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Abstract: Ecotourism is a viable alternative for the development of regions and countries with a strong natural resource base. Sustainable development involves the compatibility of the growth in the number of tourists and the preservation of ecologically valuable natural resources. This paper focuses on the relationships between environmental degradation and physical capital in the management of natural resource based tourist products. An ecotourist product is defined as a destination whose basic resource is nature and attracts an inflow of tourists as the main source of income. In particular, we introduce a simple predator-prey model which allows us to derive a general pattern for natural capital with a final phase of declining. This particular pattern is due to the negative influence of the implementation of physical infrastructure on natural resources which are also major sources of consumer attraction. According to this, in a classical welfare optimization framework, we have obtained optimal trajectories for the local consumption and the use of natural capital. In the steady state case, the optimal rate of consumption is strongly dependent on the relationship between the impacts of physical capital in both demand and environmental degradation. The results have general implications for consumer goods with negative externalities which are appreciated by the status of their environmental attributes.

Keywords: Economic welfare, predator-prey model, Life cycle, Natural capital, Ecotourist product.

1. Introduction

Tourism is an industry which in many cases involves the utilization of valuable land and other natural resources. The intensive utilization of natural resources is particularly relevant in nature based tourism products, or ecotourism, where the main attracting factors are related with the enjoyment of highly preserved natural environments. However, the development of tourism requires the implementation of physical infrastructure for the variety of services that the industry has to provide to potential tourists. For instance, accommodation, transportation, and complementary services all require large quantities of investment in physical capital.

The relationships between tourism and the environment have been reported by Green et al. (1990) and Green and Hunter (1992) among others. A central aspect of these relationships is that the development of physical capital can have impacts on the state of natural capital and environmental resources. Clarke and Ng (1993) argued that the presence of non-priced external effects in tourism could lead to a failure of the market mechanism to maximize social welfare. In a similar line, Harari and Sgro (1995) suggested that tourism development could lead to a lower welfare for the local residents because of the competition between tourists and residents for the consumption of non-tradable goods.

The possibility of market failure in tourism makes useful to evaluate the optimal paths of economic welfare as natural capital is impacted by the development of physical infrastructure. Previous research by Mananyi (1998) proposed a dynamic model for the optimal management of the number of tourists in ecotourism as wildlife amenities are impacted by human presence. This model assumes that the natural environment is negatively affected only by the numbers of tourists.

The objective of this paper is to study the relationships between physical and natural capital in the evolution of an economic activity which depends on the amount and quality of the natural environment, such as nature based tourism. We propose a predator-prey model which takes into account the fact that both types of capital are necessary for the development of tourism. The natural capital is transformed by the implementation of physical capital, and can be also used in the production of tourist services. On the other hand, the physical capital requires natural capital for its development, and both types of capital are driving the production of tourist services.

2. A model for physical and natural capital

Nature based destinations utilize natural resources and physical capital in the production of tourist services. The objective is to maximize welfare to the local community from the production of tourist services. This involves determining the optimal trajectories of consumption in the local area and the use of the environmental resource.

Initially, we consider that the production of tourist services $Y=Y(q)$, depends on the number of tourists q attended by the local economy. The tourists are attracted by the stock of physical capital offered K (hotels, transport infrastructure and services) and the stock of natural resource X in the area. Assuming a constant return to scale Cobb-Douglas production function, the expression for the gross income is

$$Y = bK^{\alpha}(aX)^{1-\alpha}, \qquad (1)$$

where α is the share of physical capital and b indicates the profitability of the tourist activity. Parameter a stands for the use of the natural capital and represents the exploitation of the environment as a tourist attraction. For instance, in a beach area it would include all attractions that can be offered on the beach, such as sea motor-bykes, pedal-boats, aquatic sky, etc.; in a natural protected area, it represents the excursions or visits allowed in the area or the tracks designed to be used by the users, etc.

Let us consider that all non consumed rent in the economy is invested in physical capital. Thus, we obtain the neoclassical growth equation,

$$\dot{K} = s\,b\,K^{\alpha}(aX)^{1-\alpha} - \delta_K K, \qquad (2)$$

where s is the saving rate and δ_K is capital depreciation.

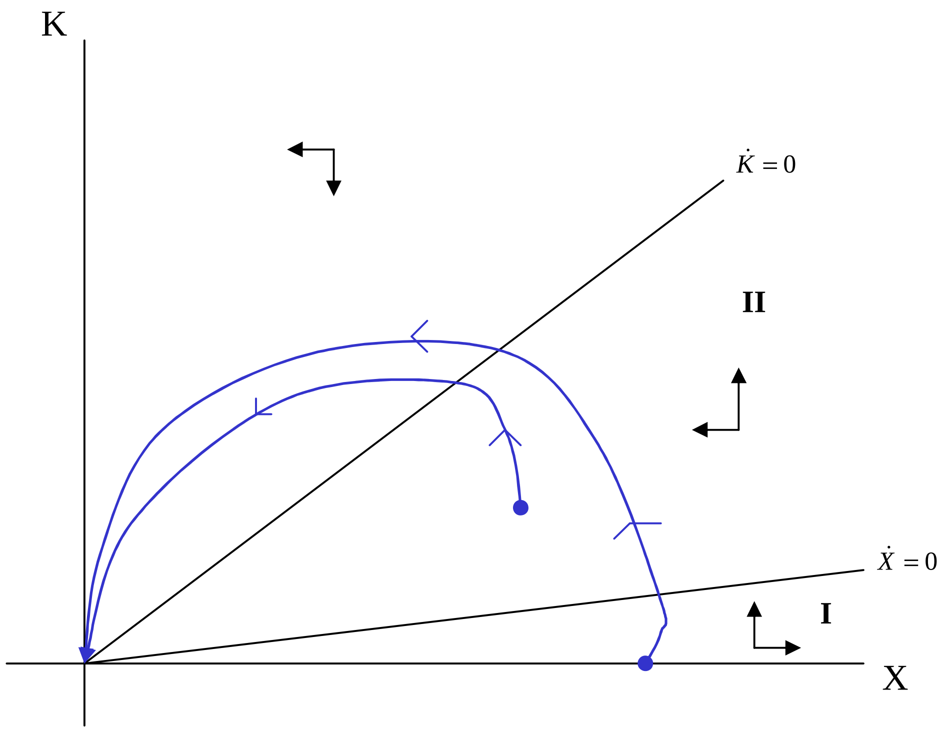

Figure 1. Phase portrait *(X,K)* of tourism activity dynamic model. Blue curves show the different realistic trajectories.

On the other hand, natural capital is negatively influenced both by the implementation of physical capital in the area and by the use of the natural resource. However, these factors do not have to be equally shared in the degradation of the natural resource as in the tourist demand. Thus, proportional increments in the use of the natural capital can injure the natural resource more than the benefit produced in the gross rent. This is the case of the use of some motor-bykes in a protected seaside area, which provoke serious damage to the local fauna and not necessary attract a significant amount of tourists. On the other hand, some physical capital, as the rural cabins, more respectful with the environment, plays a very significant role in the total rent. Thus, considering again a constant return to scale of both effects, the natural resource evolves according to the following equation,

$$\dot{X} = -dK^{\beta}(aX)^{1-\beta} + \delta_X X, \qquad (3)$$

where β is now the share of physical capital in the degradation of the natural resource. We assume

$$\beta < \alpha, \qquad (4)$$

so the physical capital effect over the attraction of visitors is higher than its negative effects over the environment. Parameter $d>0$ indicates the multiplicative effect over the variation in natural capital of proportional increments in physical capital and use of natural resource. We include also a regeneration rate δ_X.

Initially, all parameters in the model are assumed to be fixed. Thus, the model above shows a well known predator-prey scheme between the physical and the natural capital in tourism development. The physical capital (predator) needs the natural capital (prey) to grow through the joint generated rent, but this natural capital is degraded by the existence of the former one. This kind of systems uses to exhibit a convergence to stable oscillations or convergence to an equilibrium point depending on the specific relation between predator and prey. In order to analyze the dynamic patterns in our case, we present in Figure 1 the phase diagram (*X*, *K*) for the system above. The diagram allows us to infer the potential trajectories which should follow the variables by considering the isoclines $\dot{K} = 0$, $\dot{X} = 0$ (Hirsch and Smale 1974).

As it can be observed in Figure 1, both isoclines are straight lines crossing in the origin, that is the only equilibrium point. We assume the slope of isocline $\dot{K} = 0$ steeper than the one of $\dot{X} = 0$, since the latter is proportional to the regeneration rate δ_X, that use to adopt very low values in reality. The isoclines divide the phase portrait in three regions. The initial conditions of an attractive and non exploited area fall on the two first regions, where low levels of physical capital are combined with high natural values. The trajectories followed by both capitals for realistic parameters are also illustrated in Figure 1. There is a first stage where the physical capital is increasing due to the reinvestment of the tourist revenues in the local economy, followed by a second stage of destruction of this investment, started when the trajectory enters in region III, and the low levels of natural capital makes the tourist industry unprofitable.

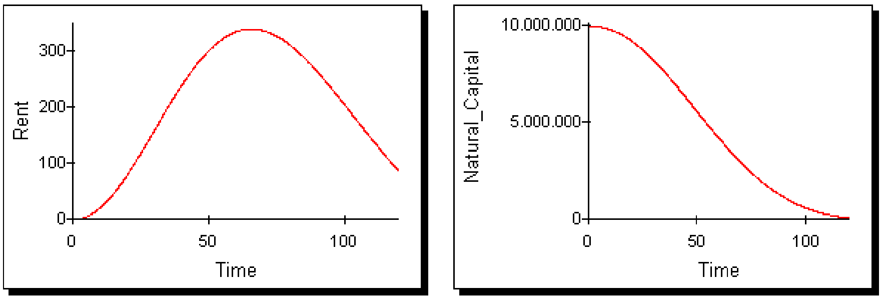

Figure 2. Intertemporal trajectories for rent (left) and natural capital (right) in the dynamic model. Parameter values and initial conditions are: $a=1$, $b=0.01$, $d=0.5$, $\alpha=0.7$, $\beta=0.4$, $\delta_K=0.05$, $\delta_X=0.0001$, $K(0)=0.0001$, $X(0)=10^7$.

We can more specifically describe the evolution of the variables by showing their intertemporal trajectory. In particular, Figure 2 illustrates the trajectory of the rent for some concrete values of the parameters, although the same pattern is exhibited for a very large range of them. We observe in Figure 2 a logistic growing phase of the rent, where a first period of tourist boom is followed by a lower growth and stagnation period, emulating them typical cycle of the tourist product. However, we expect from this model a second phase of continuous declining in the tourist revenues after the stagnation period due to the extreme deterioration of the natural attraction of the area.

3. Optimal consumption of natural capital

The model above presents a pessimistic horizon of the long term evolution of the nature based tourism. Note that we have assumed that agents act myopically not reacting to economic significant variations or other exogenous stimulus along the activity lifetime. However, policy makers could transform the patterns of tourist consumption by implementing adequate policies influencing economic agents. In particular, they can adopt some environmental protection policies which could have an effect on the relative composition of the natural and physical capital in tourism.

We can include these preventive measures in our model considering the use of natural resource as a control variable. The objective of the social planner will be to optimize the social welfare deriving of the tourism activity. Therefore, we restate the model in a consumer optimization framework where both the use of natural resources a and local consumption c are now controlled. That is,

$$\begin{aligned}
&\max_{c,a} \int_0^{+\infty} u(c)e^{-rt}dt \\
&s.a.\ \ \dot{K} = bK^{\alpha}\left(aX\right)^{1-\alpha} - c - \delta_K K, \\
&\dot{X} = -dK^{\beta}\left(aX\right)^{1-\beta} + \delta_X X, \\
&K(0) = K_0, \\
&X(0) = X_0, \\
&(K(t), X(t), c(t), a(t)) \geq 0,
\end{aligned} \tag{5}$$

where $u(c)$ is the society's utility function which depends on private consumption in the local area, discounted with rate r. We assume, as usual in endogenous growth models, a constant intertemporal elasticity of substitution in the utility function. Thus, marginal utility adopts the expression $u'(c) = c^{-\varepsilon}$, where ε is the inverse of the intertemporal elasticity of substitution.

For the sake of simplicity, we initially assume that both the state and the control variables in the optimal path do not satiate the frontier conditions. Therefore, the optimal trajectory for consumption and use of natural capital has to maximize the present value Hamiltonian,

$$\mathrm{H} = u(c) + \lambda_1\left(bK^{\alpha}\left(aX\right)^{1-\alpha} - c - \delta_K K\right) - \lambda_2\left(-dK^{\beta}\left(aX\right)^{1-\beta} + \delta_X X\right), \tag{6}$$

where λ_1 and λ_2 are the Lagrange multipliers related with physical and natural capital respectively. Applying the first order conditions, the optimal path has to preserve equality between the marginal utility of consumption and the marginal contribution of physical capital to social welfare in present values,

$$\frac{\partial H}{\partial c} = 0 \Leftrightarrow \lambda_1 = u_c > 0. \tag{7}$$

From this equation, it follows that the growth rate of consumption path is proportional to the growth rate of Lagrange multiplier λ_1, with the constant elasticity of substitution as the proportion rate, that is,

$$\frac{\dot{\lambda}_1}{\lambda_1} = -\varepsilon\frac{\dot{c}}{c}. \tag{8}$$

Moreover, the optimal use of natural capital leads to a specific relation between both multipliers,

$$\frac{\partial H}{\partial a} = 0 \Leftrightarrow \lambda_2 = \frac{b(1-\alpha)}{d(1-\beta)}\left(\frac{K}{aX}\right)^{\alpha-\beta}\lambda_1 > 0, \tag{9}$$

that depends on the evolution of the ratio between the physical capital and the total use of the natural capital K/aX, that we denote as the physical capital per unit of use of the environment.

Concavity of the Hamiltonian function in (a,c) is guaranteed by the assumption $\alpha > \beta$, hence a greater share of physical capital in the production function with respect to its share in the degradation function is essential to fulfill the sufficient condition for the optimal trajectory.

According to the Pontryagin's maximum principle, both multipliers verify the following equations:

$$\dot{\lambda}_1 = \lambda_1 r - \frac{\partial H}{\partial K} = \lambda_1\left(r + \delta_K - \frac{b(\alpha-\beta)}{1-\beta}\left(\frac{K}{aX}\right)^{\alpha-1}\right), \tag{10}$$

$$\dot{\lambda}_2 = \lambda_2 r - \frac{\partial H}{\partial X} = \lambda_2\left(r - \delta_X\right). \tag{11}$$

Equation (11) indicates that the current value multiplier increases exponentially at a rate lower than the discount rate. Therefore, in the optimal path the marginal valuation of the natural capital, discounted back to initial time, decreases with rate δ_X, that is, the regeneration rate. This announces a progressive devaluation of the natural resource until reaching null values in the very long-term.

Using equations (8) and (10), we can obtain the optimal growth rate of the local consumption,

$$\frac{\dot{c}}{c} = \frac{1}{\varepsilon}\left(\frac{b(\alpha-\beta)}{1-\beta}\left(\frac{K}{aX}\right)^{\alpha-1} - \left(r + \delta_K\right)\right). \tag{12}$$

Therefore, the evolution of the optimal consumption in the local area depends inversely on the physical capital per unit of use of the environment. Higher levels of this physical capital per unit of use produces lower growth rates of consumption. Eventually the consumption growth may be negative for high discount or depreciation rates.

The physical capital per unit is an essential variable to determine the optimal growth in the local economy. Deriving equation (9) we obtain the dynamic evolution of this variable,

$$\dot{\left(K/aX\right)} = \frac{b}{1-\beta}\left(K/aX\right)^{\alpha} - \frac{\delta_K + \delta_X}{\alpha - \gamma}\left(K/aX\right). \quad (13)$$

We observe that $\left(K/aX\right)$ has a growth dynamic in the optimal path similar to Solow-Swan capital per capita growth, depending only on the depreciation and regeneration rates and the shares of physical capital. Figure 3 presents the trajectory that the capital per unit has to follow. We expect low levels of this variable at the beginning of the tourism activity, which increases in a logistic type shape until converging to a stable equilibrium point, that is,

$$\left(K/aX\right)^{*} = \left[\frac{b(\alpha-\beta)}{(\delta_K + \delta_X)(1-\beta)}\right]^{1/1-\alpha}. \quad (14)$$

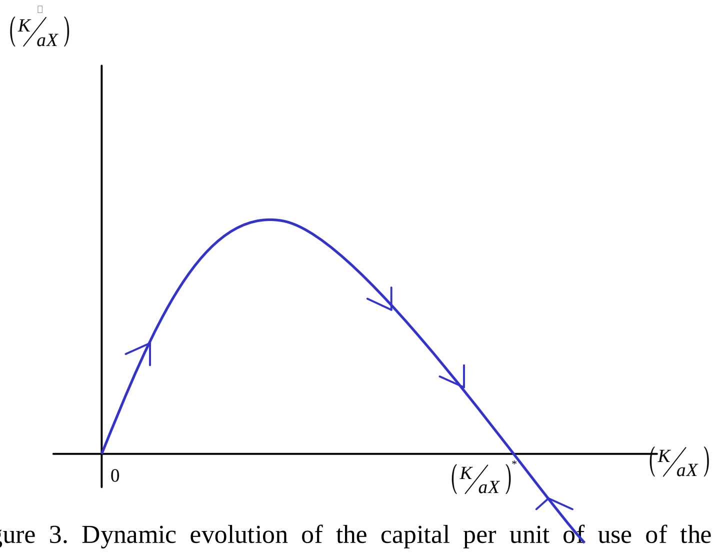

Figure 3. Dynamic evolution of the capital per unit of use of the environment $\left(K/aX\right)$. There is an asymptotically stable equilibrium point in $\left(K/aX\right)^{*}$.

Thus, the optimal capital per unit of use of the environment in equilibrium is positively dependent on the difference between the share of physical capital in the production and degradation function. The larger this difference, the higher the capital per unit permitted in the area. This conclusion fulfilled the intuitive conception of the system, that is, very profitable physical capital with no large impact into the environment, as rural cabins close to the natural area, are more acceptable than other kind of less environment respectful buildings.

The convergence to an equilibrium in the capital per unit determines the growth rate of consumption in the local area at the long term. Substituting equation (14) in (12) we obtain,

$$\frac{\dot{c}}{c} = \frac{1}{\varepsilon}\left(\delta_X - r\right). \quad (15)$$

So, we have a negative influence of the discount rates for a permanent growth. A positive growth in consumption is assured only if the regeneration rate is higher than the discount rate. This is not very expectable as the natural area use to take very long time to be naturally regenerated. However, this parameter can be artificially increased through investment in protection, cleaning or foresting. Nevertheless, if we consider $\delta_X < r$, the growth rate of consumption in the optimal path is necessarily negative, so we can not maintain a long term welfare growth in a tourist activity.

4. Conclusions

Nature tourism and many tourist products are strongly based on the use of natural resources for its development. These resources act as attracting factors for demand and are exploited with the aim of generating income for the local communities. However, the implementation of tourism infrastructure can have an impact on these natural resources, degrading their values and reducing their potential to attract demand. This paper has proposed a predator-prey type model to accommodate the particular relationships between natural and physical capital, assuming that both types of capital are essential for the development of the tourist product. These types of relationships are common to many market products where natural and physical aspects are combined either in production or in consumption.

The dynamic system of the motions for both types of capital shows that as physical capital is implemented there could be a corresponding reduction of natural capital, and eventually the latter is completely degraded. The extinction of natural capital leads to a declining rate of physical capital, with the final collapse of the product. These patterns are possible for the tourist product, because natural capital is needed to attract tourists, and as these attracting factors die out, this would be followed by disinvestment of tourist facilities.

The management of the product requires optimal decisions about consumption in the local economy driven by tourism growth and the consumption of the natural capital. These are crucial decisions which can counteract the tendency of the natural capital to die out as the physical capital and infrastructure develops in the local economy. The results for the optimal control paths show that non-declining optimal consumption would require that the rate of regeneration of the natural capital to be larger than the interest rate. Thus, long term growth in welfare is not possible if the natural capital is not managed properly with the aim of maintaining its characteristics.

The amount of physical capital per unit of consumption of natural capital is also a variable which influences the rate of growth of local consumption. As this ratio increases, the optimal rate of growth of consumption becomes smaller. The ratio reaches an equilibrium point which depends on the relationship between the respective shares of natural capital in production and environmental deterioration. The optimal physical capital will be larger when its impact on environmental deterioration is small, but this would be coupled by a lower rate of consumption growth.

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