pi_i = \int_0^{+\infty} \left\{ [A_i(t) - Bx_i - D\sum_{j\neq i} x_j]x_i - c(x_i) - z\cdot[k_i(t)]^2/2 \right\} e^{-\rho t}dt$$

s.t.: $$\frac{dA_i(t)}{dt} \equiv \dot{A}_i(t) = -x_i + k_i(t) - \delta A_i(t)\,;\; \{A_i(0) = A_{i0}\}_{i=1}^{n}.$$

The control variable is $k_i(t)$, and the state variable is $A_i(t)$. The corresponding Hamiltonian function is

$$(7)\quad H_i = \left\{ [A_i(t) - Bx_i - D\sum_{j\neq i} x_j]x_i - c(x_i) - \frac{z[k_i(t)]^2}{2} + \lambda_i(t)\left[-x_i + k_i(t) - \delta A_i(t)\right] \right\} e^{-\rho t}$$

where $\lambda_i(t)$ is the current-value co-state variable associated to the state variable.

The first order condition and the adjoint equation for the maximum are:

$$(8)\qquad \begin{cases} \dfrac{\partial H_i(t)}{\partial k_i(t)} = 0 \\ -\dfrac{\partial H_i(t)}{\partial A_i(t)} = \dfrac{d\lambda_i(t)}{dt} - \rho\lambda_i(t) \end{cases}$$

to be considered along with the transversality condition $\lim_{t\to+\infty} A_i(t)\lambda_i(t)e^{-\rho t} = 0$. The first and the second condition of system (8) respectively imply:

$$(9)\qquad k_i(t) = \lambda_i(t)/z$$

$$(10)\qquad d\lambda_i(t)/dt \equiv \dot{\lambda}_i(t) = -x_i + (\rho+\delta)\lambda_i(t)$$

Differentiating eq. (9) with respect to time, and then substituting eq. (10), we obtain:

$$(11)\qquad dk_i(t)/dt \equiv \dot{k}_i(t) = \dot{\lambda}_i(t)/z = -x_i/z + (\rho+\delta)k_i(t).$$

The simultaneous consideration of (11) and (2) describes the dynamic system under optimum condition, and can be represented in matrix notation as follows:

$$\begin{bmatrix} \dot{k}_i(t) \\ \\ \dot{A}_i(t) \end{bmatrix} = \Omega \begin{bmatrix} k_i(t) \\ \\ A_i(t) \end{bmatrix} + \begin{bmatrix} -x_i / z \\ \\ -x_i \end{bmatrix} \quad , \quad \Omega = \begin{bmatrix} (\rho+\delta) & 0 \\ \\ 1 & -\delta \end{bmatrix} \tag{12}$$

Notice that the motion equation are of type:

$$\begin{aligned} &\dot{k}_i(t) = \phi(k_i(t) | x_i) \\ &\dot{A}_i(t) = \gamma(k_i(t), A_i(t) | x_i) \end{aligned} \tag{12'}$$

Provided that x_i is constant over time, it is easy to verify that a steady state does exist ($\dot{k}_i(t) = \dot{A}_i(t) = 0$):

$$k_i{}^* = \frac{x_i}{z(\rho+\delta)} \quad ; \quad A_i{}^* = \frac{x_i[1 - z(\rho+\delta)]}{\delta z(\rho+\delta)} \tag{13}$$

Obvious parameter restrictions are required in order to have economically meaningful steady-state values. In particular, under the restriction $0 < z(\rho+\delta) < 1, \delta > 0$ pertaining to the case of resources depreciation, we have A_i*>0, k_i*>0. The graphical representation of the system under these restrictions is provided by Figure 1.[3]

Figure 1.

From the study of matrix Ω, it is immediate to notice that the steady state, in the case under the above mentioned parameter restrictions, is a saddle, as long as: $\det(\Omega) = -\delta^2 - \rho\delta < 0$ and $tr(\Omega) = \rho > 0$. The stable branch coincides with the horizontal line k_i=k_i*.

[3] The extension to the more general case that $\alpha \in (-\infty, +\infty)$ is very simple. When α in eq. (2) is not necessarily equal to 1, the steady state is: $k_i{}^* = x_i / [z(\rho+\delta)]$, $A_i{}^* = x_i[1 - \alpha z(\rho+\delta)] / [\delta z(\rho+\delta)]$.

Let us focus on the steady-state point. Both the investment efforts and the size of resources stock depend positively on the parameter x_i, which measures the size of tourism flow. The corresponding steady-state profit is:

(14) $$\pi_i{}^* = \left[\frac{1 - z(\rho+\delta)}{\delta z(\rho+\delta)} - B - \frac{1}{2z(\rho+\delta)^2}\right] x_i{}^2 - D(\sum_{j \neq i} x_j) x_i - c(x_i)$$

Comparative statics exercises can be made, as parameter x_i changes. The larger is x_i, the larger are k_i^* and A_i^*.[4] More interestingly, notice that the parameter x_i, has a non-monotonic effect on the (steady-state) profit of destination *i*. Moreover, for any given level of x_i, parameter *D* (and the sum of x_j alike) has a negative effect on the profit of destination *i*. Verbally, the stronger is the product differentiation (i.e., the lower is parameter *D*), the higher the steady-state profit is. Finally, and rather trivially, the larger are the tourism flows in competing destinations, the lower the steady-state profit is in any given destination, ceteris paribus.

3.1 A digression: the fixed-price case

In the previous case, the increase of the carrying capacity of the destination translates into an increase of the price paid by tourists, given that tourism flows are constant by hypothesis. The opposite case, however, is equally possible: we can imagine that prices are constant parameters, and the modification of carrying capacity translates into a modification of tourism flow (see figure 2). Roughly speaking, the former case corresponds to the situation where tourism flow is constant over time and the increasing carry-capacity translates into higher price; this is the case of a development strategy that we can label as "elite"-tourism. The latter case, on the contrary, corresponds to a strategy recalling the mass-tourism: the increase of carrying capacity translates into a larger presence of tourists, and price remains constant over time. The model allows verifying that

[4] As a consequence of a modification of parameter x_i, and in the absence of adjustment cost concerning $k_i(t)$, a jump of variable $k_i(t)$ allows the dynamic system to jump from the "old" to the "new" horizontal stable branch.

the parameter configuration determines which case is more convenient, in terms of (steady-state) profit.

Figure 2.

In the fixed-price case, it is convenient to deal with direct demand function. The direct demand corresponding to inverse function (1) is:[5]

$$(1') \qquad x_i(t) = \frac{1}{B+D(n-1)}\left\{ A_i(t) + \frac{D}{B-D}\cdot\sum_{j\neq i} p_j(t) - \frac{B+D(n-2)}{B-D} p_i(t) \right\}$$

where n denotes the number of destinations. (Notice that the limit case $D=B$ describes the homogeneous oligopoly model, and the individual demand functions are indeterminate, as it is well-known from the Bertrand model). Let p_i be the constant value of price in destination i. For the sake of analytical simplicity, we also assume that marginal costs of production are constant, $\partial c(x_i)/\partial x_i = c'_i > 0$. The dynamic problem of destination i (with k_i as the choice variable and A_i the state variable) gives rise to the following steady state:

$$(13') \qquad \begin{aligned} k_i^* &= \frac{p_i - c'_i}{z(\rho+\delta)[B+D(n-1)]} \\ A_i^* &= \frac{1}{1+[B+D(n-1)]\delta}\left\{ \frac{p_i - c'_i}{z(\rho+\delta)} + \frac{[B+D(n-2)]p_i - D(\sum_{j\neq i} p_j)}{B-D} \right\} \end{aligned}$$

Straightforward substitutions lead to the steady-state profit.

We are interested in comparing the steady-state allocations and profits under the two alternative settings, i.e., the fixed-presence ("elite"-development) case and the fixed-price ("mass"-development) case.

First of all, it is worth noticing that marginal cost of production enters the steady-state levels of variables only in the case of the "mass"-tourism development strategy: this is obvious, given that the increase in the amount of presence entails, in this case, increasing

[5] See Ottaviano, Tabuchi and Thisse (2002,Appendix) for the analytical derivation.

production cost. Of course, the marginal cost c'_i has to be sufficiently small in order to have meaningful solutions for the problem in this case.[6] In other words, the marginal cost of production represents a constraint which can be severe in the case of "mass-torusim" development strategy: high marginal cost can prevent the possibility of mass-development strategy.

Secondly, steady-state profits depend on a number of parameters, and the parameter configuration determines whether the "elite" development leads to a larger steady-state profit as compared to the "mass" development. Both cases are, in principle, possible;[7] this means that, under some parameter configurations, mass tourism (if possible) can lead to higher profit as compared to elite tourism. Moreover, appropriate shocks on parameter may cause a "switch" as concerns the more convenient development strategy. This observation may explain why destinations change their tourism development strategy, moving from "elite" destination to "mass" destination (or vice versa).

4. The optimal plans when tourism flows are endogenously set by destinations

Now we take into account the case that the tourism flows are neither exogenously given (nor constant over time), but they are choice variables of destinations. This is to some extent realistic, as long as destinations can choose different policies as concerns the size of admissible tourists. In such a case, the Hamiltonian function associated to the dynamic problem of destination i is still eq. (7), but $x_i(t)$ is a control variable for player i, as well as $x_j(t)$ is a control variable of player j. Strategic interaction is indeed present and we are facing a differential game, as long as A_i (and any A_j alike) moves over time. The law describing the dynamics of $A_i(t)$ is still eq. (2), and the market demand is still eq. (1).

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[6] It is immediate to see that $c'_i<p_i$ must hold, for having $k_i>0$; if marginal costs are increasing (instead of constant) they must be limited from above.

[7] In general, parameters interact in a very complex way, and it is difficult to find clear-cut comparative statics conclusions. However, numerical simulations are easy to compute. Just to give an examples, set z=1, B=4, D=.5, n=5, $\rho = \delta = .02$, c'_i=.1; moreover, p_i=2, $\sum p_j = 4$ and $\sum x_j = 30$. The steady state profit under the fixed-presence case turns out to be .11, which is larger than the steady-state profit under the fixed presence development strategy, for $0<x_i<.04$. Of course, and rather trivially, the given level of fixed presence (as well as the given value of fixed price) are relevant parameters for determining the more convenient development strategy.

Different solution concepts for differential games are available in literature. We focus on the open-loop Nash equilibrium. Under this solution concept, players precommit their decisions on the control variables to a given time path: they design the optimal plan at the initial time and then stick to it forever. Differently, under the closed-loop solution concept, players do not precommit on any path and their decisions at any instant *t* depend on all the preceding history, and specifically on the observable value of the state variable at that instant. The closed-loop solution is strongly time consistent and therefore sub-game perfect, while the open-loop solution is generally not time-consistent.[8] In the case of the present section, however, the open-loop Nash equilibrium coincides with the closed-loop Nash equilibrium and it is therefore strongly time-consistent (see also below, footnote 9).

The first order conditions and the adjoint equations pertaining to player *i*, when x_i is a choice variables are as follows:

$$(15)\quad \begin{cases} \dfrac{\partial H_i(t)}{\partial x_i(t)} = 0 \\ \dfrac{\partial H_i(t)}{\partial k_i(t)} = 0 \\ -\dfrac{\partial H_i(t)}{\partial A_i(t)} = \dfrac{d\lambda_i(t)}{dt} - \rho\lambda_i(t) \end{cases}$$

along with the initial condition and the transversality condition $\lim_{t\to+\infty} A_i(t)\lambda_i(t)e^{-\rho t} = 0$.[9]

The three conditions of system (15) imply, respectively:

$$(16)\quad A_i(t) - 2Bx_i(t) - D\sum_{j\neq i} x_j(t) - c'(x_i(t)) - \lambda_i(t) = 0$$

$$(17)\quad k_i(t) = \lambda_i(t)/z \quad \Rightarrow \dot{\lambda}_i(t) = z\,\dot{k}_i(t)$$

[8] Another strongly time-consistent (and therefore subgame perfect) solution concept is the feedback equilibrium using Bellman's equation. For a clear exposition of the difference among these equilibrium solutions see Basar and Olsder (1982, pp. 318-327, and chapter 6, in particular Proposition 6.1). There exist classes of games where the closed-loop and the open-loop solutions coincide (see Mehlmann, 1988, ch. 4; Reinganum, 1982; Fershtman, 1987; Fershtman, Kamien and Muller, 1992; Dockner, Jørgensen, Van Long and Sorger, 2000, ch. 7, Cellini and Lambertini, 2001).

[9] We have not inserted the dynamics of state variables A_j, $j\neq i$, in the problem if player *i*, since it is immaterial to the solution: it is true that A_j represent state variables also for player *i*, but A_j does not affect the optimal value of the control variables of player *i*. Technically, the game has "separated dynamics". This property entails that the open-loop Nash equilibrium coincides, in the present case, with the closed-loop equilibrium, since there is no feedback from the state variable pertaining to a player to the control variables of the other players (see also Cellini and Lambertini, 2001, for further details in a similar game).

$$(18)\qquad \dot{\lambda}_i(t) = -x_i(t) + (\rho+\delta)\lambda_i(t)$$

From equation (16) we can obtain the reaction curve, which links x_i with the sum of x_j. Then, we impose the symmetry condition $x_i=x_j=x\ \forall i,j$, so that $\sum_{j\neq i} x_j = (n-1)x$. Similarly, we assume $A_i=A_j=A$, $k_i=k_j=k$, $\forall i,j$. Thus, the equilibrium under symmetry condition turns out to imply:

$$(19)\qquad A(t) - [2B + D(n-1)]x(t) = c'(x(t)) + zk(t)$$

Intuitively, the left-hand side of equation (19) can be interpreted as the marginal revenue from the tourism presence, while the right-hand side represents the marginal cost, taking into account that the tourism flows generate damages to the natural resources stock that must be paid (according to addendum $zk(t)$).

Differentiate eq. (19) and eq. (17) w.r.t. time, and consider them along with eq. (18) and (2); in the resulting dynamic system , the relevant variables are $x(t)$, $k(t)$, $A(t)$.

It is easy to find the steady state of such a system. Condition $\dot{A}(t)=0$ implies $A=(k-x)/\delta$; condition $\dot{k}(t)=0$ implies $k = x/[z(\rho+\delta)]$; moreover, $\dot{A}(t)=\dot{k}(t)=0$ imply $\dot{x}(t)=0$; substituting these values into equation (19) we obtain:

$$(20)\qquad x\cdot\left[\frac{1-z(\rho+\delta)}{\delta z(\rho+\delta)} - (2B + D(n-1))\right] = c'(x) + \frac{x}{z(\rho+\delta)}$$

Eq. (20) gives the steady-state value of variable x. Also in this case we can offer an intuitive explanation for the optimality condition (20): it requires to equate the marginal cost of tourism flow (the right-hand side) with the marginal revenue from tourism (the left-hand side). However, a relevant problem is present in the steady-state solution of the problem at hand, as compared to a standard static problem: a larger tourism flow, x, requires a larger k in steady state (ceteris paribus); this -in turn- may imply a larger market size, A. The steady-state market size, hence, is positively related to the steady-state quantity of good x. Consequently, the marginal revenue is not necessarily a decreasing function of the sold quantity. Put differently, the first order condition (20) is not necessarily associated to a maximum point, but it could be associated to a minimum point, the maximum being a corner solution (if it exists). This issue is well-known in similar problems in environmental economics.[10] A complete study of the second order condition is required. Alternatively, we can compare the marginal revenue function with the marginal cost function. The intersection is a maximum (that is, condition (20) identifies the tourist flow associated with the maximum profit), if and only if the slope of the marginal revenue function is smaller (algebraically) than the slope of the marginal cost function. Hence different cases must be considered as concerns the optimum condition (20).

(a) If $[2B + D(n-1)] \geq \frac{1 - z(\rho+\delta)}{\delta z(\rho+\delta)}$, the marginal revenue is decreasing and non-positive for any positive value of x. Consequently, the corner solution x=0 is the optimum.

(b) If $[2B + D(n-1)] < \frac{1 - z(\rho+\delta)}{\delta z(\rho+\delta)}$, the marginal revenue is positive, and the intersection between the marginal revenue curve and the marginal cost curve represents the maxim profit point iff the marginal cost curve intersect the marginal revenue curve from below. Hence, we distinguish three sub-cases:

(b.1) if $c'(x)$ is constant, i.e., $c'(x)=c' \geq 0$, the optimum is $x \to +\infty$;[11]

(b.2) if $c'(x)$ is a linear function of x, i.e., $c''(x)=c''>0$, the optimum is:

$$x = \begin{cases} 0 & for \quad \frac{1 - z(\rho+\delta)}{\delta z(\rho+\delta)} - [2B + D(n-1)] < c'' + \frac{1}{z(\rho+\delta)} \\ \to +\infty & for \quad \frac{1 - z(\rho+\delta)}{\delta z(\rho+\delta)} - [2B + D(n-1)] > c'' + \frac{1}{z(\rho+\delta)} \\ ind. & for \quad \frac{1 - z(\rho+\delta)}{\delta z(\rho+\delta)} - [2B + D(n-1)] = c'' + \frac{1}{z(\rho+\delta)} \end{cases}$$

(b.3) if $c'(x)$ is a positive, increasing and convex function of x (so that $c''(x)>0$ and $c'''(x)>0$) the interior solution identified by eq. (20) is a maximum profit point if

[10] See, for instance, the antipollution policy problem by Forster (1980), as it is presented by Chiang (1992).

[11] This is due to the fact that the marginal revenue increases at a speeder pace than the marginal cost, as x increases. Unless some capacity constraint on the tourism flows is operative, $x \leq \hat{x}$ (when the optimum is the corner solution $x=\hat{x}$), there is no finite solution for x.

$$(21)\qquad \left[\frac{1-z(\rho+\delta)}{\delta z(\rho+\delta)}-(2B+D(n-1))\right]<c''(x)+\frac{1}{z(\rho+\delta)};$$

otherwise, the point identifies a minimum.

In sum, the dynamic problem can lead to a steady state with a positive and finite value for x, only under condition (21) in case (b3). We focus on this case. We are interested in some comparative statics on the equilibrium steady-state allocation. To this end, let us consider eq. (20) as an implicit function $g(.)=0$:

$$(22)\qquad g(x,B,D,n,z,\rho,\delta)=x\cdot\left[\frac{1-z(\rho+\delta)}{\delta z(\rho+\delta)}-(2B+D(n-1))\right]-c'(x)-\frac{x}{z(\rho+\delta)}=0$$

We can apply to (22) the implicit function theorem, in order to study how the steady-state value of x react to the parameters; provided that $0<\delta<1$, we obtain:

$$(23)\qquad \begin{aligned}
&\frac{\partial x}{\partial B}=-\frac{\partial g(.)/\partial B}{\partial g(.)/\partial x}<0 \;;\quad \frac{\partial x}{\partial D}=-\frac{\partial g(.)/\partial D}{\partial g(.)/\partial x}<0 \;;\\
&\frac{\partial x}{\partial n}=-\frac{\partial g(.)/\partial n}{\partial g(.)/\partial x}<0 \;;\quad \frac{\partial x}{\partial z}=-\frac{\partial g(.)/\partial z}{\partial g(.)/\partial x}<0 \;;\\
&\frac{\partial x}{\partial \rho}=-\frac{\partial g(.)/\partial \rho}{\partial g(.)/\partial x}<0 \;;\quad \frac{\partial x}{\partial \delta}=-\frac{\partial g(.)/\partial \delta}{\partial g(.)/\partial x}<0 \;;
\end{aligned}$$

Just to have an explicit solution, consider the particular case where the marginal cost is the increasing and convex function $c'(x)=cx^2$, $c>0$, so that the cost function (apart from fixed costs) is $c(x)=cx^3/3$. In this particular case, the steady-state solution for x is:

$$(24)\qquad x=\frac{1}{c}\cdot\left[\frac{1-z(\rho+\delta)}{\delta z(\rho+\delta)}-(2B+D(n-1))-\frac{1}{z(\rho+\delta)}\right]$$

It is immediate to verify that the comparative statics properties outlined by (23) hold in the particular case of (24); moreover, in this case, $\partial x/\partial c<0$.

The economic meaning of these properties is easily explained: (i) the larger is the number of destinations competing with substitutable products, n, the smaller the steady-state individual production of each destination in the symmetric Nash equilibrium is. (ii) The larger is B (ceteris paribus), the smaller the marginal revenue, and hence the smaller the optimal amount of sold product. (iii) The larger is D the less differentiated are the products: competition among destinations is harsher and the marginal revenues are lower: this leads to a smaller optimal production. (iv) The higher is the investment cost in protecting the natural stock (connected with parameter z), the smaller the optimal amount is of tourists' presence.

As a last remark, we note that, in the case of the present section, the closed-loop Nash equilibrium collapses into the open-loop: the latter is therefore strongly time consistent. This is due to the fact that there is no feedback from the current value of state variables to the current value of control variables, so that the possibility of changing the choice during the time where the game takes place is pointless.

4.1 A digression: the effect of the number of products

The model can easily provide an answer to a simple question: is it always convenient –for the system of destinations– to introduce new products? Just to give a real and up-to-date example, let us think of the debate among Italian and Croatian Adriatic destinations concerning the convenience of offering a "new package" (i.e., a new destination) of integrated stay in Italy and Croatia. We can assume that the introduction cost of this destination is negligible, so that we can simply study how the (steady-state) aggregate profits depends on n.

It is easy to check that the maximum profit (in steady state) for the system of the destinations *is not* a monotonic function of the number of products. Indeed, focussing on the steady-state profit (under the hypothesis of an interior solution), it is immediate to find that the aggregate profits, $\Pi = n\pi$ is a function of degree 4 in n. In fact, n affects (negatively) the individual optimal production, x, and consequently the production cost $c(x)$ and the investment efforts in carrying capacity, k, and the reservation price A; the effect on price is not clearcut as long as steady-state levels of both A and x depend negatively on *n*. Hence, it is not surprising that the aggregate profits are not necessarily increasing in the number of products. Put differently, we can state that an increase of the number of products, even if it is costless, does not necessarily lead to a larger aggregate profit.[12]

From the policy-making perspective, the introduction of a new product within the Adriatic tourism, affects the equilibrium values of investment in carrying capacity, the reservation prices of tourists, the optimal quantities and prices; the dimension of such effects are rather complicate to compute, and no simple recommendation is possible in this case. Moreover, as a note of caution on this consideration, remember that in this model the number of products coincides with the number of destination, and the focus is only on the steady state of the symmetric equilibrium.

5. Investing in product differentiation

Now we sketch the optimal solution in the case that destinations can invest in order to increase the product differentiation. To this end, remember that, up to now, we considered D as a parameter, capturing the degree of differentiation between any pair of tourism products. Strictly speaking, D is a parameter connected with the consumer preferences, but we can guess that it reflects the fact that destinations are objectively differentiated, thanks to difference in natural resources, history, tradition, and so on.

To some extent, however, the differentiation may be modified, by appropriate investment efforts by part of destinations, for instance through advertising efforts. In this respect, the degree of differentiation becomes a state variable, which is affected -at least in part- by appropriate investment. Thus, in this Section we treat D as a variable moving over time, as a result of investment efforts. Notice, however, that D is common to all destinations, since D denotes the *symmetric* degree of differentiation among products. In this respect, D is a public good.

[12] Just to give a numerical example, if we set z=.1, B=1, D=.5, $\rho = \delta = .02$, c=1, the steady state optimal production is x_i=(24397-n)/2 and the aggregate profits are $n\pi_i = n(n-24397)^2(15775-n)/12$ which are increasing in n over the interval 1<n<5075 and decreasing over 5075<n<15775.

We assume that, at the initial instant t=0, it is $D(0)=D_0$, with $0<D_0\leq B$. (If $D_0=B$ destinations offer the same homogeneous good.) Product differentiation may increase, i.e., parameter D may decrease, through appropriate investments, h_i, according to the following law, borrowed from Cellini and Lambertini (2002a):

$$(25) \qquad \frac{dD(t)}{dt} \equiv \dot{D}(t) = -\frac{\sum_{i=1}^{n} h_i(t)}{1+\sum_{i=1}^{n} h_i(t)} \cdot D(t)$$

The dynamic equation (25) can be interpreted as a production function whose output is a decrease in $D(t)$, obtained through appropriate investments. It is immediate to check that this technology exhibits decreasing returns to scale w.r.t. $\sum_{i=1}^{n} h_i(t)$. As a result, $D(t)$ is non-increasing over time, and approaches zero as $\sum_{i=1}^{n} h_i(t)$ tends to infinity. When $D(t)$=0, increasing differentiation is no longer possible. (Of course, we are aware that it could be questionable that investment k_i affecting the size of the resources stock, on the one side, and investment h_i affecting the differentiation among destinations, on the other side, are different variables: in the real world, it is likely that the investment affecting the natural resources stock also affect the perceived product differentiation.)

Given the symmetric nature of product differentiation in this model, there exists a complete spillover effect in investment process: just to give a trivial example, when Las Vegas invests in order to offer a more and more differentiated product, any other site over the world becomes more and more differentiated with respect to Las Vegas! Notice that the externality effect we consider here entails that the outcome of investment activity is public domain via the demand function. On the contrary, the externality effects usually considered in the literature are associated with information leakage or transmission (see, inter alia, d'Aspremont and Jacquemin, 1988).

We assume that the cost of the investment effort in differentiation obeys the linear equation $w(h_i(t)) = w \cdot h_i(t),\ w > 0.$ Hence, the individual problem faced by destination i is:

$$(26) \qquad Max\Pi_i = \int_0^{+\infty} \left\{ [A_i(t) - Bx_i(t) - D(t)\sum_{j\neq i} x_j(t)]x_i(t) - c(x_i(t)) - z\cdot[k_i(t)]^2/2 - wh_i(t) \right\} e^{-\rho t} dt$$

s.t.: $\dot{A}_i(t) = -x_i(t) + k_i(t) - \delta A_i(t) \quad ; \quad A(0) = A_0 > 0$;

$$\dot{D}(t) = -D(t)\sum_{i=1}^{n} h_i(t) \Big/ \left[1 + \sum_{i=1}^{n} h_i(t)\right] \quad ; \quad 0 < D(0) = D_0 \leq B$$

The control variables in this problem are $x_i(t)$, $k_i(t)$, $h_i(t)$, while $A_i(t)$ and $D(t)$, are the state variables. Let $\eta(t)$ be the current-value co-state variable associated with $D(t)$. The construction of the Hamiltonian function H_i is as usual.

Notice that $D(t)$ is common to all players, and the effort for investment in differentiation made by j-site *directly* affects the objective function of the i-site through a relevant state-variable. For this reason, the open-loop Nash equilibrium does not coincide with the closed-loop one, in this case: the control variable of player j directly affects the state variable pertaining to different players, that -in turn- affect the optimal choice regarding their control variables. We present here only the open-loop solution, that is, we assume that each site chooses the plan of its actions at the initial time, and then stick to it forever. We are aware that the solution is only weakly time consistent, as long as each site would find it optimal to change its plan, if the implementation of the plans by part of competing sites were observed over time. However, the analytical closed-loop solution is, in this case, rather difficult to be found, and it requires strict conditions on parameter in order to exist. (See Cellini and Lambertini (2002b) for the closed-loop solution of a similar - though simpler- problem, and the comparison with the open-loop solution).

The first order conditions and adjoint equations pertaining to $x_i(t)$, $k_i(t)$ and $A_i(t)$ are the same as (16), (17) and (18), apart from the fact that D has to be interpreted a variable rather than as a parameter; moreover two further conditions have to be considered:

(27) $$\frac{\partial H_i(t)}{\partial h_i(t)} = 0 \quad \Rightarrow \quad -\frac{\eta(t)D(t)}{\left(1 + \sum_{i=1}^{n} h_i(t)\right)^2} = w$$

(28) $$-\frac{\partial H_i(t)}{\partial D(t)} = \dot{\eta}(t) - \rho\eta(t)$$

Equation (27) can be solved under the symmetry assumption $h_i(t)=h_j(t)=h$, $\forall i,j$, (along with similar symmetry assumptions concerning x and k) and a function linking h to D can be obtained. Differentiation w.r.t. time and appropriate substitutions lead to obtain:

(29) $$\dot{h}(t) = \frac{D(t)}{2w^2\left(1+\sum_{i=1}^{n} h_i(t)\right)} \cdot \left[(n-1)x^2 - \frac{\left(1+\sum_{i=1}^{n} h_i(t)\right)^2 \rho w}{D(t)} \right]$$

Steady state $\dot{h}(t) = \dot{D}(t) = 0$ establishes for $D(t)=0$ or for $D = \rho w / [(n-1)x^2]$.

The case $D(t)=0$, describes the situation where products have become completely independent, so that it is pointless to invest further in product differentiation.

The case where $D = \rho w / [(n-1)x^2]$ describes a steady state, where a certain degree of substitutability among products is indeed present. Notice that this solution is incomplete, as long as x itself has to be interpreted as the steady-state value of x, which depends on the parameters (and, in particular, negatively depends on variable D itself, according to first order condition (16)). Moreover, appropriate conditions on parameter have to be posed, in order to guarantee that the solution is economically meaningful and acceptable. However, the positive direct effect of w on D is rather obvious: the higher is the investment cost, the higher the optimal level of D, that is, the lower the optimal effort for investment in differentiation is.

In order to find a solution for the steady-state configuration it is not sufficient to postulate a quadratic marginal cost function $c(x)$: in this case, a cubic equation has to be solved, and we need further numerical constraint to find the solution analytically.

As to the economic meaning of the solution, it is worth noticing that each site compares the costly efforts of investing in differentiation with the benefits from product differentiation, and –in the Nash equilibrium solution concept– it chooses the optimal amount of efforts, given the efforts of his opponents. However, because of the complete externality from individual efforts to the degree of differentiation (which is common to all sites), the individual effort in product-differentiation is generally under-sized as compared to a cooperative solution. This result is common to the models on R&D investment (when investment have positive spillovers for the rivals) or to the models on advertising (when advertisement of a firm benefits all the competing firms as well).

In sum, a positive level of differentiation is optimal for destinations, but the efforts in differentiation carried out by private agents are lower than the socially optimal level. As an immediate corollary of this point, we can state that some forms of inter-destination coordination, or appropriate policy interventions, are necessary to overcome the market inefficiency implied by the public-good nature of differentiation. This point is in our future research agenda.

8. Conclusions

In this article, we have argued that a differential model of differentiated oligopoly is appropriate to study tourism development strategies. As a matter of fact, tourism goods are differentiated; dynamic plans are necessary to sustain carrying capacity over time; more importantly, competition among different destinations takes place over time.

We have taken a truly microeconomic approach, to answer up-to date questions concerning the strategies for a sustainable development of tourism markets.

In particular, we have proposed a differential game approach to study the optimal plans of competing tourism destinations. Our general framework permits to deal with some specific points: (i) the determination of the time path of optimal investment in carry-capacity; (ii) the preferability of elite *vs.* mass tourism, (iii) the determination of the optimal amount of tourism flows and its interaction with product differentiation and with the available number of products; (iv) the optimal efforts of investment in product differentiation.

Unfortunately, when realistic hypotheses are considered, no clear-cut and simple suggestions emerge. In particular, our model has shown that: (i) it is not true that a elite-tourism strategy is always associated with higher profit for destination: under some (general) circumstances, mass-tourism can be preferable (even if high marginal cost of production may hinder the mass development strategy); (ii) it is not true that the introduction of new products is always beneficial to the aggregate profits of a system of tourism destinations, even when the introduction of new products is costless; (iii) the optimal degree of differentiation among different destinations is positive (but finite, provided that increasing differentiation is costly); the individually optimal degree of differentiation is generally lower than the socially optimal level. In general, an active role of policy-making is necessary for an appropriate design of the development of the tourism market.

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FIGURES

Figure 1. Dynamics in the (A,k) space, under the case $0 < z(\rho + \delta) < 1, \delta > 0$.

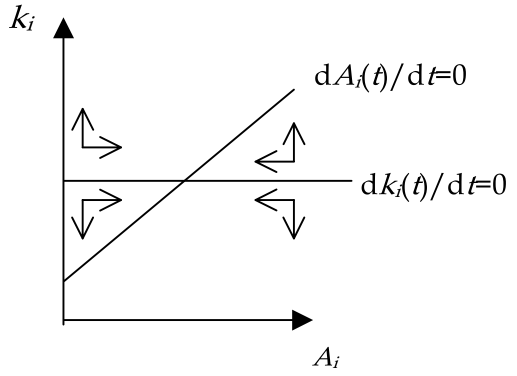
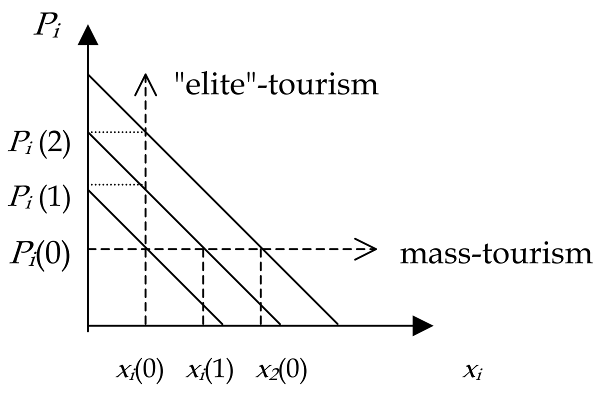


Figure 2. Dynamics in the (A,k) space, under the case $0 < z(\rho + \delta) < 1, \delta > 0$.



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(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
(lxii) This paper was presented at the ENGIME Workshop on "Communication across Cultures in Multicultural Cities", The Hague, November 7-8, 2002
(lxiii) This paper was presented at the ENGIME Workshop on "Social dynamics and conflicts in multicultural cities", Milan, March 20-21, 2003
(lxiv) This paper was presented at the International Conference on "Theoretical Topics in Ecological Economics", organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
(lxv) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications" organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003
(lxvi) This paper has been presented at the 4th BioEcon Workshop on "Economic Analysis of Policies for Biodiversity Conservation" organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL) , Venice, August 28-29, 2003
(lxvii) This paper has been presented at the international conference on "Tourism and Sustainable Economic Development – Macro and Micro Economic Issues" jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003

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