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**Pigouvian Taxation in Tourism**

**Claudio Piga**

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Dept Economics  
Loughborough University  
Loughborough  
LE11 3TU United Kingdom  
Tel: + 44 (0) 1509 222701  
Fax: + 44 (0) 1509 223910  
<http://www.lboro.ac.uk/departments/ec>



# Pigouvian Taxation in Tourism

Claudio A.G. Piga\*

Loughborough University, Economics Department

Leicestershire, Loughborough, LE11 3TU

tel. (+44)(0)1509-222755, fax. (+44)(0)1509-223910

email: eccagp@lboro.ac.uk

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## Abstract

The paper studies the characteristics and the effects of a tax imposed by a local government on the land used to create new tourists' accommodations. First, a dynamic policy game between a monopolist in a tourist area and a local government is considered. In each period the former has to decide the size of land undergoing development, whereas the latter has to choose the tax to levy on each newly developed area unit. Linear Perfect Markov strategies are derived for both the non-cooperative and the public monopoly case. In equilibrium, a public monopoly would develop land more rapidly than a private monopoly. Furthermore, the more the monopolist discounts the future, the more the long run use of the natural resource is reduced. Second, the properties of the tax are studied considering an oligopolistic market structure. The tax alone does not lead to the socially optimal level of land use. However, its combined effect with another policy instrument such as a quota, induces the optimal level of resource use.

Keywords: Differential game, land use, tourism, taxation.

JEL classification: H21, Q32, R52

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# 1 Introduction

Environmental quality is an extremely important input in the tourist industry. But tourism also makes extensive use of environmental resources, thereby jeopardising its main “*raison d’être*” and hence its long term viability. Thus, local government can play a pivotal role in encouraging sustainable forms of tourism (Sinclair and Stabler, 1997).

Land, which is used to build holiday accommodations, represents the natural resource under study. More precisely, in each period a developer has to decide the size of territory to develop, i.e. the increase in capacity. A local government levies a tax per unit of newly developed territory. The tax is announced before the developer takes a decision on how much land is to be built. Following Benchekroun and van Long (1998) and Tahvonen (1996) *inter alia*, the interaction between the developer and the public authority is analysed as a Stackelberg differential game. At a first glance, allowing a strategic advantage to the local government, i.e. making it the leader, may not appear plausible because in practice the government might be induced to yield to the requests of the developer, in order to lessen the pressure due, for instance, to regional labour market problems. However, elsewhere I report the case study of the “Master Plan” in Sardinia, Italy, where the local Sardinian government resisted the “sirens’ song” of an influential tourist developer in Costa Smeralda, because the developer’s project was deemed environmentally unsustainable (Piga, 1999). In particular, the Sardinian government behaved like a Stackelberg leader when it declared its commitment to uphold the existing territorial planning legislation and to refuse special permissions to the private developer to build within 300 metres from the coastline. It is noteworthy that Sardinia is characterised by one of the highest level of unemployment in Italy (46% is the youth unemployment rate, while the total rate is 21%) and that the estimated number of new jobs from the project was about 12,000. Nonetheless, the Sardinian government did not alter its position when the developer took the decision to withdraw the project. Furthermore, from a practical viewpoint, the fact that planning rules are a “given” for any developer constitutes an example of local governments’ leadership, although it does not necessarily rule out the possibility that those rules are designed to facilitate, rather than restrain, development. Indeed, to take this into account in this paper the government’s pay-off function is modelled in a flexible way that accommodates for different preferences towards environmental conservation.

The main objective of the paper is to show how a development tax can constitute a useful policy instrument in tourist areas with sensitive environmental features. To this

end, four cases are considered, whereby the characteristics and the effects of the tax are studied under different model's specifications and market structures. In the first, the Pareto optimal cooperative case is derived as a benchmark for the subsequent analysis. In the second, the agents behave non-cooperatively. A comparison between the first two cases shows that the tax is Pigouvian. However, more insights are obtained by looking at the differences in the two cases. Firstly, if the monopolist discounts time more than the local authority, an inverse relationship between land development and the discount rate is established, i.e. more land is used in the cooperative relative to the non-cooperative case. Rowthorn and Brown (1999) derive a similar relationship within an endogenous growth model. Secondly, it is shown that land exploitation occurs more slowly under the non-cooperative framework. Similar qualitative results are also found in Wirl (1994) and Tahvonen (1996), who consider the effects of a tax levied on energy consumption in, respectively, a Cournot and a Stackelberg dynamic game between energy producers and a government.

The third case demonstrates that the previous results are robust to a different specification of the local government's pay-off function. Furthermore, it identifies situations where the optimal tax is always increasing, decreasing or constant over time.

The fourth case shows that, under a duopolistic market structure, to prevent a "Tragedy of the Commons" situation from arising, the optimal tax has to be discontinuously increased to eliminate the firm's incentive to continue development. This policy can be generalised to the case of a market structure consisting of more than two firms.

Barnett (1980) shows that the optimal tax on effluents generated by a monopolist may be less than the marginal effluent harm. Indeed, a higher tax would induce the monopolist to further reduce the level of production and, consequently, the consumer's surplus. Ebert and von dem Hagen (1998) develop a model where consumption and production costs depend on the level of emissions. They obtain a result similar to Barnett's for the optimal tax when pollution and the monopolist's product are complements, and the opposite result when they are substitutes. In this paper, the optimal tax levied by the local government is always above the marginal damage, except in steady state where they are equal. This is due to the re-distributive role of the tax, which is used by the government to appropriate some of the profits of the foreign developer.

To my knowledge, there is no formal model explicitly linking tourism, its use of natural resources and policy intervention. But there exists an empirical literature linking tourist demand and environmental quality. Bell and Leeworthy (1990) find, using a sample of Florida's tourists, that a higher perceived level of crowdedness increases the number of days spent at saltwater beaches and, hence, the extra-market value of the

beaches' services and resources. Such a finding can be explained by taking into account the social dimension associated with the consumption of many leisure activities, where the demand of one consumer can depend on the demands by other consumers (Becker, 1991).<sup>1</sup> Using data from the Balearics Islands, Font (2000) finds that the areas least altered by man, with the lowest levels of environmental alterations and more vegetation are most frequented by tourists. This is in line with the assumption in this paper that the price of a holiday is positively related to the quality of a destination's environment. That is, tourists are willing to pay a higher price to stay in a non-crowded resort.

The following section lays out the model. The socially optimum equilibrium is characterised in Section 3, whereas the dynamic Stackelberg game is solved in Section 4. Section 5 adopts a different specification for the local government's pay-off function. The oligopoly case is developed in Section 6. Section 7 concludes. The Appendix contains the proofs of the main propositions.

## 2 Model Specification

### 2.1 The monopolist's profit function

We consider a territory of size  $\bar{L}$ , privately owned by a monopoly. In each period the monopolist has to decide the rate of land exploitation, that is, the portion of the territory on which new tourist facilities (hotels) will be erected. Denote the rate of exploitation as  $\sigma(t)$ . Thus, the stock of built territory,  $\mathcal{B}(t)$ , evolves over time as follows:

$$\dot{\mathcal{B}}(t) = \sigma(t); \quad \sigma(t) \in \mathcal{R}_+; \quad \mathcal{B}(0) = 0; \quad \mathcal{B}(t) \leq \bar{L}. \quad (1)$$

The previous expression indicates that the development is irreversible, its initial size is nil and it is not subject to depreciation.<sup>2</sup> Through appropriate normalisation, capacity, i.e. the number of rooms in the establishment, can be expressed as equal to the size of developed territory:  $K(t) = \mathcal{B}(t)$ . Development costs are equal to  $C_d(t) = \frac{1}{2} \sigma^2(t)$ .<sup>3</sup> The model depicted so far highlights the well-known impact of

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<sup>1</sup>Bell and Leeworthy (1990) do not report the estimates of two other measures of environmental quality used in their study, i.e. the *perceived cleanliness of waters* and the *physical appearance of the site*, which, if negative, would indicate that social factors, and not environmental considerations such as those assumed in this paper, drive tourist demand in their sample.

<sup>2</sup>Ageing of the buildings entails costs for maintenance, redecoration and refurbishing. These are, without loss of generality, normalised to zero.

<sup>3</sup>The extreme assumption of diminishing return in development can be mitigated by considering a more general cost function, in which the development costs depend also on the stock of built territory:  $C_d = \frac{1}{2} \sigma(\sigma \pm B)$ . In the case of the 'minus' sign, a learning by doing effect is present. On the other hand, the 'plus' sign cannot be ruled out because, as the project progresses, a ricardian diminishing

tourist development on environmental quality: maintaining the resource base intact is impossible if some level of tourist activity takes place.

As discussed in the Introduction, the importance of the environmental quality in the tourist industry is reflected in the trade-off for the monopolist between the size of the development and the price of a holiday.<sup>4</sup> The following inverse demand function emphasises that tourists are willing to pay more if the resort is not too intensely exploited:

$$p(t) = a + \bar{L} - \mathcal{B}(t), \quad 0 < a < \bar{L}; \quad (2)$$

Indeed, this expression shows that the price charged in each period depends positively on  $\bar{L} - \mathcal{B}(t)$ , that is, the amount of land which is not built upon. However, it can be argued that visitors have some interior “*degree of developedness*” which they prefer and which trades-off the desire for facilities, other visitors and local inhabitants to interact with etc., with the desire to not to be entirely surrounded by concrete. This would imply a demand function that, at least at low levels of capacity, is upward sloping, as Becker (1991) demonstrates. Thus the present analysis is therefore applicable to resorts where the visitors’ psychological carrying capacity has been reached, and an extra visitor provides a negative externality to the existing tourists. However, even if the territory was entirely developed ( $\mathcal{B} = \bar{L}$ ), consumers would still attribute a positive value to their visits, given by  $a$ , which depends on the other site features that are exogenous to our model.

## 2.2 The government’s objective function

The local government may levy a tax, denoted as  $\psi(t)$ , on each unit of newly built territory. Thus, the first element of the government’s instantaneous pay-off function is represented by the tax receipts,  $\psi(t)\sigma(t)$ , which are redistributed within the generation that collects them.

Because in many tourist destinations the great majority of tourists and tourism enterprises come from abroad, I assume that the consumer surplus enjoyed by the tourists and the profits made by the developer do not enter specifically into the government’s utility function.

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return effect can compel the monopolist to choose less advantageous sites for its buildings. In both cases, no meaningful insights are gained, which is why the simpler cost specification is chosen.

<sup>4</sup>It has to be stressed that the product sold is a perishable good such as a holiday and not a durable good such as a house, because, as Coase (1972) first pointed out, a monopoly selling a durable good will behave differently from the familiar monopoly selling a flow good. See Tirole (1988) for a further discussion of the Coase conjecture.

However, the second part of the government’s pay-off function consists of the net value derivable from the use of the land. On the one hand, its development generates a multiplier/growth effect on the local economy that can also include the surplus enjoyed by the locals buying a holiday from the developer. On the other, development engenders environmental costs and loss for the local population in non-use benefits such as bequest, option and existence values (Pearce et al., 1989).

The “net local value function” ( $NLVF$ ) represents the net effect of these two opposing forces:

$$NLVF(\mathcal{B}(t)) \equiv \beta(\bar{L} - \mathcal{B}(t)). \quad (3)$$

Such specification deserves further explanation. For  $\beta > 0$ , the  $NLVF$  depends positively on the size of the undeveloped territory. That is, the environmental costs from development exceed the multiplier/growth benefits. In the other case, when  $\beta < 0$ , the  $NLVF$  is increasing in the size of the development and the multiplier effect dominates. In this case, the  $NLVF$  corresponds to the loss in income due to foregone development. To sum up, a positive  $\beta$  represents the marginal value of a unit of undeveloped territory, whereas a negative  $\beta$  corresponds to the net income loss from leaving a unit of territory undeveloped.

Finally, the interpretation of  $\beta$  can be further extended so as to incorporate into the model other aspects which are taken into account in the literature on sustainable development. When positive, I argue that the definition of  $\beta$  by the public authorities should reflect concerns on the preservation of the natural system complexity and its resilience, in the sense that a higher value of  $\beta$  should be associated with a frailer natural system (Barbier and Markandya, 1990).

### 3 The publicly owned monopoly.

The Pareto socially optimal solution provides a benchmark for our analysis. In this framework, the monopolist and the local authority are combined into a single entity, that is a social planner who has to solve the following problem:

$$\max_{\sigma_c(t)} \int_0^\infty e^{-\rho t} \left[ \mathcal{B}_c (a + \bar{L} - \mathcal{B}_c) - \frac{1}{2} \sigma_c^2 + \beta (\bar{L} - \mathcal{B}_c) \right] dt \quad \text{s.t.} \quad \dot{\mathcal{B}}_c = \sigma_c, \quad (4)$$

where  $\rho$  denotes the time invariant government’s discount rate, the maintenance and production costs are normalised to zero, subscript  $c$  the cooperative outcome and



the time arguments are suppressed.

**Proposition 1** *The optimal exploitation rule in the cooperative problem (4) is*

$$\sigma_c^*(t) = -4 \frac{\mathcal{B}_c(t)}{\rho + \sqrt{(\rho^2 + 8)}} + 2 \frac{a + \bar{L} - \beta}{\rho + \sqrt{(\rho^2 + 8)}}. \quad (5)$$

The state variable  $\mathcal{B}_c(t)$  evolves along the following time path with steady state in  $\mathcal{B}_c^{ss}$ :

$$\mathcal{B}_c(t) = \mathcal{B}_c^{ss} - \frac{1}{2} \left[ (a + \bar{L} - \beta) e^{-\frac{4}{\rho + \sqrt{(\rho^2 + 8)}} t} \right], \quad (6)$$

$$\mathcal{B}_c^{ss} = (a + \bar{L} - \beta)/2. \quad (7)$$

As (5) shows, the land exploitation rule is declining in time. Indeed, the biggest portion of territory is developed at the beginning of the planning horizon, when  $\mathcal{B}_c(0) = 0$ . The rationale behind such a choice is clear: it is optimal to build the capacity as soon as possible, because an extra unit of capacity today generates revenues forever. Such a result emphasises the importance of the chosen dynamic approach, as no insights of this kind can be obtained in a static model.

Higher values of  $\beta$  affect negatively both the rate of exploitation and the steady state level of the stock of built territory. Of course, this result is inverted when the  $\beta$  is negative, that is, when the growth benefits overcome the environmental costs.<sup>5</sup>

## 4 The noncooperative case

The framework used in this section to analyse the interaction between the monopolist and the local government is that of a differential game. To solve the game, a Stackelberg equilibrium in linear Markov-Perfect strategies is derived (Benchekroun and van Long, 1998; Başar and Olsder, 1995; Dockner et al., 2000; Mäler and de Zeeuw, 1998). Başar and Olsder (1995, 375-85) and Dockner *et al.* (2000, 141-42) distinguish between a feedback and a global Stackelberg solution.<sup>6</sup> The former implies that in each period the leader/government first announces a given level of tax, and then the monopolist decides the size of the territory on which new capacity will be built. In this case, the government only faces a stagewise advantage over the developer. The latter assumes that the follower knows the rule that the leader will use throughout the game. That is, the government announces at the outset of the game that the tax rule is given by the strategy  $\psi^* = \psi(\mathcal{B})$ . Then the follower, taking this rule as given, seeks to maximize her

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<sup>5</sup>When  $\beta = 0$ , only the profits from the establishment are taken into account in (4): this is the case where a private monopolist operates without any State intervention.

<sup>6</sup>This point was raised by an anonymous referee.

objective function. However, for the models considered in this paper it can be shown that when the global tax rule is a linear affine function of  $\mathcal{B}$ , namely  $\psi(\mathcal{B}) = \alpha + \psi \mathcal{B}$ , the feedback and the global Stackelberg equilibria coincide (Proof available from the author on request).

Restricting the analysis to the Stackelberg case is a natural choice, as in practice it is the government that sets the rules by which developers have to abide. A counter-argument could be that rules may be set so as to please, rather than restrain, the developer. This would be tantamount to allowing the multiplier effects to be greater than the environmental costs, a case we tackle by considering the consequences of a negative  $\beta$  and by the further analysis in Section 5.

The monopolist and the policymaker maximise the discounted infinite flow of instantaneous pay-offs, respectively given by (subscript  $nc$  denotes the non cooperative solution):

$$\max_{\sigma_{nc}} V_1(\mathcal{B}) = \int_0^{\infty} e^{-\rho_1 t} \left[ \mathcal{B}_{nc} (a + \bar{L} - \mathcal{B}_{nc}) - \psi_{nc} \sigma_{nc} - \frac{1}{2} \sigma_{nc}^2 \right] dt \quad (8)$$

and

$$\max_{\psi_{nc}} V_g(\mathcal{B}) = \int_0^{\infty} e^{-\rho_g t} [\psi_{nc} \sigma_{nc} + \beta (\bar{L} - \mathcal{B}_{nc})] dt \quad (9)$$

$$\text{both s.t. } \dot{\mathcal{B}}_{nc} = \sigma_{nc}.$$

The discount rate of the government and the private monopolist, denoted respectively as  $\rho_g$  and  $\rho_1$ , differ so as to consider the possibility that these two agents might give different weights to future pay-offs. As Rowthorn and Brown (1999, p.322) explain, “*one way to encourage conservation would be to use a low discount rate for species while maintaining a high discount rate for consumption goods. ... when conservationists call for a low discount rate for environmental profit, they are tacitly assuming that the discount rate for the consumption goods will remain high*”. Hence, we assume  $\rho_1 > \rho_g$ , that is, public authorities discount the future less than a private agent.

The Bellman equation for the monopolist’s autonomous infinite horizon problem is:

$$\max_{\sigma} \rho_1 V_1(\mathcal{B}) = \mathcal{B} (a + \bar{L} - \mathcal{B}) - \psi \sigma - \frac{1}{2} \sigma^2 + (V_1'(\mathcal{B})) \sigma, \quad (10)$$

where  $V_1(\mathcal{B})$  denotes the monopolist’s value function for the game which starts at  $\mathcal{B}$ . It can be interpreted as the maximum price that the monopolist would be willing to pay to buy the land or as the maximum lump-sum tax that the local government can impose on the monopolist. The time arguments and the subscript  $nc$  are neglected as

no confusion can arise. Applying f.o.c. yields:

$$\sigma^* = V'_I(\mathcal{B}) - \psi. \quad (11)$$

In each period the marginal cost of an extra unit of developed territory must be equal to the marginal intertemporal benefit it provides. That is, the marginal benefit for the monopolist of the last unit of developed territory must equal the marginal cost represented by the development tax.

The government's Bellman equation is defined as:

$$\max_{\psi} \rho_g V_g(\mathcal{B}) = \psi\sigma + \beta (\bar{L} - \mathcal{B}) + (V'_g(\mathcal{B})) \sigma, \quad (12)$$

where  $V_g(\mathcal{B})$  denotes the government value function for the game starting at  $\mathcal{B}$ . After substituting (11) into (12), the f.o.c. in the government problem yields:

$$\psi^* = \frac{1}{2} [V'_I(\mathcal{B}) - V'_g(\mathcal{B})] \quad (13)$$

Therefore, the government behaves like a Stackelberg leader, as it incorporates the monopolist's optimal choice before deciding its optimal strategy. Thus, the optimal tax depends on the difference between the **shadow prices** of land for the developer and the government. Moreover, in steady state  $\sigma^{ss} = 0$ . Hence, from (11) we have:

$$V'_I(\mathcal{B}^{ss}) = V'_g(\mathcal{B}^{ss}) = \psi^{ss}. \quad (14)$$

**Proposition 2** *For the policy game identified by (8) and (9), there exists a unique (global) feedback Stackelberg equilibrium in linear and stable Markov Perfect strategies for the exploitation rate,  $\sigma_{nc}^*(t)$ , and the tax level,  $\psi_{nc}^*(t)$ :*

$$\sigma_{nc}^*(t) = -\frac{2\rho_g}{\rho_g\rho_I + \Omega} \mathcal{B}_{nc}(t) + \frac{(a\rho_g + \bar{L}\rho_g - \beta\rho_I)}{\rho_g\rho_I + \Omega}, \quad (15)$$

$$\psi_{nc}^*(t) = \frac{-2(\rho_g^2 + 2\Omega)\mathcal{B}_{nc}(t) + (\rho_g^2 + 2\Omega)(a + \bar{L}) + (2\rho_I^2 + \Omega)\beta}{(2\rho_I + \rho_g)(\rho_g\rho_I + \Omega)}, \quad (16)$$

$$\text{where } \Omega = \sqrt{\rho_g(\rho_g\rho_I^2 + 4\rho_I + 2\rho_g)}. \quad (17)$$

**Proof:** See Appendix.

The exploitation rule in (15) follows a pattern similar to that identified in Proposition 1. That is, it is declining in time and depends linearly and negatively on the stock of developed land. The government's optimal response is to impose a tax with a downward time trend, thereby providing the monopolist with an incentive to postpone development.

In time, the magnitudes of both choice variables decrease as the stock of built territory grows, until they reach their steady state values.

**Proposition 3** *The steady state values for the tax level, the price and the built territory are:*

$$\psi_{nc}^{ss} = \frac{\beta}{\rho_g} \quad (18)$$

$$p_{nc}^{ss} = \frac{1}{2} \left( a + \bar{L} + \frac{\beta \rho_1}{\rho_g} \right) \quad (19)$$

$$\mathcal{B}_{nc}^{ss} = \frac{1}{2} \left( a + \bar{L} - \frac{\beta \rho_1}{\rho_g} \right). \quad (20)$$

**Proof:** See Appendix.

Different policy conclusions can be drawn depending on the sign of  $\beta$ . First, relative to the case of a positive  $\beta$ , the instantaneous tax in (16) is always lower when  $\beta < 0$ .

Second, when  $\beta < 0$ , at time  $t = 0$  the tax is positive. However, as the rate of land development declines, it is optimal for the local government to reduce the tax, until it becomes negative, i.e. a subsidy (see (18)). Such a switch in policy would not occur when  $\beta > 0$ .

An inspection of (7) and (20) reveals that, when  $\rho = \rho_1 = \rho_g$ , the steady state value for the stock of developed land is the same in both of the cases considered. Therefore, since the imposition of a tax leads to the Pareto optimal use of the territory, the tax considered here is Pigouvian. Once again the interpretation of the Pigouvian nature of the tax hinges on the sign of  $\beta$ . Consider  $\beta > 0$ . As (18) shows, in steady state the tax is equal to the government's present discounted value of the marginal cost of developing a unit of land. As the tax is declining over time, *a fortiori* the tax is always above the marginal damage. By the same token, when  $\beta < 0$ , the subsidy is always below the government's marginal benefit, and, as we have seen, can be even negative, i.e. a tax.

These findings depend crucially on the particular role played here by the tax, which differs from that in Barnett (1980) and Ebert and von dem Hagen (1998) where the social planner maximises the sum of producer's and consumer's surplus. As we have outlined in section 2.2, many tourist destinations around the world attract foreign visitors who buy their holidays from international enterprises. Thus the local government need not be concerned of the surplus that tourists enjoy or the profit that the firm makes. Under these circumstances, the tax on land can serve the purpose of redistributing some of the monopolist's profit in favour of the local government. This is only possible if the tax is above the marginal damage or the subsidy is not introduced

from the outset but only at a later stage of development.

Interestingly, when  $\beta > 0$  and  $\rho_1 > \rho_g$ , (20) shows that the use of the territory under two independent agents acting non-cooperatively is unambiguously less than that obtained under a single social planner.<sup>7</sup> Thus, in situations where the private developer discounts the future more than the government, the use of the natural resource is lower than in the case when the two agents have the same discount rate. Moreover, land use in the non-cooperative case is greater than the social optimum when the government discounts the future more heavily than the developer.

**Proposition 4** *The built territory describes the following time trajectories:*

$$\mathcal{B}_{nc}(t) = \mathcal{B}_{nc}^{ss} + \frac{1}{2} \left( \frac{\beta \rho_1}{\rho_g} - \bar{L} - a \right) e \left[ -\frac{2\rho_g}{\rho_g \rho_1 + \Omega} t \right]. \quad (21)$$

If  $\rho = \rho_1 \geq \rho_g$ , then a comparison of (6) with (21) reveals that in the cooperative setting the rate of territory exploitation occurs at a faster speed than in the non-cooperative framework.

**Proof:** See Appendix.

It is noteworthy that, when  $\rho_1 \geq \rho_g$ , the development tax slows the rate of land exploitation, relative to the case of a public monopoly. Together, (20) and (21) highlight the beneficial effects of tax on the natural resource and hence emphasise the active role that the local authorities can play in order to implement environmentally conscious policies. Furthermore, the tax generates results consistent with the rules traditionally imposed by territory planners. For instance, construction is not usually allowed in a park. When  $\beta$  is big, as in a natural park, the level of the announced tax should be so high that the monopolist would not find it profitable to develop the site.

## 5 An alternative specification.

Thus far, the  $NLVF$  was either positive or negative over the entire planning horizon. This implies that the environmental values of the resource always overcome the increase in local income generated by the tourism development, or vice versa. In this section, I consider a formulation of the  $NLVF$  such that, at an early stage of development, the growth effect dominates the environmental one, but, as the development progresses, the environmental cost of development outweighs its benefits:

$$NLVF(t) = \mathcal{B}(t) - \gamma \mathcal{B}^2(t) \quad (22)$$

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<sup>7</sup>The opposite conclusion can be drawn when  $\beta < 0$ .

where  $\gamma > 0$  measures the significance of the environmental opportunity costs previously discussed.

The analysis is carried out as in Section 4. Most of the previous results still hold under this specification. In particular, the tax is still Pigouvian and, relative to the cooperative framework, the tax determines a slower rate of land use.

**Proposition 5** *If (22) is substituted in (9), the policy game given by (8)-(9) has a unique (global) feedback Stackelberg equilibrium in linear Markov Perfect strategies for the rate of land use,  $\tilde{\sigma}(t)$  and the tax level  $\tilde{\psi}(t)$ :*

$$\tilde{\sigma}(t) = -\frac{2(\rho_g + \gamma\rho_1)}{\rho_1\rho_g + \Upsilon}\tilde{\mathcal{B}}(t) + \frac{\rho_g(a + \bar{L}) + \rho_1}{\rho_1\rho_g + \Upsilon}, \quad (23)$$

$$\tilde{\psi}(t) = \frac{[2\gamma(\Upsilon + 2\rho_1^2) - 2\rho_g^2 - 4\Upsilon]\tilde{\mathcal{B}}(t) + \rho_g^2(a + \bar{L}) + \Upsilon(2a - 1 + 2\bar{L}) - 2\rho_1^2}{(\rho_g + 2\rho_1)(\rho_1\rho_g + \Upsilon)} \quad (24)$$

where  $\Upsilon = \sqrt{2\gamma\rho_1\rho_g + 4\rho_1^2\gamma + 4\rho_1\rho_g + 2\rho_g^2 + \rho_g^2\rho_1^2}$ . The steady state values are:

$$\tilde{\mathcal{B}}^{ss} = \frac{1}{2} \frac{\rho_g(a + \bar{L}) + \rho_1}{\rho_g + \gamma\rho_1} \quad (25)$$

$$\tilde{\psi}^{ss} = \frac{\gamma(a + \bar{L}) - 1}{\rho_g + \gamma\rho_1} \quad (26)$$

**Proof:** The proof is available from the author on request.

The rate of land exploitation in (23) keeps its declining profile but, from (24), the tax may now increase, remain constant or decrease over time for, respectively,  $(2\gamma(\Upsilon + 2\rho_1^2) - 2\rho_g^2 - 4\Upsilon) \gtrless 0$ , with the negative sign occurring for low enough values of  $\gamma$  and high enough values of  $\rho_1$  and  $\rho_g$ .

Two points are noteworthy. First, (24) and (26) indicate that, for low enough values of  $\gamma$ , there exists a point in time,  $\tilde{t} > 0$ , where the local government switches its regulatory regime and turns the tax into a subsidy.

Secondly, a significant environmental externality dictates an upward trend in the tax. At low levels of development, postponing the investment is not the optimal response, as the benefits from growth outweigh the costs. An increasing tax prevents further development when the environmental cost becomes conspicuous. A similar result is obtained in Ulph and Ulph (1994), where the time profile of a carbon tax is increasing over time whenever the GNP loss from having to cut CO<sub>2</sub> emissions is greater than the damage done.

## 6 The oligopoly case

The analysis in this section considers how the tax has to be modified when two, or more generally  $n$ , developers operate on the same territory. The analysis shows that in these circumstances, excess exploitation occurs unless the optimal tax is discontinuous over time. That is, a jump in the level of the land tax is required to establish the socially optimum outcome.

Consider, for simplicity, two firms operating on a territory of size equal to  $\bar{L}$ . If we assume homogenous quality in the two adjacent sites, the price equation (1) becomes:

$$p(t) = a - \bar{L} - \mathcal{B}_1(t) - \mathcal{B}_2(t), \text{ with } \dot{\mathcal{B}}_1 = \sigma_1 \text{ and } \dot{\mathcal{B}}_2 = \sigma_2. \quad (27)$$

That is, now  $\sigma_i$  and  $\dot{\mathcal{B}}_i$ ,  $i = 1, 2$  identify, respectively, the firms' development rates and capacities located on a territory under the administration of a local government, whose objective function is represented as in (9).

**Proposition 6** *Assuming equality of the discount rates ( $\rho_1 = \rho_2 = \rho_g = \rho$ ), the steady state values of the size of territory developed by each firm is:*

$$\mathcal{B}_1^{ss} = \mathcal{B}_2^{ss} = \frac{a + \bar{L} - \beta}{3} \quad (28)$$

*That is, the total use of land in the unrestricted duopoly case exceeds the social optimum (see the Appendix for a proof).*

This indicates that even in the simplest context considered in the paper, the tax alone fails to limit the use of land to the optimal level when two or more firms operate. This is due to the fact that in oligopolistic markets, a firm does not internalise the negative effects on the other firms' revenues that result from an increase in its capacity. Hence, firms develop more territory and their revenues are reduced. The tax therefore capture less rents for the government, which then has an incentive to allow more development. This implies that land use increases with the number of firms operating in the market. However, in order to reconcile the analysis in the preceding sections with the case of an oligopolistic market structure, we show that the development tax can re-establish the Pareto outcome when the following constraint is imposed to the government maximization problem:

$$\mathcal{B}_1 + \mathcal{B}_2 \leq \mathcal{B}_c^{ss} = \frac{a + \bar{L} - \beta}{2}. \quad (29)$$

That is, the total amount of territory firms are allowed to develop cannot exceed the socially optimal level given in (7). Such a constraint is equivalent to the imposition of a quota on the total number of tourists that can visit the territory. To deal with

this state-space constraint, we adopt the modified version of the Maximum Principle described in Chiang (1992, pp. 298-313).

**Proposition 7** *Under the exploitation time path implied by (28), there exists a point in time  $\tau$  when the constraint (29) becomes binding, with  $\mathcal{B}_1(\tau) = \mathcal{B}_2(\tau) = \frac{\mathcal{B}_c^{ss}}{2}$ . At  $\tau$ ,  $\psi(\tau) = \frac{a+\bar{L}+3\beta}{4\rho}$ . The optimal policy is to increase  $\psi(\tau)$  by an amount equal to the value of the Lagrange multiplier,  $\theta$ , attached to the space constraint (29):  $\theta(\tau) = \frac{a+\bar{L}-\beta}{4\rho}$  (See the Appendix for a proof).*

The discontinuous increase is made necessary to prevent further development. Indeed, at time  $\tau$  the market price is, from (19),  $p(\tau) = (a + \bar{L} + \beta)/2$ : for the tourism industry as a whole, the total discounted value of an extra unit of developed land would therefore be  $\frac{p(\tau)}{\rho}$ , which equals the sum  $\psi(\tau) + \theta(\tau)$ .

With a greater number of firms, the jump in the tax would still be necessary to realign the private and the public interests. The timing of the policy change would be brought forward by an increase in the number of firms, as more firms would exploit the natural resources more quickly. However, the magnitude of the tax increase is not affected by the number of firms, as it depends solely on the shadow price of land evaluated when  $\mathcal{B}(\tau) = \mathcal{B}_c^{ss}$ .

In practical terms, when imposing the constraint the government is effectively applying a quota restriction on the number of visitors. The quota is set at a level that represents the territory's carrying capacity or, equivalently, the socially optimal level of the land use. Although carrying capacity can be difficult to quantify, it constitutes an essential element for tourism planning in real-world situations. For instance, McIntyre (1993) reports that in Goa, India, the application of the standard of one meter of beach frontage per tourist bed results in an overall regional maximum development of 46,000 tourist beds, with no more than 35 km of beach frontage expected to be utilized for development.

To conclude, the analysis in the present section shows that when an oligopolistic market is considered, the socially optimal outcome can be achieved if the development tax is complemented by another policy instrument, namely a quota on the number of tourists. As shown in the previous sections, the tax continues to play an essential role in so far as it enables the government to appropriate some of the surplus generated by the tourism development and it slows down the rate of land use, thereby postponing the negative effects associated with development.



## 7 Conclusion

The impacts of tourist activity on the natural environment are manifold: their long-term effects are therefore difficult to predict. The interest in the use of different policy instruments (information and education, taxation and subsidies, permissions and quota, legal instruments), under various circumstances, is growing (Hunter and Green, 1995). A recent study by Cremer and Thisse (1999) shows that taxation proves to be a robust environmental policy instrument in imperfectly competitive markets where consumers, like in the present case, are willing to pay more to buy an environmentally friendly product.

In this paper, the properties of a development tax on land are studied by considering different specifications of the government's pay-off function and different market structures. Focussing on such an instrument constitutes a natural choice, as it is traditionally used in a great number of countries. The optimal tax exhibits some noteworthy features. First, it is Pigouvian. Second, it may become negative (i.e. a subsidy) when the damage level from environmental degradation is low and tourism spurs growth. However, the government should never offer the subsidy at the starting point of the development, especially if it cannot make sure that the great bulk of profits generated by tourism is kept within the regional/national borders.

Furthermore, the tax induces a slowing down in the speed with which a private monopolist develops land, relative to the case where/ the developer is a public enterprise. Such a result implies that concerted forms of tourism development between a private agent and the public authority may not be necessary and could result in a faster exploitation of the natural resource. More precisely, the results show that the best outcome from an environmental point of view is obtained when the local government uses its strategic role as a Stackelberg leader and commits to an optimal, sub-game perfect taxation policy. The optimal level of the tax, in each period, depends, among other things, on the weight given to the concerns regarding the preservation of the natural system complexity and its resilience.

Finally, the application of the development tax needs to be accompanied by another policy instrument, namely a quota on the number of tourists, to obtain the Pareto outcome under an oligopolistic market structure. Such a result is consistent with the observation that both the tax and the land-use planning systems are jointly used to regulate the tourist industry in practice (Sinclair and Stabler, 1997, pp.207–211).

## Appendix

**Proof of Propositions 2, 3 and 4** By assigning (13) and (11) to the Bellman equations (10) and (12), we obtain a system of differential equations, with unknowns  $V_i(\mathcal{B})$ ,  $i = 1, 2$ :

$$\begin{cases} 8 \mathcal{B} (a + \bar{L} - \mathcal{B}) + (V_1'(\mathcal{B}) + V_g'(\mathcal{B}))^2 - 8 \rho_1 V_1(\mathcal{B}) = 0, \\ (V_1'(\mathcal{B}) + V_g'(\mathcal{B}))^2 + 4\beta(\bar{L} - \mathcal{B}) - 4\rho_g V_g(\mathcal{B}) = 0 \end{cases} \quad (30)$$

Given the linear-quadratic structure of the game, we know that the value functions  $V_i(\mathcal{B})$  are quadratic, that is,

$$V_1(\mathcal{B}) = \eta_1 \mathcal{B}^2 + \eta_2 \mathcal{B} + \eta_3, \quad (31)$$

$$V_g(\mathcal{B}) = \beta_1 \mathcal{B}^2 + \beta_2 \mathcal{B} + \beta_3, \quad (32)$$

which we substitute into (30) to get

$$\begin{cases} ((2(\beta_1 + \eta_1))^2 - 8(\rho_1 \eta_1)) \mathcal{B}^2 + (4(\beta_1 + \eta_1)(\beta_2 + \eta_2) + 8(a + \bar{L}) - 8\rho_1 \eta_2) \mathcal{B} + \\ (\beta_2 + \eta_2)^2 - 8\rho_1 \eta_3 = 0; \\ ((2(\eta_1 + \beta_1))^2 - 4\rho_g \beta_1) \mathcal{B}^2 + (4(\beta_1 + \eta_1)(\beta_2 + \eta_2) - 4\rho_g \beta_2 - 4\beta + 4\eta_2 \beta_1) \mathcal{B} + \\ 4\beta \bar{L} - 4\rho_g \beta_3 + (\eta_2 + \beta_2)^2 = 0 \end{cases} \quad (33)$$

These two expressions hold true if their terms multiplying  $\mathcal{B}^2$ ,  $\mathcal{B}$  and their constant terms are simultaneously equal to zero. To achieve this, we need to solve a system of six equations in the six unknowns  $\{\beta_1, \beta_2, \beta_3, \eta_1, \eta_2, \eta_3\}$ , which has the following sets of solutions:

$$\begin{cases} \eta_1^1 = \frac{\rho_g^2 \rho_1 - 2 \rho_g - 4 \rho_1 + \rho_g \Omega}{(\rho_g + 2 \rho_1)^2}, & \eta_2^1 = \frac{\rho_1 \rho_g (2a + 2\bar{L} - \beta) - \Omega (2a + 2\bar{L} + \beta) + 2\rho_g^2 (a + \bar{L})}{(\rho_g + 2 \rho_1)(\rho_1 \rho_g - \Omega)} \\ \beta_1^1 = 2 \frac{\rho_g + 2 \rho_1 + \rho_g \rho_1^2 + \rho_1 \Omega}{(\rho_g + 2 \rho_1)^2}, & \beta_2^1 = \frac{\rho_1 \rho_g (2a + 2\bar{L} - \beta) + \Omega (2a + 2\bar{L} + \beta) - 4 \beta \rho_1}{(\rho_g + 2 \rho_1)(\rho_1 \rho_g - \Omega)} \end{cases} \quad (34)$$

$$\begin{cases} \eta_1^2 = \frac{\rho_g^2 \rho_1 - 2 \rho_g - 4 \rho_1 - \rho_g \Omega}{(\rho_g + 2 \rho_1)^2}, & \eta_2^2 = \frac{\rho_1 \rho_g (2a + 2\bar{L} - \beta) + \Omega (2a + 2\bar{L} + \beta) + 2\rho_g^2 (a + \bar{L})}{(\rho_g + 2 \rho_1)(\rho_1 \rho_g + \Omega)} \\ \beta_1^2 = 2 \frac{\rho_g + 2 \rho_1 + \rho_g \rho_1^2 - \rho_1 \Omega}{(\rho_g + 2 \rho_1)^2}, & \beta_2^2 = \frac{\rho_1 \rho_g (2a + 2\bar{L} - \beta) - \Omega (2a + 2\bar{L} + \beta) - 4 \beta \rho_1}{(\rho_g + 2 \rho_1)(\rho_1 \rho_g - \Omega)} \end{cases} \quad (35)$$

where the values of  $\beta_3$  and  $\eta_3$  were omitted because of their irrelevance to the proof. Recalling (1), (11), (13) and the value functions (31)–(32), the differential equation expressing the law of motion for the state variable  $\mathcal{B}(t)$  becomes:

$$\dot{\mathcal{B}}(t) = (\eta_1 + \beta_1)\mathcal{B}(t) + (\eta_2 + \beta_2)/2. \quad (36)$$

Substituting the first solution set (34) and solving the differential equation yields:

$$\mathcal{B}_1(t) = \frac{1}{2} \left( a + \bar{L} - \frac{\beta \rho_1}{\rho_g} \right) + \frac{1}{2} \left( \frac{\beta \rho_1}{\rho_g} - \bar{L} - a \right) e^{-\frac{2 \rho_g}{\rho_g \rho_1 - \Omega} t}. \quad (37)$$

The above expression depicts an explosive path for the state variable, since  $\Omega > \rho_g \rho_1$ , and is therefore ruled out. When the second solution set (35) is substituted into (36), we obtain:

$$\mathcal{B}_2(t) = \frac{1}{2} \left( a + \bar{L} - \frac{\beta \rho_1}{\rho_g} \right) + \frac{1}{2} \left( \frac{\beta \rho_1}{\rho_g} - \bar{L} - a \right) e^{-\frac{2 \rho_g}{\rho_g \rho_1 + \Omega} t}, \quad (38)$$

which globally and asymptotically converges towards the steady state value (20).

Having shown that the game has a stable solution, it is straightforward to derive (15) and (16) by

assigning (35), (31) and (32) to (11) and (13). ■

**Proof of Propositions 6 and 7.** We will look for the open-loop Nash equilibrium of the following problems for, respectively, the duopolists and the local government:

$$\max_{\sigma_i^d(t)} V_i^d(\mathcal{B}_i, \mathcal{B}_j) = \int_0^\infty e^{-\rho t} \left[ \mathcal{B}_i^d(t) \left( a + \bar{L} - \mathcal{B}_i^d(t) - \mathcal{B}_j^d(t) \right) - \psi_{nc}(t) \sigma_i^d(t) - \frac{1}{2} \left( \sigma_i^d(t) \right)^2 \right] dt, \quad (39)$$

$$\text{s.t. } \dot{\mathcal{B}}_i^d(t) = \sigma_i^d(t), \dot{\mathcal{B}}_j^d(t) = \sigma_j^d(t), i, j = 1, 2; i \neq j$$

and

$$\max_{\psi_d(t)} V_g(\mathcal{B}_i, \mathcal{B}_j) = \int_0^\infty e^{-\rho t} \left[ \psi_d(t) \left( \sigma_i^d(t) + \sigma_j^d(t) \right) + \beta \left( \bar{L} - \mathcal{B}_i^d(t) - \mathcal{B}_j^d(t) \right) \right] dt \quad (40)$$

$$\text{s.t. } \dot{\mathcal{B}}_i^d(t) = \sigma_i^d(t), \dot{\mathcal{B}}_j^d(t) = \sigma_j^d(t) \text{ and } \mathcal{B}_i^d(t) + \mathcal{B}_j^d(t) \leq \frac{a + \bar{L} - \beta}{2}$$

First of all, the state-space constraint is transformed by taking the derivative w.r.t. time:

$$\frac{d \left( \mathcal{B}_i^d(t) + \mathcal{B}_j^d(t) - \frac{a + \bar{L} - \beta}{2} \right)}{dt}, \text{ so that the constraint becomes: } \sigma_i^d(t) + \sigma_j^d(t) \leq 0.$$

Given its leader role, it suffices to impose the constraint only on the government's problem, so that the usual conditions apply to the Hamiltonian of the duopolists (dependance on time is omitted):

$$\mathcal{H}_i^d = \left[ \mathcal{B}_i^d \left( a + \bar{L} - \mathcal{B}_i^d - \mathcal{B}_j^d \right) - \psi \sigma_i^d - \frac{1}{2} \left( \sigma_i^d \right)^2 \right] + \phi_{ii} \left( \sigma_i^d \right) + \phi_{ij} \left( \sigma_j^d \right) \quad i, j = 1, 2; i \neq j. \quad (41)$$

where  $\phi_{ii}$  and  $\phi_{ij}$  are the costate variable of the two usual constraints. Note that the same result would be obtained if the state-space constraint were applied to the duopolists' problems. Applying the Maximum principle yields:

$$\frac{d \mathcal{H}_i^d}{d \sigma_i} = 0 = -\psi - \sigma_i + \phi_{ii} \quad (42)$$

$$\dot{\phi}_{ii} = \rho \phi_{ii} - \frac{d \mathcal{H}_d}{d \mathcal{B}_i} = \rho \phi_{ii} - a - \bar{L} + 2 \mathcal{B}_i + \mathcal{B}_j; \quad i, j = 1, 2; i \neq j. \quad (43)$$

After substituting for  $\sigma_i$  from (42), the Hamiltonian for the government is:

$$\mathcal{H}_g = \psi \left( -2 \psi + \phi_{ii} + \phi_{jj} \right) + \beta \left( \bar{L} - \mathcal{B}_i - \mathcal{B}_j \right) + \phi_{gi} \left( -\psi + \phi_{ii} \right) + \phi_{gj} \left( -\psi + \phi_{jj} \right) + \theta \left( -2 \psi + \phi_{ii} + \phi_{jj} \right), \quad (44)$$

where  $\theta$  is the Lagrange multiplier associated with the modified state-space constraint. The conditions are:

$$\frac{d \mathcal{H}_g}{d \psi} = 0 = -4 \psi + \phi_{ii} + \phi_{jj} - \phi_{gi} - \phi_{gj} + 2 \theta \quad i, j = 1, 2; i \neq j \quad (45)$$

$$\frac{d \mathcal{H}_g}{d \theta} = \sigma_i^d + \sigma_j^d \geq 0; \quad \theta \geq 0; \quad \theta \frac{d \mathcal{H}_g}{d \theta} = 0 \quad (46)$$

$$\mathcal{B}_i^d + \mathcal{B}_j^d \leq \frac{a + \bar{L} - \beta}{2}; \quad \theta \left[ \frac{a + \bar{L} - \beta}{2} - \mathcal{B}_i^d + \mathcal{B}_j^d \right] = 0 \quad (47)$$

$$\dot{\phi}_{gi} = \rho \phi_{gi} - \frac{d \mathcal{H}_d}{d \mathcal{B}_i} = \rho \phi_{gi} - \beta, \quad i = 1, 2 \quad (48)$$

Notice that (28) can be obtained by simply disregarding the state-space constraint, that is, for  $\theta = 0$ . This also holds when the constraint is not binding, from (46). When the constraint is activated,  $\theta$  becomes positive. Hence,  $\sigma_i = \sigma_j = 0$ , which implies, from (42)  $\psi = \phi_{ii} = \phi_{jj}$ . The expression

in square brackets in (47) is also equal to zero. Substitute these findings in (45) and recall that in equilibrium  $\dot{\phi}_{gi} = \dot{\phi}_{gj} = 0$ . Finally, to find  $\psi(\tau)$ ,  $\theta(\tau)$ ,  $\mathcal{B}_1(\tau)$  and  $\mathcal{B}_2(\tau)$  in the Proposition, solve the system of ordinary equations made up by (43), (45), the expression in square brackets in (47) and (48). ■

## References

- Başar, T. and Olsder, G. (1995). *Dynamic Noncooperative Game Theory*. Academic Press, New York, 2nd edition.
- Barbier, E. B. and Markandya, A. (1990). The Conditions for Achieving Environmentally Sustainable Development. *European Economic Review*, 34:659–669.
- Barnett, A. H. (1980). The Pigouvian Tax Rule under Monopoly. *American Economic Review*, 70:1037–1041.
- Becker, G. S. (1991). A note on restaurant pricing and other examples of social influences on price. *Journal of Political Economy*, 99:1109–1116.
- Bell, F. and Leeworthy, V. (1990). Recreational Demand by Tourists for Saltwater Beach Days. *Journal of Environmental Economics and Management*, 18:189–205.
- Benckroun, H. and van Long, N. (1998). Efficiency inducing taxation for polluting oligopolist. *Journal of Public Economics*, 70:325–342.
- Chiang, A. C. (1992). *Elements of Dynamic Optimization*. McGraw-Hill, Int. Editions.
- Coase, R. (1972). Durable Goods Monopolists. *Journal of Law and Economics*, 15:143–150.
- Cremer, H. and Thisse, J. F. (1999). On the taxation of polluting products in a differentiated industry. *European Economic Review*, 43:575–594.
- Dockner, E., Jørgensen, S., van Long, N., and Sorger, G. (2000). *Differential games in economics and management science*. Cambridge University Press, Cambridge, UK.
- Ebert, U. and von dem Hagen, O. (1998). Pigouvian Taxes under Imperfect Competition if consumption depends on Emissions. *Environmental and Resource Economics*, 12:507–513.

- Font, A. R. (2000). Mass Tourism and the Demand for Protected Natural Area: a Travel Cost Approach. *Journal of Environmental Economics and Management*, 39:97–116.
- Hunter, C. and Green, H. (1995). *Tourism and Environment. A sustainable relationship?* Routledge, London.
- Mäler, K. and de Zeeuw, A. (1998). The Acid Rain Differential Game. *Environmental and Resource Economics*, 12:167–184.
- McIntyre, G. (1993). *Sustainable Tourism Development: Guide for Local Planners*. World Tourism Organization, Madrid.
- Pearce, D., Markandya, A., and Barbier, E. (1989). *Blueprint for a green Economy*. Earthscan Publications Ltd, London.
- Piga, C. A. (1999). Pigouvian Taxation and Sustainable Development in Tourism. Discussion Paper 01, De Haan Tourism and Travel Research Institute.
- Rowthorn, B. and Brown, G. (1999). When a High Discount Rate Encourages Biodiversity. *International Economic Review*, 40:315–332.
- Sinclair, M. T. and Stabler, M. (1997). *The economics of tourism*. Routledge, London and New York.
- Tahvonen, O. (1996). Trade with Polluting Nonrenewable Resources. *Journal of Environmental Economics and Management*, 30:1–17.
- Tirole, J. (1988). *The Theory of Industrial Organization*. MIT Press, Cambridge, MA.
- Ulph, A. and Ulph, D. (1994). The Optimal Time Path of a Carbon Tax. *Oxford Economic Papers*, 46:857–868.
- Wirl, F. (1994). Pigouvian Taxation of Energy for Flow and Stock Externality and Strategic, Noncompetitive Energy Pricing. *Journal of Environmental Economics and Management*, 26:1–18.