Common-Pool Resources, Ecotourism and Sustainable Development

Huang, Deng-Shing and Yo-Yi Huang*

Abstract

This paper establishes an ecotourism model to analyze the role of local residents and government in achieving sustainable development. By incorporating into the model the properties of common-pool resources to which the tourism activities are linked, we prove that ecotourism does not guarantee sustainable development for a rural area unless it is accompanied by suitable policies of reducing firm numbers and/or the levying of a tourist tax. More specifically, we find two stable equilibria: one characterized by low or even a zero level of natural resources, and the other has a high level of natural resources. In low equilibrium, the extinction or zero stock of natural resources occurs under open access of zero transport cost and marginal environmental maintenance cost. High equilibrium corresponds to greater social welfare, which can be guaranteed through policies of a tourist tax, license fee, limiting the number of firms, and restrictions on the population of potential tourists. More importantly, we prove that although high equilibrium is better than low equilibrium, it may not be socially optimal. The maximum welfare can only be achieved by a direct tax on tourists and not solely by policies controlling the number of firms.

Keywords: Ecotourism, Common-Pool Resources, Sustainable Development, Tragedy of Commons

JEL Classification: Q01, Q57, L83

---

* Huang, Deng-Shing, Research Fellow of Institute of Economics, Academia Sinica, No. 128, Academia Rd., Sec. 2, Nankang Dist., Taipei City 11529, Taiwan, R.O.C., Tel: 886-2-27822791 ext. 204, E-mail: dhuang@econ.sinica.edu.tw. Yo-Yi Huang, Professor of Applied Economics, National Taiwan Ocean University, No. 2, Beining Rd., Keelung City 20224, Taiwan, R.O.C., Tel: 886-2-24622192 ext. 5412, E-mail: hyy@ntou.edu.tw. We are grateful to the three anonymous referees for useful comments on the earlier version of this paper. Any remaining errors are our responsibility.

Received 5 January 2015; revised 27 April 2015; accepted 12 October 2016.

經濟研究 (Taipei Economic Inquiry), 53:1 (2017), 87-128。

臺北大學經濟學系出版

1. Introduction

Most remote and undeveloped areas are economically impoverished but biologically and environmentally rich, with clean air, water, charming landscapes, forests, wildlife, lack of noise etc. The combination of economic growth, progress in information and transportation technology, excessive urban growth and environmental consciousness elevates the attractiveness of rural areas. Thus, ecotourism is often considered a suitable development strategy for rural areas.

However, the natural resources upon which tourism relies are a typical type of common-pool resources (CPRs) as addressed by Hardin (1968) and later by Ostrom (1990) and Ostrom et al. (1999), characterized by the non-exclusiveness from one user to another. In addition, tourism activities are to some extent detrimental to the environment resources. As a result, overuse due to the common pool property of the resources will inevitably lead to a higher depletion rate than its intrinsic recovery rate. Thus, the natural resources begin to decline, and finally are fully exhausted and extinct unless the visitation rate of tourism can be controlled to a certain degree below the limit of the environmental carrying capacity.

In sum, the natural resources behind ecotourism, like all types of CPRs, are inherently subject to reciprocal externalities in the form of short-run congestion and long-run depletion. How to manage the natural resources and protect them from extinction is the key to making ecotourism for local development sustainable.

How to manage common-pool resources is a classic and important issue. Several approaches have been raised in the literature. Firstly, as advocated initially by Hardin (1968) and most recently by Holden (2005), there is a moral or environment ethic approach calling for the requirement of morality consciousness to make CPRs sustainable. However, in an experimental study, Osés-Eraso et al. (2008) show that that “concern” for resource scarcity is not enough to prevent resource depletion. Once players believe some others may not have the concern and anticipate the likelihood of depletion in the future, extraction activities will be sped up, leading to earlier depletion.

Secondly and not surprisingly, there is a “fences and fines” approach, calling for regulations to restrict access and thus to protect the natural resources. Typical examples are the establishment of national park and reservation areas. However, the fences-and-fines method is well documented in many regions and cases as having failed to stop the human behaviors of poaching, illegal logging, mining and destructive development activities such as land clearing.[1] Consequently, we observe a significant decline of wild life population, forest areas, etc.

Finally, probably the most debated in the literature is the market approach. The approach calls for designing a market-based measure to provide economic incentive, especially for indigenous communities, to protect common-pool resources. It is hoped that through such market mechanisms we can integrate harmoniously the conservation of natural resources and local community development. In this regard, ecotourism is often raised as one of the most popular and promising strategies in the last several decades, as addressed by Holden et al. (2014). However, as noted by Coria and Calfucura (2012), the success of ecotourism depends on three complicated aspects, (i) distribution of benefits, (ii) community control over land and resources, and (iii) power relations between the stakeholders. Thus, the effectiveness of ecotourism can be questioned.

Firstly, due to the involvement of many stakeholders, including not only local residents but also outside investors and government, and lack of a fair distribution mechanism,[2] only a very small portion of the tourism benefit goes to local communities, thus contributing very little incentive for local residents to protect common resources. Examples are the integrated conservation-development projects (ICDPs) widely established in Africa and other areas, as described in Barrett and Arcese (1995).

Secondly, there is an inherent income effect on resources conservation in the ICDPs. More specifically, there are two basic instruments in the ICDPs for the purposes of development and conservation: benefit-sharing of game meat distribution and monetary transfer from tourism to local residents. However, as analyzed in Barrett and Arcese (1998) and Johannesen (2006) in a bio-economic model, both instruments may in the

---

[1] See Barrett and Arcese (1995) and the references therein.

[2] See Coria and Calfucura (2012).

first step increase the income of local residents, which will in turn induce more demand for the game meat. Consequently, the illegal hunting becomes more severe, under the weak linkage between money transfer from tourism and fines for illegal hunting.

In addition to the small-portion reward problem and negative income effect, an important element, that is not considered in the above mentioned articles, but which should play a key role in the failure of ecotourism strategy, is market failure due to the common-pool property. Thus, the theme of this paper is to illustrate that the inherent properties of common goods can lead to market failure of ecotourism, even if all the tourism benefit goes to the local community. In other words, this paper will show that, while ecotourism is a commonly suggested strategy for a form of economic development in harmony with conservation of natural resources, the market mechanism itself cannot guarantee success without a suitable policy design.

As mentioned earlier, the natural resources behind ecotourism are in general characterized by common-pool properties. More specifically, local resident can operate tours and compete with each other to serve as many tourists as possible to maximize their own earnings. Thus intuitively, the common-pool theory in the existing literature on renewable resources such as the fishing industry can be applied directly.[3] However, there are some unique features of tourism products in contrast to other renewable resources, and thus tourism deserves special treatment in the modeling. First of all, since consumption of tourism products requires personal arrival, transportation cost is borne by the tourists. Thus, accessibility of the area, mainly the transport cost and/or regulation by the government, becomes an important factor in determining the market equilibrium. Secondly, demand for ecotourism service varies from individual to individual depending on the level of income, wealth, education and other personal features. In other words, visitors are heterogeneous in preference on tourism; more specifically, people usually gain different utility levels

---

3 Basically, we will borrow the approaches commonly adopted in fishing economics, i.e., optimal catching problem as in the related literature of Gordon (1954), Clark and Munro (1980), Berck and Perloff (1984), Clark (1990), Neher (1990), Fan and Wang (1998), Huang and Huang (2006), Huang et al. (2008), etc. to build our model by considering the unique properties of ecotourism to be discussed later.

from visiting the same natural resort. In this regard, the tourism product is different from other renewable resource products, and thus deserves different treatment, considering the degree of accessibility and the heterogeneous consumers.

The rest of this paper is organized as follows Section 2 establishes the model and solves for equilibrium under a free market. It will be shown that the opening up of tourism resources may lead to low- or high-level resource equilibrium, depending on the accessibility cost, number of operators and population of potential tourists. In extremes, under zero access cost and when the tourist population size is too large or local operators are too numerous, the tourism resources will become extinct, an ecotourism version of the tragedy of the commons. Section 3 conducts comparative statics to analyze the roles for access cost, number of operators, and tourist population in affecting the equilibrium, based upon which the policy implications for how to achieve high equilibrium through either a tax on tourists, imposing operation licenses or direct firm-number controls, will be discussed during the analysis. Section 4 turns to the welfare for the local community as a whole. We prove that even though the high-level equilibrium is better than the low-equilibrium, it may not be optimal; the optimal level of welfare cannot be achieved by merely the firm-number control policy without the tourist tax.

2. The Model

Consider a biological resource, a newly discovered ecological resource in a village. With the advantage of better information on the resource, the local resident can operate a service business for tourists, to earn extra income. Assume each tourist pays a price P to receive the tour service. The price level will negatively affect the potential number of tourists as generally reflected in a demand function which we now turn to.

2.1 Demand for Ecotourism

Tourists attend an ecological tour are not homogeneous in general, due to different education levels, cultural backgrounds and/or income levels. To model this feature of heterogeneous consumers, we follow the setup by Gayer and Shy (2003). Assume that those who decide to be ecotourists will have to pay a given amount of direct or indirect transport cost τ to reach the destination. In addition, he/she also has to pay to the local resident operator fee P for the service to visit the ecological place. As a result, only the people with positive utility from attending the tour after paying the total costs of $(\tau+P)$ will visit the ecological site. For convenience we use index x to represent a potential tourist. Assume x is a random variable of uniform distribution with range of [0, 1], with probability density function $g(x)=1$. Obviously, $G(1)=1$ and $G(0)=0$, where $G(.)$ denotes the accumulated p.d.f. of x. Let the total number of potential tourists be N, which can be interpreted as the population size of the underlying economy if every person is allowed to visit the ecological area, or as the population of the legally permitted group. His net utility of attending the tour can be described as follows:

$$U(x)=\begin{cases} S\cdot x-\tau-P, & \text{if attending the tour} \\ 0\quad, & \text{otherwise} \end{cases} \tag{1}$$

where S represents the current stock of the natural resources in the ecological site. Equation (1) denotes the net utility of a potential tourist from attending the tour, which is equal to the utility earned from visiting the ecological site minus total cost of transport and service fee.

Clearly, under this setup, different tourists have different levels of net utility earning, de- pending on their preference represented by x. Higher x represents higher preference in the ecological tour, and thus, a tendency to earn higher utility and a higher likelihood of attending the tour. Theoretically, there exists a marginal tourist, denoted as x_0, to whom attending the tour or not makes no difference in net utility. That is,

$$S\cdot x_0-\tau-P=0,$$

hence, the marginal tourist can be denoted as

$$x_0=\frac{\tau+P}{S}. \tag{2}$$

There are two factors determining the marginal consumer: the total cost of attending the tour, i.e., transport cost and service charge $(\tau+P)$, and the stock of natural resources S. The discussion can be illustrated geometrically by Figure 1. The horizontal axis in the figure represents x, an individual index, ranging between 0 and 1. And x_0 represents the marginal tourist. A potential tourist on the left-hand side of the marginal individual x_0 earns a negative net utility from the tour, and therefore will not join. Consumers on the right-hand side of x_0, i.e., $x \in (x_0, 1)$, earn a positive net utility of $S_x - \tau - P > 0$ from the tour, and hence will decide to join.

By the assumption of the uniform distribution of x and population size of N, x_0 equals the share of the population not taking the tour, and $(1-x_0)$ the share taking the tour. Let n be the total number of tourists; then accordingly $n = N(1-x_0)$. Thus, x_0 can be solved as follows:

$$x_0 = \frac{N-n}{N}.$$

Substituting x_0 into equation (2) yields

$$P = S\left(\frac{N-n}{N}\right). \tag{3}$$

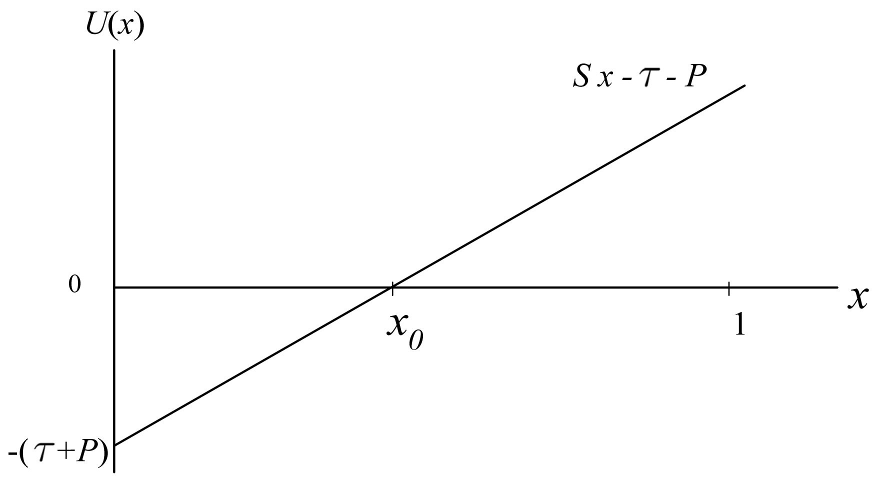

Figure 1 Distribution of Heterogeneous Tourists

Equation (3) is obviously the inverse function of demand for ecotourism, reflecting the negative relationship between the service fee P

and number of tourists n.[4] Clearly, the higher the P and/or τ, the lower the number of tourists n. In addition, the higher the S or N, the larger the number of tourists n. Note that incorporating the heterogeneous consumers and the population size N allows us to analyze the population growth effect of depleting the common resources as frequently mentioned in the literature, e.g. Hardin (1998).

2.2 The Dynamics of Natural Resources

Let $f(S)$ be the reproduction function of the natural resources, for example a forest, meadow, special variety of wildlife or some particular natural scenery,[5] which is a function of the current level of stock S and the carrying capacity K. The function takes the following form:

$$f(S) = rS\left(1 - \frac{S}{K}\right). \tag{4}$$

The function contains some important ecological sense. Firstly, r represents the "intrinsic" growth rate of the natural resources, and normally $0 < r \leq 1$. In addition, the constant K represents the carrying capacity of the natural resource.[6] As $S = K$, the natural resource reaches the maximum capacity, and the amount of reproduction equals zero. Thus, the resource will not grow anymore. It will be easy to see that $S = K/2$ corresponds to the turning point of the reproduction curve and is the maximum value of $f(S)$ for equation (4). That is, when $S = K/2$, the amount of reproduction reaches the maximum level, i.e., the maximum sustainable yield (MSY) of the ecosystem,

---

4 To assure a positive price, the transportation cost τ must be less than the upper bound of $S[(N-n)/N]$, and the higher the natural resources stock, the higher the upper bound.

5 The logistic functional form, which is widely adopted in the field of resources economics, can be traced far back to the ecological economist, Verhulst (1838).

6 The carrying capacity of land is the largest number of living animals (number of tourists in our case) which it can support. If the population of its supported animals is beyond (below) the capacity, then the living environment will begin to decline (increase). See Libosada (2009) and Salerno et al. (2013) for a similar concept of carrying capacity in the tourism industry.

$$S^{MSY} = \frac{K}{2}. \tag{5}$$

If the resource stock is less than one half of the carrying capacity, that is, $S < K/2$, then the amount of reproduction will increase as shown by $f'(S) > 0$. In contrast, when the current stock is greater than one half of the carrying capacity i.e., $S > K/2$, then the amount of reproduction will decrease ($f'(S) < 0$), although the stock still increases ($f(S) > 0$).

The change rate with respect to time of the natural resources, denoted as $\dot{S}$, can be defined as below:

$$\dot{S} = f(S) - \theta n, \tag{6}$$

where θ is a constant and represents the average amount of resources depleted by a tourist. Thus, θn is total depletion amount of the natural resources when there are n visitors. In other words, there are two factors determining the change rate of the natural resources level: one is the amount of reproduction; the other the depletion effect arising from visitors. At equilibrium, the change rate of the natural resources is equal to zero $(\dot{S} = 0)$, and the amount of reproduction should equal the total amount of depletion by visitors. That is,

$$f(S) = \theta n. \tag{7}$$

In fact, equation (7) is essentially the same as the equilibrium of the "predator-prey" model of (Lotka (1925) and Volterra (1926)), in the sense that tourists are the predator while the natural resources are the prey. Thus, if the total amount of depletion θn is greater than the amount of reproduction $f(S)$, that is, $\theta n > f(S)$, then the level of natural resources will decline $(\dot{S} < 0)$. In contrast, if the amount of depletion is less than the amount of reproduction, then the stock will increase, i.e., $(\dot{S} > 0)$.

Furthermore, according to the equations representing the balance of the ecosystem, equations (4) and (7), we can derive the number of tourists which will keep the ecological system at balance, n, as below:

$$n = \frac{1}{\theta} \cdot f(S) = \frac{rs}{\theta}\left(1 - \frac{s}{K}\right). \tag{8}$$

Obviously, factors affecting the number of n, include the intrinsic growth rate of the natural resources, r, the carrying capacity of the environment, K, the average depletion rate by a visitor, θ, and the stock of natural resources, S.

Graphically, the relation between n and S indicated by equation (8) can be depicted as the SS-line in Figure 2. All the points above the SS-line imply too many visitors for the current stock of S, thus $\dot{S} < 0$ and S must decline, as shown by the leftward arrows. On the other hand, any point below the SS-line implies the number of visitors is low enough that the resource stock will grow, i.e., $\dot{S} > 0$, as indicated by the rightward arrows.

Simple algebra on equation (8) yields

$$\frac{\partial n}{\partial S} \lesseqgtr 0 \text{ if } S \lesseqgtr \frac{K}{2}, \text{ and } \frac{\partial^2 n}{\partial S^2} < 0.$$

That is, the SS-line is concave and passes through the origin (0, 0) and point (K, 0). In addition, n reaches the highest value $rK/4\theta$ at $S = K/2$, the most sustainable yields as defined in the literature, denoted as n^{MSY} hereafter.

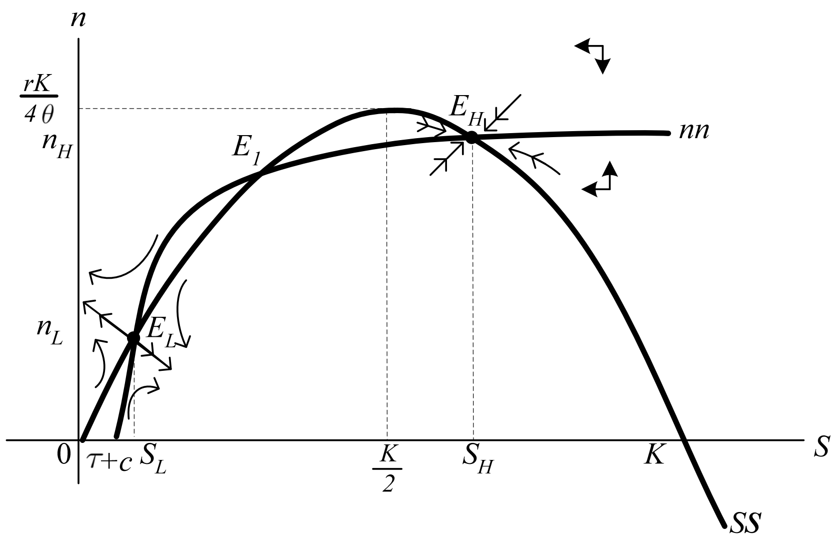

Figure 2 Ecotourism Equilibrium

2.3 Supply of Ecotourism

Let m be the number of operators organized by the local residents. Each operator under the given demand function of equation (3) decides the number of tourists to maximize his profit or utility. We also assume that operators are identical in terms of the cost structure and the service provided. In addition, we assume that there is Cournot-Nash competition between them, that is, each operator takes the other's amount of service supply as given. Let n_i be the total tourists served by operator i; thus the total number of tourists n is

$$n = \sum_{j=1}^{m} n_j .$$

Let c be the marginal service cost, and F be the fixed cost, including an established cost and/or license fee, for each operator to run the business legally. Then, the operator i's profit can be written as

$$\pi_i = (P - c)n_i - F, \quad i = 1, 2, \ldots, n.$$

By using the demand equation (3), π_i can be rewritten as

$$\pi_i = \left[S\left(\frac{N-n}{N} \right) - \tau - c \right] n_i - F, \quad i = 1, 2, \ldots, n. \tag{9}$$

Under Cournot-Nash competition $(\partial n_j / \partial n_i = 0,\ j \neq i)$, solving the representative opera tor, i's, maximization problem yields the first-order condition as below:

$$\frac{\partial \pi_i}{\partial n_i} = \left[S\left(\frac{N-n}{N} \right) - \tau - c \right] + n_i \left(\frac{-S}{N} \right) = 0.$$

At equilibrium, identical cost structure will assure that an equal amount of tourists will be served by each operator, that is, $n_i = \bar{n}, \forall i.$ Thus, $n = \Sigma n_i = m\bar{n},$ or $n_i = n/m.$ Consequently, the first-order condition can be simplified further as

$$n\left(1+\frac{1}{m}\right)=N\left(1-\frac{\tau+c}{s}\right).$$

Accordingly, the profit-maximized level of n can be derived, denoted as n^*. Let δ denote the speed of adjustment for n, that is

$$\dot{n}=\frac{dn}{dt}=\delta(n^*-n), \quad \text{where} \quad 0<\delta\leq 1. \tag{10}$$

At the steady state $\dot{n}=0$ implies $n=n^*$, or

$$n=\frac{N\left(1-\dfrac{\tau+c}{s}\right)}{1+\dfrac{1}{m}}. \tag{11}$$

This is the equilibrium relation between n and S under a given m, to be represented by the nn-line in Figure 2. For simplicity and without losing generality, we hereafter assume $\delta = 1$, that is, the operators can fully adjust the number of tourists to maximize the profit. Simple algebra on equation (11) shows that $\partial n/\partial S>0$, and $\partial^2 n/\partial S^2<0$, indicating the concave property of the nn-line. And obviously, $S = \tau + c$ at $n = 0$.

In addition, any point above the nn-line indicates that the operator is serving too many visitors, and will reduce the number of tourists to raise profit. On the other hand, any point below the nn-line means increasing visitors will increase the operator's current profit, and thus more tourists will be served.

According to equation (11), factors affecting the number of tourists that the operators are willing to serve can be classified into two groups. Firstly, there are positive factors, including m (number of operators), S (the stock of natural resource) and N (population of potential tourists). Secondly, there are negative factors including the sum of $\tau+c$, where τ represents all the direct and indirect access cost borne by each tourist; and c the environmental maintenance cost per tourist borne by the operator.

2.4 Equilibrium

At equilibrium, equations (8) and (11) should hold simultaneously. Let S^* and n^* denote the equilibrium value. Clearly, the solution of S^* and n^* can also be represented graphically by the cross points of the *SS*- and *nn*-lines of Figure 2. According to the properties of the *SS*- and *nn*-line, there are at most three equilibria which are depicted as E_L (denoted as low equilibrium hereafter), E_1 (middle) and E_H (high) in Figure 2. Obviously, the number of solutions can be reduced to one or even zero, depending on the relative position and shape of the two lines, which in turn reflects the corresponding parameters of access cost (τ+c), m, K, r and N. Mathematical conditions are derived in Appendix 1, and the economic meaning will be clearly discussed under the comparative statics analysis in the next section.

In the three-equilibrium case, the corresponding stock of resources S_H^* at E_H is higher than S^{MSY}, while both S_1^* at E_1 and S_L^* at E_L are less than S^{MSY}. As indicated by the directional arrows, both points E_L and E_H are stable and charactered by higher slope of the *nn*-line than that of the *SS*-line, while E_1 is a local saddle-point. The results are summarized in the following proposition.

Proposition 1.

(i) *The ecotourism dynamic system defined in equations (6) and (11) will have three equilibria of S_L, S_1 and S_H if either the conditions of ($\tau+c>0$) and $Kr[1+(1/m)]/\theta>3N$ or the conditions of ($\tau+c=0$) and $Kr[1+(1/m)]/\theta > 4N$ hold. Moreover, the equilibria of S_L and S_H are always stable, while the equilibrium of S_1 is unstable.*

(ii) *The ecotourism dynamic system defined in equations (6) and (11) will have a unique stable equilibrium if $Kr[1+(1/m)]/\theta > 3N$.*

Proof. See Appendix 1.

That is, to support a given level of potential visitors (N), the carrying capacity (K) and intrinsic growth rate (r) must be large enough and/or operators (m) and the average amount of resources depleted by a tourist (θ) be small enough. In addition, the condition becomes more severe for the case of free access $\tau + c = 0$, that is, $Kr[1+(1/m)]/\theta > 4N$, compared to $Kr[1+(1/m)]/\theta > 3N$ for the case of $(\tau + c) > 0$.

3. Comparative Statics

We are now ready to conduct the comparative statics analysis to see how the equilibria are affected by the parameters, especially the policy-related ones. By totally differentiating equations (8) and (11), we have

$$\begin{bmatrix} S\left(\frac{m+1}{m}\right) & -N\left(\frac{\tau+c}{S}\right) \\ K\theta & 2rS - Kr \end{bmatrix} \begin{bmatrix} dn \\ dS \end{bmatrix} = \begin{bmatrix} -Nd(\tau+c) + \left[S\left(\frac{m+1}{m}\right)^2 - (\tau+c) \right] dN + \left(\frac{n}{m^2}\right) dm \\ -nd\theta + (rS-n)dK + (K-S)Sdr \end{bmatrix}. \qquad (12)$$

By Cramer's rule, we can derive

$$dn = \frac{1}{\Delta}\left\{ \left[(2Sr - Kr)[-Nd(\tau+c) + \left[S(1+\frac{1}{m})^2 - (\tau+c) \right] dN + \frac{n}{m^2} dm \right] + N\left(\frac{\tau+c}{s}\right)\left[-nd\theta + (rS-n)dK + (K-S)Sdr \right] \right\},$$

$$dS = \frac{1}{\Delta}\left\{ S\left(\frac{m+1}{m}\right)[-nd\theta + (rS-n)dK + (K-S)Sdr] - K\theta \left[-Nd(\tau+c) + \left(S\left(\frac{m+1}{m}\right)^2 - (\tau+c) \right) dN + \left(\frac{n}{m^2}\right) dm \right] \right\}, \qquad (13)$$

where $\Delta \equiv S[(m+1)/m](2rS - Kr) + K\theta N[(\tau+c)/s] \lesseqgtr 0$, and the stability condition requires $\Delta > 0$, implying that the slope for the *nn*-line should be greater than that of the *SS*-line, as derived in Appendix 1. Since E_1 is an unstable equilibrium, we will focus on the effect of the comparative statics for E_L and E_H.

Factors affecting the state of equilibrium include not only the nature-determined elements of K, r and θ, but also the policy-related factors such as τ, c, N and m. Policies should aim at a high equilibrium, which obviously represents higher welfare. To guarantee high equilibrium, several policies can be suggested by changing the access cost $\tau + c$, population size N, and the number of operators m, which we now discuss in the following.

3.1 Access Costs Effect ($\tau + c$)

Transport cost τ reflects the fact that the degree of accessibility and the marginal maintenance cost c, are borne by the tourist and the operators respectively, and thus should affect the equilibrium. By the results of comparative statics of equation (13), the effects of an increase in τ and c on S^* and n^* are mathematically expressed as:

$$\frac{dS^*}{d(\tau + c)} = \frac{1}{\Delta} K\theta N > 0, \tag{14a}$$

$$\frac{dn^*}{d(\tau + c)} = \frac{-1}{\Delta} N(2Sr - Kr) \gtrless 0 \text{ if } S \gtrless \frac{K}{2}. \tag{14b}$$

This means that an increase in τ and c always leads to a higher S^*, while its effect on n^* is ambiguous, depending on whether the initial state is low or high. At the low state of $S < K/2$, the number of tourists will increase, while at high equilibrium, i.e., $S > K/2$, the number of n^* will decrease. Geometrically, an increase in the access cost will only move the *nn*-line rightward, as indicated by equation (13) and shown in Figure 3. In the figure, the cross point of the *nn*-line on the *S*-axis moves to a ($a = \tau + c$) and further to a' as the cost increases more. With a small adjustment of $\tau + c$, the E_L will move upward along the *SS*-line, while E_H will move downward.

In the extreme, if the access cost keeps increasing, then as is clearly shown in the figure, only the high equilibrium of E''_H will exist. In this case, even if the initial state is at the low equilibrium E_L, we can still reach the high equilibrium, that is, an instant drop of n from E_L to the corresponding level on the point vertically down to the nn''-line and then gradually moving upward to E''_H.[7] The above results can be summarized in the following proposition.

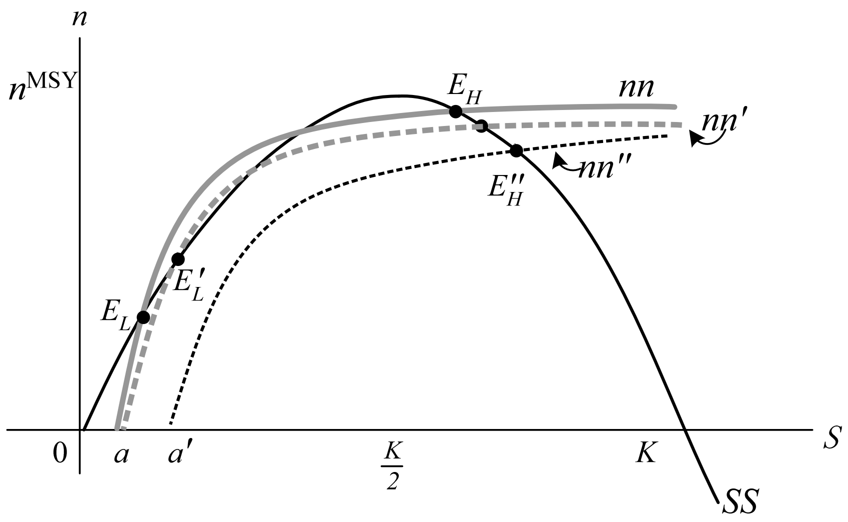

Figure 3 Effect of Ecotourism Tax

Proposition 2.

At the low equilibrium, a small amount of increase in the access cost ($\tau + c$) would lead to a better state of higher resource stock and tourists. In addition, a big-enough increase in the access cost would drive the state to the high equilibrium. However, at the high equilibrium, any increase in the access cost would always lead to higher resources stock and low tourists.

Policy implications from the results are clear, knowing that the access cost can be raised by imposing a tax either on the operator (raising c) or on the tourist (raising τ). Accordingly, the government can raise the tax level to increase the natural resource stock and importantly can avoid the low

[7] Note that the comparative statics does not apply to the situation of the big jump of the ($\tau + c$), the curve of single equilibrium case with high ($\tau + c$).

level equilibrium by levying a high tax.[8]

On the other hand, policies reducing the access cost, such as improving road conditions and subsidy to the operator, will lead to a lower level of the ecological resources in the end. An extreme case occurs when the access cost is zero, i.e. open access. In this case, the low equilibrium E_L coincides with the origin, that is, the extinction of the resource. And, unfortunately, the E_L will become the unique equilibrium when N the population and/or the number of operations m is large enough, which as will be analyzed in section 3.4 the case of the classical "tragedy of the commons".

3.2 Number of Operators *m*

By equation (13), the effects of an increase in m on S^* and n^* can be expressed mathematically as below:

$$\frac{dS^*}{dm} = \frac{-1}{\Delta} K\theta\left(\frac{n}{2m^2}\right) < 0, \tag{14c}$$

$$\frac{dn^*}{dm} = \frac{1}{\Delta}(2Sr - Kr)\left(\frac{n}{2m^2}\right) \gtrless 0 \text{ if } S \gtrless \frac{K}{2}. \tag{14d}$$

That is an increase in the number of operators, m, will certainly decrease the equilibrium level of the resources; however its effect on the number of tourists n^* is ambiguous, depending on whether the initial state is low ($S < K/2$) or high ($S > K/2$). Graphically, an increase (decrease) in m will only move the *nn*-line counter-clockwise (clockwise) on the center of point a, as shown in Figure 4. Thus, if m increases then the equilibrium shifts from E_L to E_L' or from E_H to E_H'. At low equilibrium, both n^* and S^* will decline. However, if high equilibrium is the case, then S^* will still decline but n^* will increase.

---

8 This policy-related result is essentially similar to that raised in the articles of Morey (1980), Clark (1990) and Tietenberg (1996), that is, the purpose of preventing the fish stock from extinction can be reached by increasing any kind of catching cost, for example, the fee for fishing licenses. See also in Baral et al. (2008) for a similar argument of raising the entry fee to help preserve the Annapura Conseravation Area, Nepal.

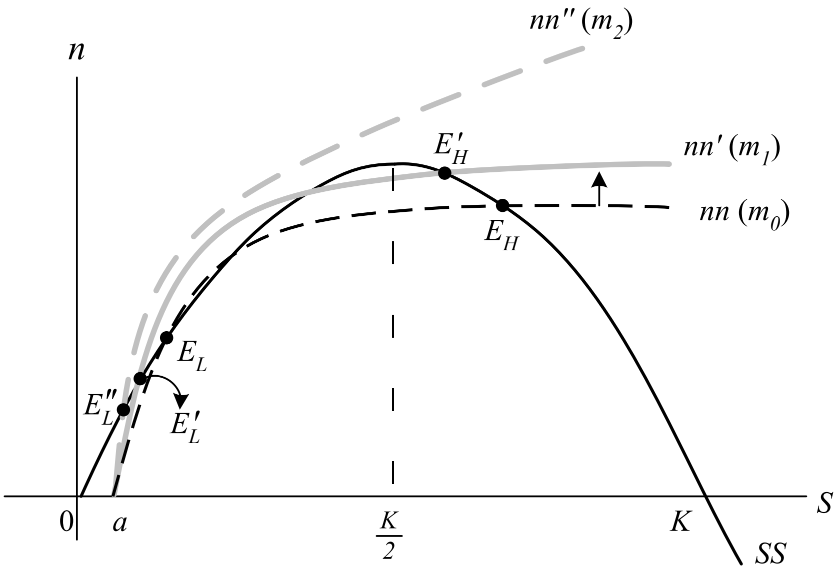

Figure 4 Effects of More Operators ($m_2 > m_1 > m_0$)

It is worth noting that if the number of operators m keeps increasing, then the nn-line will continue to rotate upward, and the high equilibrium E_H will no longer exist in the end, left only with the low equilibrium as is shown in the case of the nn''-line in Figure 4.[9] This is more likely to occur if the current operator's profitably is higher and free entry is permitted.[10] Note that the larger the population size, N and/or the smaller the establishment cost F, the higher the profitability. The implication is clear; that is, the higher the population size and/or lower the establishment cost, the more likely it is that the tragedy of low equilibrium will occur to the common-pool of ecological resources under free entry.

9 Similar to footnote 7, the following discussion is based on the case of single equilibrium as proved in Appendix 1.

10 The theoretical result in principle supports the argument by Kilipiris and Zardava (2012), the necessity of control over the tourism firms, especially the micro-tourism enterprises like travel agents, tour operators etc.

3.3 Population Growth and Tragedy of Commons

The effect of population size is similar to that of the operator numbers. As can be derived from equation (13), the population effect is mathematically as below:

$$\frac{dS^*}{dN} = \frac{-1}{\Delta} K\theta[S-(\tau+c)] < 0, \tag{14e}$$

$$\frac{dn^*}{dN} = \frac{1}{\Delta}(2Sr - Kr)[S-(\tau+c)] \gtrless 0 \text{ if } S \gtrless \frac{K}{2}. \tag{14f}$$

Again the effect on S^* is certainly negative; however the effect on n^* can be positive or negative depending on whether the initial state is high ($S > K/2$) or low ($S < K/2$).

Graphically, the change in N only makes the nn-line rotate on the center of a (by equation (13)), and again like that of the change in m, it will move the nn-line counter-clockwise (clockwise) as N increases (decreases) as shown in Figure 5. And, in the extreme case, the high equilibrium will disappear, left only with the low equilibrium, as shown by the nn''-line. Thus, the above results can be summarized in the following proposition:

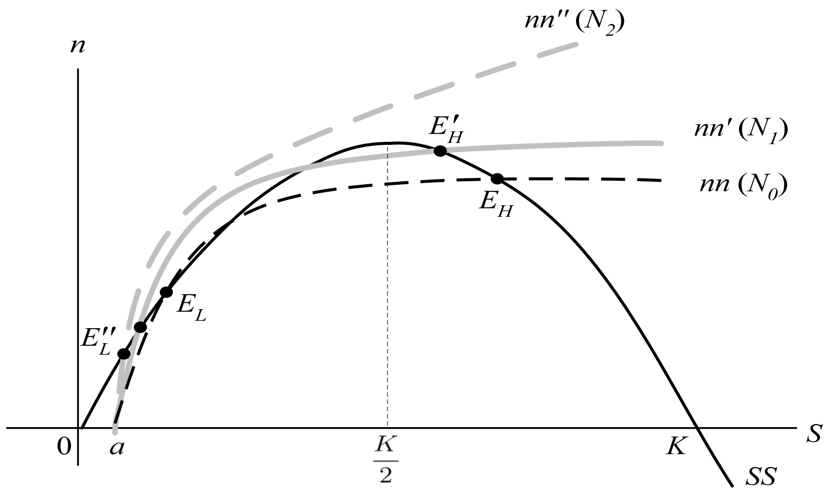

Figure 5 Effects of Population Growth ($N_2 > N_1 > N_0$)

Proposition 3.

At lower equilibrium (E_L), an increase in population size (N) and/or number of operators (m) will decrease both tourists and the resources stock. However, if the initial equilibrium is high (E_H), then an increase in population size and/or the number of operators, will lead to higher tourists but lower resources stock. If the increase is big enough, the state will jump to the worst case of low equilibrium (E_L'').

Roughly speaking, based on the above analytical results we find that an increase in the number of operators, and unlimited increase in the population size of the tourist potential will worsen the damage to the ecological environment.

3.4 Open Access and The Tragedy of The Commons

The unique low equilibrium due to high population size or too many operators will become a serious problem, if the access is free for both the tourists and operators, that is, $\tau + c = 0$.

Figure 6 depicts the case when $\tau + c = 0$. In this case the *nn*-line is horizontal with $n^* = mN/(1+m)$, as equation (11) now becomes

$$n^* = \frac{m}{1+m} N. \tag{15}$$

It can be easily seen that if m or N is large enough then E_L will become the unique equilibrium, and more importantly, the equilibrium is characterized by $S^* = n^* = 0$, i.e., an extinction tragedy. More specifically, the threshold for the tragedy to occur can be derived as

$$\frac{mN}{1+m} \geq n^{MSY} = \frac{rK}{4\theta}. \tag{16}$$

This states that other things being equal, the lower the intrinsic growth rate, the lower the environmental capacity and the higher the average rate of depletion caused by tourism, the more likely an extinction tragedy will occur. The above results can be summarized in the following proposition:

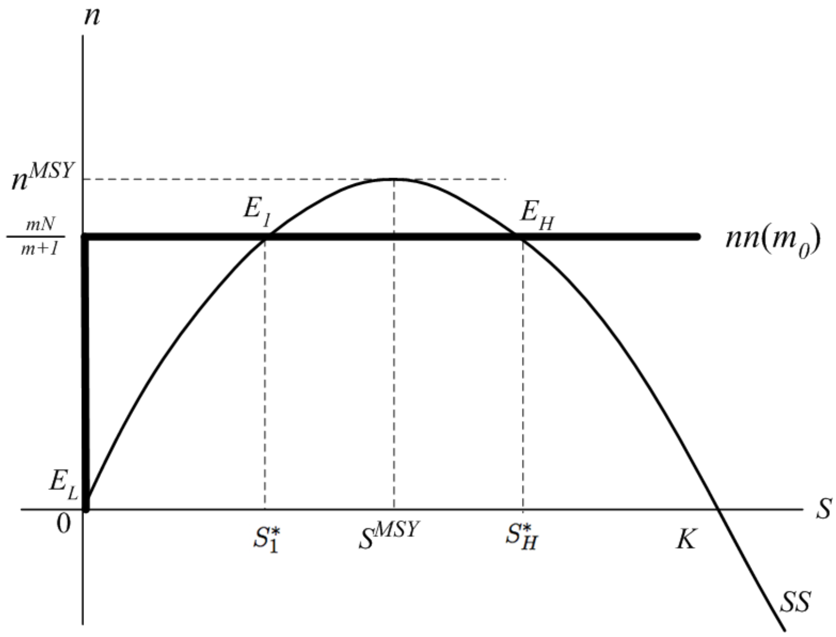

Figure 6 Equilibrium under Open Access ($\tau + c = 0$)

Proposition 4.

If the site is free to access, then the opening-up may lead to the extinction of the resources, depending on the initial resource stock. If the initial stock is low enough (e.g. lower than S_1), the system will end up with an equilibrium of zero resource stock E_L.

According to this proposition, for an area in the face of a huge number of potential tourists, it is necessary for the government authority to impose a rule of quantity limit upon arrivals, to prevent the natural resource from complete depletion. In this regard, the quantity regulation policy adopted in many ecological resorts of Taiwan, such as the Fu-San Forest Park in Ilan, can be justified by our theoretical results.

3.5 Policy Implications

Policy implications can be drawn upon the above results. It is straightforward that state E_H is better than E_L, which in turn is better than the state of extinction. To maintain the high equilibrium of E_H, policies should aim at reducing the potential population size N, decreasing the number of firms m and raising the access cost for tourists τ and marginal cost for operators c. If possible, the policies should also aim at raising the environmental capacity K, intrinsic growth rate of the ecological resource r (to which scientists can contribute), and decreasing the depletion rate of each tourist through suitable ecotourism education to enhance the environmental ethic of the tourist as discussed by Holden (2003, 2005).

4. Welfare and Socially Optimal Policies

Ideally, the aim of a policy should not be confined to avoiding the extinction tragedy or low equilibrium only. Instead, it should actively target the maximization of the social welfare for the community as a whole. Let w denote the welfare, which in this case of ecotourism should contain three components: the overall profit earned by the local operators $m\pi$, tax revenue and the environmental amenities. Suppose each operator is subject to pay a fixed license fee of L to run the business, and each tourist has to pay a tax of t. Thus, the total tax revenue equals $tn + mL$. Then, the welfare function can be written as[11]

$$w = m\pi + tn + mL + v(S), \tag{17}$$

where $v(S)$ is the environmental amenity welfare from having the ecological resource of stock S, assuming that the marginal welfare of S is positive and decreasing, i.e., $v' > 0$ and $v'' < 0$.

With the tax structure, the profit earned by each operator has to be revised from equation (9) to

$$\pi = \left[S\left(\frac{N-n}{N}\right) - \tau - c - t \right]\frac{n}{m} - (F + L), \tag{18}$$

[11] Since the welfare is for the "local" community as a whole, the tourists' welfare is not included in the function.

therefore the welfare function can be rewritten as

$$w = \left[S\left(\frac{N-n}{N}\right) - \tau - c - t \right] n - mF + v(S). \tag{19}$$

Analytically, we can add an iso-welfare curve on the (n, S) space to compare the relative welfare levels under different equilibrium positions, and, more importantly to pin down the optimal level of welfare that can be reached for the ecological economy. To draw the iso-welfare curve on the (n, S) space, note that

(i) $\partial w/\partial S > 0$, and $\partial^2 w/\partial S^2 < 0$.

(ii) $\partial w/\partial n = 0$, at $n^* = N/2[1 - (\tau + c)/S]$, and $\partial^2 w/\partial n^2 < 0$.

These properties can be depicted in Figure 7.[12] That is, at any given level of S, there exists a maximum w at $n^*(S) = N\{1-[(\tau+c)/S]\}/2$ (to be denoted as the ridge line of welfare hereafter), and $\partial w/\partial S > 0$, that is, $w(n, S_1) > w(n, S_0)$, $\forall\ S_1 > S_0$.

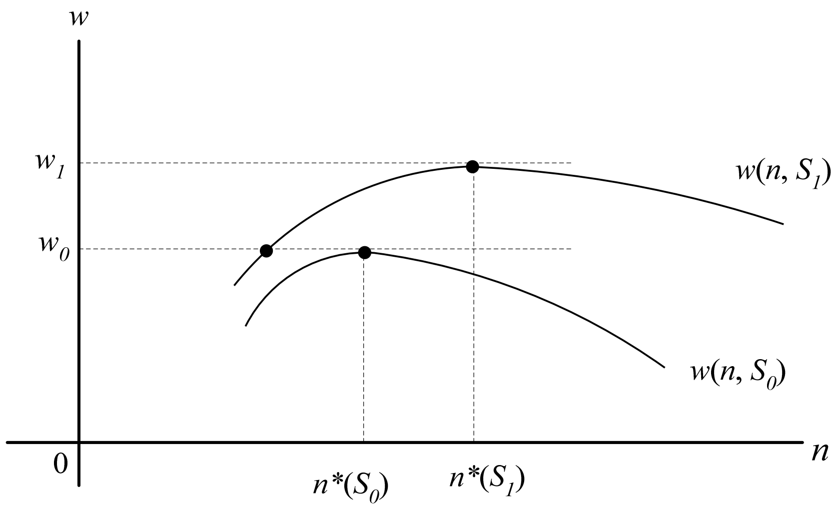

Figure 7 Social Welfare of the Local Community ($S_1 > S_0$)

[12] See Appendix 2 for properties of the iso-welfare curve.

4.1 Iso-Welfare Curve

Obviously from Figure 7, we can see that at any given level of welfare, say w_0, there exists a level S_0 of S, and a corresponding $n^*(S_0)$ such that for all $n < n^*(S_0)$, a lower n must be accompanied by a higher S, in order to maintain the same welfare level of w_0; while for all $n > n^*(S_0)$, corresponding to a higher n, a higher S is required to make w indifferent. Thus, the corresponding welfare indifference curve through point $(S_0, n^*(S_0))$ can be drawn as the w_0 in Figure 8. By the same rationale, we can derive a higher welfare indifference curve as $w1$, corresponding to $(S1, n^*(S_1))$, with $S_1 > S_0$ in the same figure. And, as shown earlier, the ridge line that links all the points of $(S, n^*(S))$ is $n^*(S) = N\{1-[(\tau+c)/S]\}/2$, which coincides with the nn-line at $m=1$ before tax. As will be shown later, this property plays some role in the content of policy design.

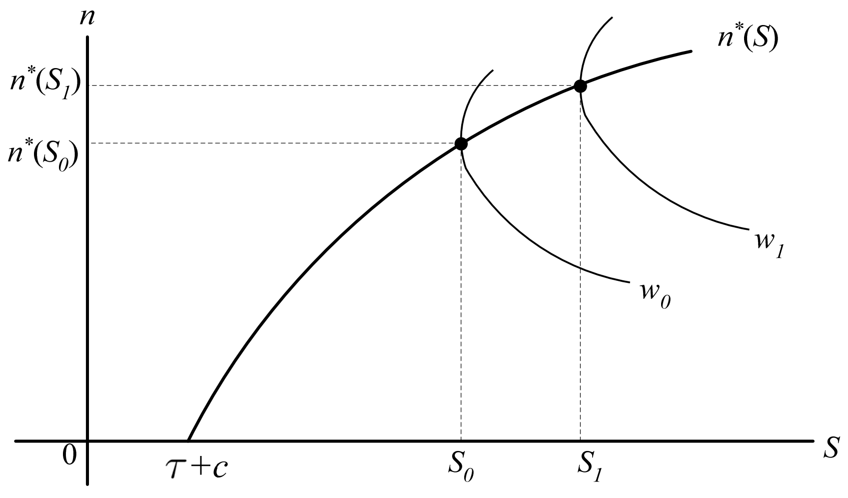

Figure 8 Iso-Welfare Curve $n^*(S) = N\{1-[(\tau+c)/S]\}/2$ and $w_1 > w_0$

4.2 Socially Optimal Policies

We are now ready to analyze the optimal ecotourism policies. To do so, the iso-welfare curve is drawn in the equilibrium diagram as in Figure 9.

In the Figure 9, the *nn*-line is drawn under the case of $m > 1$ and tax-free status. The n^*-line is the ridge line of the welfare, which as noted before coincides with the *nn*-line with $m = 1$ and $t = 0$.[13] Several interesting and important properties can be drawn from the Figure 9:

(1) High Equilibrium Is Better than Low Equilibrium

The iso-welfare curve through the high equilibrium point, E_H, represents a higher welfare of w_H than that of E_L. This confirms the previously mentioned direction of policy design, that is, aiming at approaching the high equilibrium. And as illustrated before, the high equilibrium can be attained by charging an adequate tourism tax t, reducing m and/or increasing the license fee L.

(2) High Equilibrium of E_H Is Not Necessarily Optimal

Although E_H has higher welfare than E_L, it may not be optimal, as shown by E_0 in Figure 9, leaving more room for policy to play a role. Mathematically, we can solve for the optimum of (S^{**}, n^{**}) by the tangent line of iso-welfare curve to the *SS*-line, which is obviously different from solving the high equilibrium as shown in Appendix 3. Thus, the two slopes of the w^*-line and the *SS*-line should be equal.

$$\frac{\left(1-\frac{n}{N}\right)+v'(S)}{2S\frac{n}{N}-(S-\tau-c)}=-\frac{2rS-Kr}{K\theta}. \tag{20}$$

However, the E_L and E_H are solved simultaneously by equations (6) and (8). Obviously, the equilibria of E_H and E^* may not be equal. The solutions of (S^{**}, n^{**}) can not be reached.

[13] Note that the license fee does not affect the n^*-line.

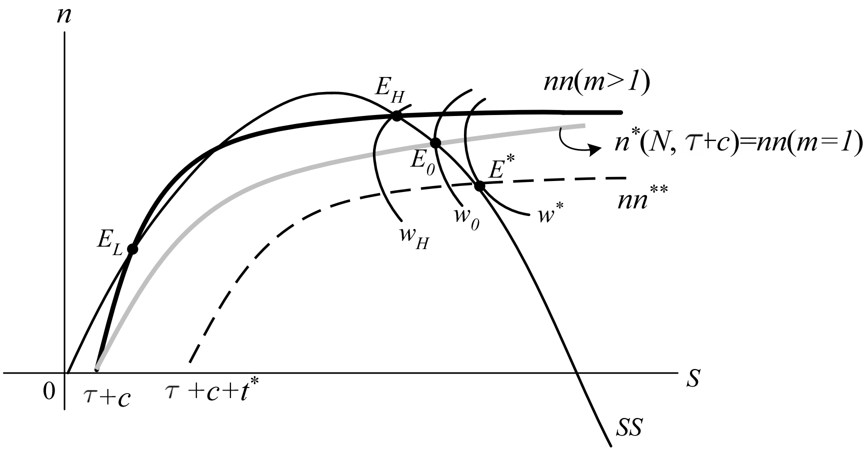

Figure 9 Equilibrium and Welfare

(3) Policies Toward The Maximum Welfare

The iso-welfare curve w^*, tangent to the *SS*-line at point E^*, represents the highest welfare value that can be reached for the ecotourism community, at a given level of *K*, *r* and *θ*. Correspondingly, point E^* indicates the target of an optimal policy. How can one reach the optimum by using the policies available? Conceptually, the optimal policy should be designed so as to move the *nn*-line to cross the *SS*-line through point E^*, such as the nn^{**}-line. For this purpose, as analyzed before and knowing that the *nn*-line lies always above the n^*-line under $m>1$, we can (i) raise the license fee of *L* to decrease the operator's profit to reduce the number of operators *m*, or simply control directly the number of *m*, or (ii) raise the tourist tax *t*, collected from either the tourist or the operator *n*. Both policies will move the *nn*-line to the "right" direction toward higher welfare. However, as will be shown in the following, the license fee or reducing *m* itself will not successfully reach the maximum welfare, without the imposition of the direct tax policy of *t*.

(a) Effectiveness of The License Fee or Controlling *m*

As shown earlier, raising *L* or reducing *m* in the extreme will only shift the *nn*-line clockwise to coincide with the welfare-ridge

n^*-line, and correspondingly can only reach the equilibrium point of E_0 with welfare level of w_0.[14] In other words, w_0 is the greatest possible welfare level that can be obtained through the policy of license and/or firm number control. And clearly, there still exists a distance between w_0 and the optimum of w^*.

(b) Effectiveness of Tourist Tax, *t*

By the properties of the *nn*-line, a tourist tax either on the tourist or on the operator will move the *nn*-line rightward, changing the intercept in the *S*-axis from $(\tau+c)$ to $(\tau+c+t)$. As a result, there exists a tax rate, say t^*, by which the the *nn*-line will move to nn^{**}-line, thus reaching the optimal equilibrium point of E^* and welfare level of w^*.

5. Discussion and Concluding Remarks

Ecotourism has been suggested recently in many studies as a promising strategy for sustainable development for an ecologically rich but economically poor rural area. The confidence lies basically in the efficiency of the market mechanism to provide incentives for local people to protect the natural resources on which the tourism is based. Coria and Calfucura (2012) stress the need for a better approach to enhance the indigenous communities, livelihood possibilities coming from ecotourism. In this paper we prove that although ecotourism can prevent the ecological resources from being depleted in the short run, the tragedy of extinction may still be inevitable in the long run, without the support of a proper policy design. This is because the common-pool properties of the ecological resource will make the local people receive too many tourists, exceeding the sustainable level.

By incorporating the factors of access cost, number of operators

---

[14] Proof: Let m = 1 and t = 0. By equation (11), the *nn*-line becomes $n=N\{1-[(\tau+c)/S]\}/2$, which is coincided with the ridge line of the iso-welfare n^*-line, $n^*=N\{1-[(\tau+c)/S]\}/2$. Note that the iso-welfare is convex to the origin, and the tangent line of w_0 on point E_0 is vertical. By the concavity of *SS*-line, there exits a w^*greater than w_0, such that the tangent point between the iso-welfare w^*-line and *SS*-line, E^* locates at the southeast of E_0. Q.E.D.

among the local residents, license fee and tourist tax into the model, the major results are: Firstly, the greater the number of operators, the smaller the equilibrium stock of the ecological resources will be. In the extreme, it may end up at a low level of equilibrium, which is far below the maximum sustainable yields, and may even result in the extinction of the resources if the access cost is zero, an ecotourism version of the "tragedy of the commons". Furthermore, if the population of potential tourists keeps growing, the extinction tragedy or low equilibrium will certainly occur.

The Ching-jing area and Mugumuyu are two contrasting examples in Taiwan. The Ching-jing resort area, where household-hotels have been permitted to operate since the early 1990s, represents the case of no access fee (except the transport cost), no limit on the number of operators (household-hotel, m), and potentially numerous visitors (n). In contrast, for the Mugumuyu reserve area, rich in ecosystem but hard to reach due to its rural, mountainous location in eastern Taiwan, each tourist has to pay an access fee of 350 NT dollars in addition to a relatively high transport cost. Furthermore, the daily allowance for visitors is limited to 600 persons, with 300 persons in the morning and the remaining 300 in the afternoon. Consequently, as implied by our model, the results are opposite for the two areas. The Ching-jing area now has been occupied by an overwhelming number of house-hold hotels along with over-constructions; the landscape quality is dramatically damaged, as shown in the movie of "Beyond Beauty- Taiwan From Above". On the other hand, the Mugumuyu area retains its attractiveness for the tourist via successfully reserving its natural resources.

To avoid the occurrence of the tragedy of low equilibrium or even extinction, we suggest the following policies: (1) controlling the number of operators, which can be achieved either by issuing a small number of licenses or by charging a higher license fee; (2) raising the access cost by either imposing a tourist tax on each visitor or charging a "sales tax" on the operators;[15] (3) reducing the population size of potential visitors.

We also prove that although a high-level equilibrium can be reached

[15] The empirical result of Baral et al. (2008) shows that most visitors report that they would be willing to pay substantially more than the current entry fee to the Annapurna Conservation Area, Nepal.

either by reducing the firm numbers or by charging a tourist tax, the former instrument is less efficient. More specifically, there exists an optimal equilibrium which can only be reached if the direct tourist tax is applied. In other words, the maximum level of welfare that can be achieved by the indirect tax of license fees is smaller than that which can be obtained through the direct tax on tourists.

In sum, we have shown that ecotourism itself cannot avoid the occurrence of the tragedy of the commons, unless it is accompanied by suitable policy interventions, such as reducing the number of operators and population size, and/or increasing the access cost for tourists. We have also shown that the direct tax policy of a tourist tax is better than the indirect tax policy of license control.

Some other polices that are not addressed in the comparative static analysis but are crucial for improving sustainability include: (1) reducing the damage done by tourists, through education, and (2) increasing the environmental capacity of the ecological resource and/or its intrinsic growth rate, which may be possible through the efforts of interested scientists. These policies are obviously worth pursuing in any situation.

Appendix 1 Multiple Equilibria and Dynamic Stability

1. Equilibrium

Solving the equations of (8) and (11) yields

$$S^3 - KS^2 + \frac{NS}{d} - \frac{N(\tau + c)}{d} = 0, \tag{A1}$$

where $d \equiv [r/(\theta K)][1+(1/m)] > 0$. Obviously, this is a third-degree algebraic equation in the unknown of S, and mathematically, the solution may give three values at most. Define the left-hand side of (A1) as a function of S, or

$$y(S) \equiv S^3 - KS^2 + \frac{NS}{d} - \frac{N(\tau + c)}{d}. \tag{A2}$$

(1) Existence of Solution in $S \in [0, K]$

Some calculations show $y(0) = -N(\tau + c)/d \leq 0$ and $y(K + \varepsilon) \geq N[K + \varepsilon - (\tau + c)]/d > 0$ for all $\varepsilon > 0$ provided $K > \tau + c$. This implies $y(S) > 0$ for all $S \geq K$. Thus, there exists at least one solution for $y(S) = 0$ when $S \in [0, K]$.

(2) Multiple Equilibria vs. Single Equilibrium

By the properties of a three-degree algebraic equation, obtaining three solutions for $y(S) = 0$ needs $y'(S) = 3S^2 - 2KS + N/d = 0$ which has two real roots as shown in Figure A1 of $\overline{S_L}$ and $\overline{S_H}$. That is, $\overline{\Delta} = K^2 - 3N/d > 0$ or

$$\frac{Kr\left(1 + \frac{1}{m}\right)}{\theta} > 3N. \tag{A3a}$$

Alternatively, the case of single equilibrium occurs surely if $\overline{\Delta} \leq 0$, for $y(S)$ is monotonically increasing as illustrated in Figure A2.

(3) $\tau + c = 0$

Applying $\tau + c = 0$ to (A1) yields the three solutions of S_L^*, S_1^* and S_H^* as:

$$S_L^* = 0, \quad S_1^* = \frac{K}{2} - \sqrt{K^2 - \frac{4\theta mNK}{r(m+1)}}, \quad S_H^* = \frac{K}{2} + \sqrt{K^2 - \frac{4\theta mNK}{r(m+1)}}.$$

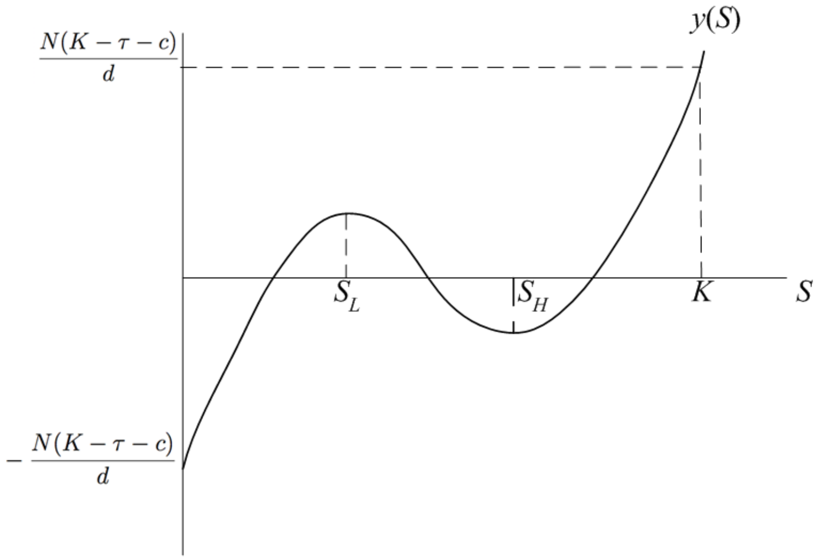

Figure A1 Multiple Equilibria

Clearly, if $K^2 - \{4\theta mNK/[r(m+1)]\} = 0$, i.e., $m = Kr/(4\theta N - Kr)$, then $S_1^* = S_H^* = K/2$. And if $K^2 - [4\theta mNK/r(m+1)] < 0$, or $m > Kr/(4\theta N - Kr)$ then S_1^* and S_H^* won't exist, and the system is reduced to one solution of $S_L^* = 0$. To ensure three solutions, we need $K^2 - [4\theta mNK/r(m+1)] > 0$, or

$$K \cdot \frac{r\left(1 + \frac{1}{m}\right)}{\theta} > 4N. \tag{A3b}$$

Comparing (A3a) with (A3b) implies a more rigid condition is necessary for supporting the ecosystem under free access.

2. Dynamic Stability

According to equation (11), the profit maximized number of tourists $n*$ can be derived as:

$$n^* = \frac{N\left(1-\frac{\tau+c}{S}\right)}{1+\frac{1}{m}}. \tag{A4}$$

Let δ denote the adjustment speed for n, then $\dot{n} = \delta(n^* - n), 0 < \delta \le 1$. The dynamics of the economy can be described as below:

$$\dot{n} = \delta(n^* - n),$$

and equation (6) of

$$\dot{S} = f(S) - \theta \cdot n.$$

For simplicity, we assume that the operators can fully adjust the number of tourists to maximize the profit, i.e. $\delta = 1$. Thus, equation (10) can be rewritten as follows:

$$\dot{n} = (n^* - n). \tag{A5}$$

To elaborate the stability properties of the system, expanding equations (A5) and (6) around the stationary values of n and S yields

$$\begin{bmatrix} \dot{n} \\ \dot{S} \end{bmatrix} = \begin{bmatrix} -1 & n_S \\ -\theta & f_S \end{bmatrix} \begin{bmatrix} n-n^* \\ S-S^* \end{bmatrix}, \tag{A6}$$

where

$$n_S = \frac{\tau+c}{S^2} \cdot \frac{mN}{m+1} > 0,$$

$$f_S = r\left(1-\frac{2S}{K}\right) \gtrless 0, \text{ if } S \lessgtr \frac{K}{2}.$$

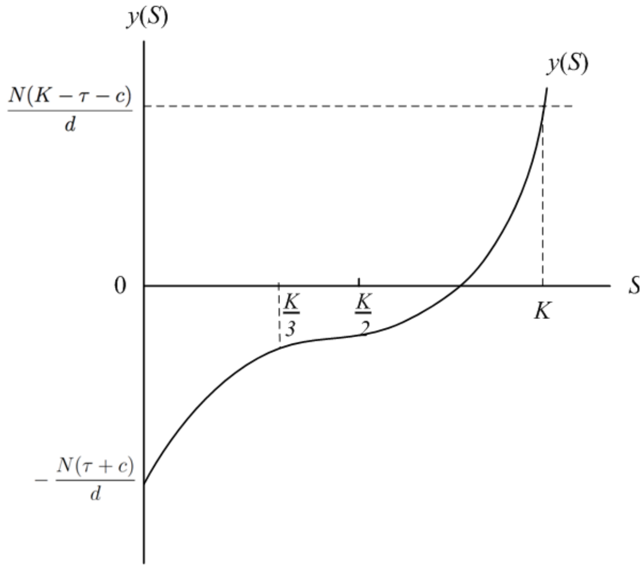

Figure A2 $y(S)$ is Monotonically Increasing

The slopes of loci $\dot{n}=0$ and $\dot{S}=0$ from equation (A6) are:

$$\left.\frac{dn}{dS}\right|_{nn}=n_S>0, \tag{A7a}$$

$$\left.\frac{dn}{dS}\right|_{SS}=\frac{f_S}{\theta}=\frac{Kr-2rS}{K\theta}\gtrless 0 \text{ if } S\lessgtr\frac{K}{2}. \tag{A7b}$$

Clearly, $\dot{n}=0$ and $\dot{S}=0$ correspond to the *nn*-line and *SS*-line respectively. In what follows, we prove that the E_L and E_H are stable, while the middle of E_1 is unstable (saddle point), as illustrated in Figure 2. Let λ_1 and λ_2 be the two characteristic roots of the system. According to equation (A6), the relation of characteristic roots can be derived as:

$$\lambda_1+\lambda_2=-1+f_S, \tag{A8a}$$

$$\lambda_1\lambda_2=-f_S+\theta n_S. \tag{A9a}$$

Mathematically, we can easily find the following properties:

(1) $S < K/2$

In this case, $0 < f_S = r[1-(2S/K)] < 1$. Thus, equations (A8a) and (A9a) will become

$$\lambda_1 + \lambda_2 = -1 + f_S < 0, \tag{A8b}$$

$$\lambda_1 \lambda_2 = -f_S + \theta n_S \gtrless 0. \tag{A9b}$$

Clearly, there are two cases on the sign of characteristic roots as follows:

(a) $\lambda_1 \lambda_2 = \theta n_S - f_S > 0$

Since both eigenvalues have the same signs, we have $\lambda_1 < 0$ and $\lambda_2 < 0$ by equation (A8b). In addition,

$$\theta n_S - fS > 0 \Rightarrow \left.\frac{dn}{dS}\right|_{nn} = ns > \frac{fS}{\theta} = \left.\frac{dn}{dS}\right|_{SS}. \tag{A10a}$$

That is, the slope of the *nn*-line is greater than the slope of the *SS*-line, as reflected by point E_L. That is, the equilibrium point of E_L for the system to be locally asymptotically stable is shown in Figure 2.

(b) $\lambda_1 \lambda_2 = \theta n_S - f_S < 0$

Clearly, λ_1 and λ_2 must be opposite signs indicating a local saddle-point.

Therefore, equation (A8a) become

$$\left.\frac{dn}{dS}\right|_{nn} = n_S < \frac{f_S}{\theta} = \left.\frac{dn}{dS}\right|_{SS}. \tag{A10b}$$

That is, the slope of the *SS*-line is less than that of the *nn*-line, i.e. the point of E_1, as shown in Figure 2. In other words, E_1 is a saddle-point, and there exists a saddle path through E_1. We now prove the slope of the saddle path line is negative and lies between the *nn*- and *SS*-lines as follows:

$$\begin{bmatrix} -1-\lambda & n_S \\ -\theta & f_S-\lambda \end{bmatrix}\begin{bmatrix} v_1 \\ v_2 \end{bmatrix}=0, \tag{A11}$$

$$\frac{n_S}{1+\lambda}=\frac{v_1}{v_2}=\frac{f_S-\lambda}{\theta}<\frac{f_S}{\theta}<0, \tag{A12}$$

where $[v_1\ v_2]$ represents the characteristic vector, and v_1/v_2 is the slope of the saddle path. Clearly, equation (A9a) becomes

$$\left.\frac{dn}{dS}\right|_{nn}=n_S<\frac{n_s}{1+\lambda}=\frac{v_1}{v_2}=\frac{f_S-\lambda}{\theta}<\frac{f_S}{\theta}=\left.\frac{dn}{dS}\right|_{SS}. \tag{A10c}$$

(2) $S > K/2$

In this case $f_S < 0$, equations (A8a) and (A9a) become

$$\lambda_1+\lambda_2=-1+f_S<0, \text{ and} \tag{A8c}$$

$$\lambda_1\lambda_2=-f_S+\theta n_S>0, \tag{A9c}$$

implying both λ_1 and λ_2 are negative and the slope of the *nn*-line is greater than the slope of the *SS*-line, as reflected by point E_H. That is, the equilibrium of E_H is locally asymptotically stable as shown in Figure 2.

Appendix 2 Properties of the Iso-Welfare Curve

The welfare function, for convenience, is rewritten as below:

$$\begin{aligned} w(S,n,N,\tau+c,F,m) &= m\pi+nt+mL+v(S) \\ &= \left[S\left(\frac{N-n}{N}\right)-(\tau+c)\right]n-mF+v(S). \end{aligned}$$

The partial derivatives of the function with respect to each argument, $w_i \equiv \partial w/\partial i$, are listed as

$$w_S = n\left(1-\frac{n}{N}\right)+v'(S)<0,$$

$$w_n = 2S\frac{n}{N}-(S-\tau-c) \gtrless 0 \text{ if } n \gtrless \frac{N}{2}\left(1-\frac{\tau+c}{S}\right),$$

$$w_N = \frac{Sn^2}{N^2}>0,$$

$$w_\tau = w_c = -n < 0,$$

$$w_F = -m < 0,$$

$$w_m = -F < 0.$$

(1) By total differentiation, $dw = w_S dS + w_n dn = 0$, the slope of the iso-welfare curve is thus

$$\frac{dn}{dS} = -\frac{w_S}{w_n} = \frac{\left(1-\frac{n}{N}\right)+v'(S)}{2S\frac{n}{N}-(S-\tau-c)} \gtrless 0 \text{ if } n \lessgtr \frac{N}{2}\left(1-\frac{\tau+c}{S}\right). \quad \text{(A13)}$$

(2) And, simple algebra yields

$$\frac{\partial\left(\frac{dn}{dS}\right)}{\partial n}<0, \text{ and } \frac{\partial\left(\frac{dn}{dS}\right)}{\partial N}>0.$$

Appendix 3 High Equilibrium of E_H May Not be Optimal

In order to examine whether the high equilibrium may not be optimal by Figure 9, we duplicate equations (A7a) and (A8a), which describe the slope of point E^*, whereas the point of tangency between the line-*SS* and line-w^*,

$$\left.\frac{dn}{dS}\right|_{SS} = \frac{Kr - 2rS}{K\theta} \gtrless 0 \text{ if } S \lessgtr \frac{K}{2}, \tag{A7b}$$

$$\left.\frac{dn}{dS}\right|_{w^*} = -\frac{w_S}{w_n} = \frac{\left(1 - \frac{n}{N}\right) + v'(S)}{2S\frac{n}{N} - (S - \tau - c)} \gtrless 0 \text{ if } n \lessgtr \frac{N}{2}\left(1 - \frac{\tau + c}{S}\right). \tag{A14}$$

Thus, the two slopes should be equal, as follows:

$$\frac{\left(1 - \frac{n}{N}\right) + v'(S)}{2S\frac{n}{N} - (S - \tau - c)} = \frac{Kr - 2rS}{K\theta}. \tag{A15}$$

Solving the equations of (A9a) and (6) yields the optimal solution, which is obviously different from that derived by using equation (6) and equation (11) of the *nn*-line.

References

Baral, N., M. J. Stern and R. Bhattarai (2008), "Contingent Valuation of Ecotourism in Annapurna Conservation Area, Nepal: Implications for Sustainable Park Finance and Local Development," *Ecological Economics*, 66:2-3, 218-227.

Barrett, C. B. and P. Arcese (1995), "Are Integrated Conservation-Development Projects (ICDPs) Sustainable? On the Conservation of Large Mammals in Sub-Saharan Africa," *World Development*, 23:7, 1073-1084.

Barrett, C. B. and P. Arcese (1998), "Wildlife Harvest in Integrated Conservation and Development Projects: Linking Harvest to Household Demand, Agricultural Production, and Environmental Shocks in the Serengeti," *Land Economics*, 74:4, 449-465.

Berck, P. and J. M. Perloff (1984), "An Open-Access Fishery with Rational Expectations," *Econometrica*, 52:2, 489-506.

Clark, C. W. (1990), *Mathematical Bioeconomics: The Optional Management of Renewable Resources*, New York: John Wiley & Sons.

Clark, C. W. and G. R. Munro (1980), "Fisheries and the Processing Sector: Some Implications for Management Policy," *The Bell Journal of Economics*, 11:2, 603-616.

Coria, J. and E. Calfucura (2012), "Ecotourism and the Development of Indigenous Communities: The Good, the Bad, and the Ugly," *Ecological Economics*, 73:15, 47-55.

Fan, M. and K. Wang (1998), "Optimal Harvesting Policy for Single Population with Periodic Coefficients," *Mathematical Biosciences*, 152:2, 165-178.

Gayer, A. and O. Shy (2003), "Copyright Protection and Hardware Taxation," *Information Economics and Policy*, 15:4, 467-483.

Gordon, H. S. (1954), "The Economic Theory of A Common-Property Resource: The Fishery," *The Journal of Political Economy*, 62:2, 124-142.

Hardin, G. (1968), "The Tragedy of the Commons," *Science*, 162:3859, 1243-1248.

Hardin, G. (1998), "Extensions of "The Tragedy of the Commons"," *Science*, 280:5364, 682-683.

Holden, A. (2003), "In Need of New Environmental Ethics for Tourism?" *Annals of Tourism Research*, 30:1, 94-108.

Holden, A. (2005), "Achieving A Sustainable Relationship between Common Pool Resources and Tourism: The Role of Environmental Ethics," *Journal of Sustainable Tourism*, 13:4, 339-352.

Holden, E., K. Linnerud and D. Banister (2014), "Sustainable Development: Our Common Future Revisited," *Global Environmental Change*, 26:5, 130-139.

Huang, D. S., Y. Y. Huang and S. P. Young (2008), "Accessibility and the Vicissitude of Ecotourism: A Two-Region Model," *Agriculture and Economics*, 41:2, 1-43.

Huang, Y. Y. and D. S. Huang (2006), "On the Policies of Ecotourism," *Taiwanese Agricultural Economic Review*, 11:2, 239-266.

Johannesen, A. B. (2006), "Designing Integrated Conservation and Development Projects (ICDPs): Illegal Hunting, Wildlife Conservation, and the Welfare of the Local People," *Environment and Development Economics*, 11:2, 247-267.

Kilipiris, F. and S. Zardava (2012), "Developing Sustainable Tourism in A Changing Environment: Issues for the Tourism Enterprises (Travel Agencies and Hospitality Enterprises)," *Procedia-Social and*

Behavioral Sciences, 44, 44-52.

Libosada, Jr. C. M. (2009), "Business or Leisure? Economic Development and Resource Protection-Concepts and Practices in Sustainable Ecotourism," *Ocean & Coastal Management*, 52:7, 390-394.

Lotka, A. J. (1925), *Elements of Physical Biology*, Baltimore: Williams & Wilkins Company.

Morey, E. R. (1980), "Fishery Economics: An Introduction and Review," *Natural Resources Journal*, 20, 827-855.

Neher, P. A. (1990), *Natural Resource Economics: Conservation and Exploitation*, Cambridge: Cambridge University Press.

Osés-Eraso, N., F. Udina and M. Viladrich-Grau (2008), "Environmental versus Human-Induced Scarcity in the Commons: Do They Trigger the Same Response?" *Environmental and Resource Economics*, 40:4, 529-550.

Ostrom, E. (1990), *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge: Cambridge University Press.

Ostrom, E., J. Burger, C. B. Field, R. B. Norgaard and D. Policansky (1999), "Revisiting the Commons: Local Lessons, Global Challenges," *Science*, 284:5412, 278-282.

Salerno, F., G. Viviano, E. C. Manfredi, P. Caroli, S. Thakuri and G. Tartari (2013), "Multiple Carrying Capacities from A Management-Oriented Perspective to Operationalize Sustainable Tourism in Protected Areas," *Journal of Environmental Management*, 128:15, 116-125.

Tietenberg, T. (1996), *Environmental and Natural Resource Economics*, New York: Haper Collins College Publishers.

Verhulst, P. F. (1838), "Notice Sur La Loi Que La Population Suit Dans Son Accroissement," *Corresspondance Mathémalique et Physique*, 10, 113-121.

Volterra, V. (1926), "Variazioni e Fluttuazioni del Numero D'individui in Specie Animali Conviventi. Memorio del Socio Vito Volterra," *Memorie della R. Accad. Naz. dei Lincei*, VI: 2, 31-113.

資源共有、生態旅遊與永續發展

黃登興、黃幼宜

摘 要

生態旅遊是建築在自然資源上的，但生態自然資源往往有著資源共有的問題。本文旨在建構一個納入資源共有屬性的生態旅遊模型，分析永續發展中在地居民與政府的角色。我們證明發展生態旅遊，未必保證生態園區得以永續發展，除非伴隨適當政策，例如減少生態區經營業者，和/或課徵生態旅遊稅。具體而言，我們證明存在兩個穩定均衡：一是生態資源存量較低或甚至為零的均衡，另一個是高資源存量的均衡。在低存量均衡，當沒有旅運成本的自由進入，以及無任何的環境維護成本下，則生態園區自然資源將會滅絕，出現共有地的悲劇。高資源存量均衡對應更高的社會福利，可以透過相關政策，例如生態旅遊稅、調整經營業者許可費、限制潛在遊客人數、或控制經營業者數量以達成。更重要的是，我們證明雖然高資源存量均衡比低資源存量均衡更好，但可能不是社會最適化的結果。社會福利極大只能透過直接對遊客課生態旅遊稅達成，不能僅僅藉由控制經營業者數量來達成。

關鍵詞：生態旅遊、資源共有、永續發展、共有地的悲劇
JEL 分類代號：Q01, Q57, L83

兩位作者分別為聯繫作者：黃幼宜，國立臺灣海洋大學應用經濟研究所教授，20224 基隆市中正區北寧路 2 號，電話：02-24622192 轉 5412，E-mail: hyy@ntou.edu.tw。黃登興，中央研究院經濟研究所研究員，11529 臺北市南港區研究院路二段 128 號，電話：02-27822791 轉 204，E-mail: dhuang@econ.sinica.edu.tw。初稿承蒙本刊三位匿名評審提供諸多寶貴意見和建議，特此致謝。惟文中若有任何疏失之處，當屬作者之責。

投稿日期：民國 104 年 1 月 5 日；修訂日期：民國 104 年 4 月 27 日；
接受日期：民國 105 年 10 月 12 日。