Fondazione Eni Enrico Mattei

Economic and Environmental Sustainability: A Dynamic Approach in Insular Systems

Fausto Cavallaro and Luigi Ciraolo

NOTA DI LAVORO 21.2002

APRIL 2002

SUST – Sustainability Indicators and Environmental Evaluation

Fausto Cavallaro *Department of Economy and Territory, University of Catania*

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Economic and Environmental Sustainability: A Dynamic Approach in Insular Systems Structures

Summary

Environmental resources constitute the 'raw materials' for tourism. This sector represents the driving force behind the economy of small islands. The sustainable use and a rational policy of conservation of these resources are prerequisites to enable their full exploitation. However, island systems have low stability, as they are highly sensitive to exogenous stress phenomena caused by economic factors, which exceeding the sustainable threshold may come together to damage the environment. This work systematically examines the effects and the feedbacks that the economy of tourism may generate in small areas like the minor islands of Sicily (Italy). The development of a dynamic model is proposed to supply a key to interpret the phenomena affecting the island of Salina (Aeolian islands-Messina) offering elements for the assessment of future local government policies.

Keywords: Sustainable development, dynamic systems, tourism, models

JEL: Q01, C89

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1.INTRODUCTION

The Aeolian islands as a whole are certainly, due to their outstanding natural beauty, a huge tourist attraction for Italians and foreigners. The launch of the tourist industry in these islands can be traced back to the scientific and cultural interest arising in the archipelago in the early 1950s. Initially, tourists were attracted by the unusual volcanic activity present on the islands of Stromboli and Vulcano and the natural thermalism on the island of Lipari. Since the 1960s the phenomenon of tourism has become an industry in its own right.

In order to satisfy the increasing demand from tourism a flourishing activity began, centred on the construction of new hotels and other facilities to host tourists. Unfortunately, owing to the lack of regulation, tourist activity in many cases has not translated into opportunity for balanced growth of the local economy. On the contrary it has created significant territorial and environmental imbalances.

The aim of this work is to attempt to develop a model based on a dynamic approach in order to:

- simulate the behaviour and the interaction of the main economic and environmental variables of the islands;
- analyse the resultant levels of stability and fragility of environmental systems on small islands, following exogenous perturbations generated by economic factors such as the presence of tourism.

The model developed, opportunely modified, could also be applied to other areas similar to the one analysed. The next section in this work illustrates the specific problems of the case analysed, the subsequent one goes on to describe methodological aspects and the elements of the model, the fourth analyses the results obtained from the simulation and lastly, conclusions are drawn from these results.

2. ECONOMIC ACTIVITY OF THE ISLAND OF SALINA (ITALY)

The Aeolian islands are situated to the north of Sicily in the southern Tyrrhenian sea and comprise the seven main islands as well as some smaller uninhabited ones and rocks of negligible size. In order of size the islands are: Lipari, Salina, Vulcano, Stromboli, Filicudi, Alicudi and Panarea. The islands are administered by the local authority of Lipari apart from Salina, which is divided into three areas that come under the province of Messina.

The economic development of the microinsular Aeolian systems is based almost exclusively on tourism and all the activities associated with this. This development model concentrates mostly on the island of Salina. There are numerous workers involved who were once employed in farming and fishing. Now however, the local workforce is mainly engaged in construction work during winter and in tourism during the summer season. As a result of this all traditional areas of economic activity have been almost totally abandoned.

For many years agriculture and fishing represented the economy of the local population and was one in which man and environment were in perfect equilibrium. It can easily be deduced that until economic activity mainly consisted of agriculture and fishing, the impacts on the territory were not as significant as those currently generated by tourism. As a consequence of this *non-policy* of tourism, it is clear that during the summer (above all in August) the island of Salina is affected by traffic congestion, production of waste, consumption of natural resources (fresh water, energy, etc.) and an impact on the environment of significant magnitude. Therefore, it can be said that the area is put under pressure by the burden of numbers of tourists that are considered to be too great for the size of the island in the long term. The long-term growth in the number of tourists could compromise the fragile local *carrying capacity* and produce marked instability in the environmental equilibrium through practices that are detrimental to the natural resources. Were the tourist industry to be managed rationally it would certainly represent an opportunity for sustainable growth in the insular systems of the Aeolian Islands. To this end it is held to be necessary and urgent to redesign a model of development for the island of Salina that, through the use of suitable tools, promotes eco-tourism but at the same time revitalizes other areas of production that have now been abandoned.

3.DEVELOPMENT AND ANALYSIS OF A DYNAMIC MODEL

3.1 Instability and exogenous shock

As stated above, the effects of tourism exert pressure on the natural environment that can give rise to phenomena harmful to the environment to a greater or lesser extent. But up to what point can the environmental system resist the distress provoked by economic activity? In addition, is the ability of self-preservation of systems to adapt to changes produced tough enough to withstand them? We will seek therefore to illustrate some fundamental concepts to understand how the model works.

The environmental system under pressure from external perturbation, including economic exploitation, may show two types of reaction:

a) a *stability* reaction*:* this implies a condition in which the system shifts from the state of equilibrium through a state of stress and then tends to return to the initial state; b) a *metastability* reaction*:* where the system modifies the initial level of equilibrium and subsequently reaches a different stable point of equilibrium[1]. A strong perturbation may instead drive the system into the domain of another stable state of equilibrium, if this exists. This type of stability is known as "global stability"[2].

The key question is whether the perturbation (exogenous shock due to economic activity) compromises the resilience and resistance of eco-systems. The environmental system may indeed move away from a state of equilibrium and may fluctuate more or less widely around a configuration called *single point attractor*. An attractor binds a system to a precise pattern of behaviour. It may be conceived as a region of limited space towards which every path of a dynamic system tends to direct itself and it may be a stable point, a regular cycle or a highly complex behaviour. When we are in the presence of a single point attractor, the system tends to return towards a state of equilibrium after having been upset.

But if we hypothesise that the oscillations, provoked by an external shock, correspond to another type of field attractor, the *strange attractor*, the system will behave in an unstable and chaotic manner[3].

When the system finds itself in this state it is structurally unstable and it is impossible to make forecasts. The environmental system, far from equilibrium, because of the presence of non-linearity may show more pronounced disorder. In this specific case the heavy flow of tourists may be the cause of the chaotic behaviour of environmental systems that could translate into irreversible damage.

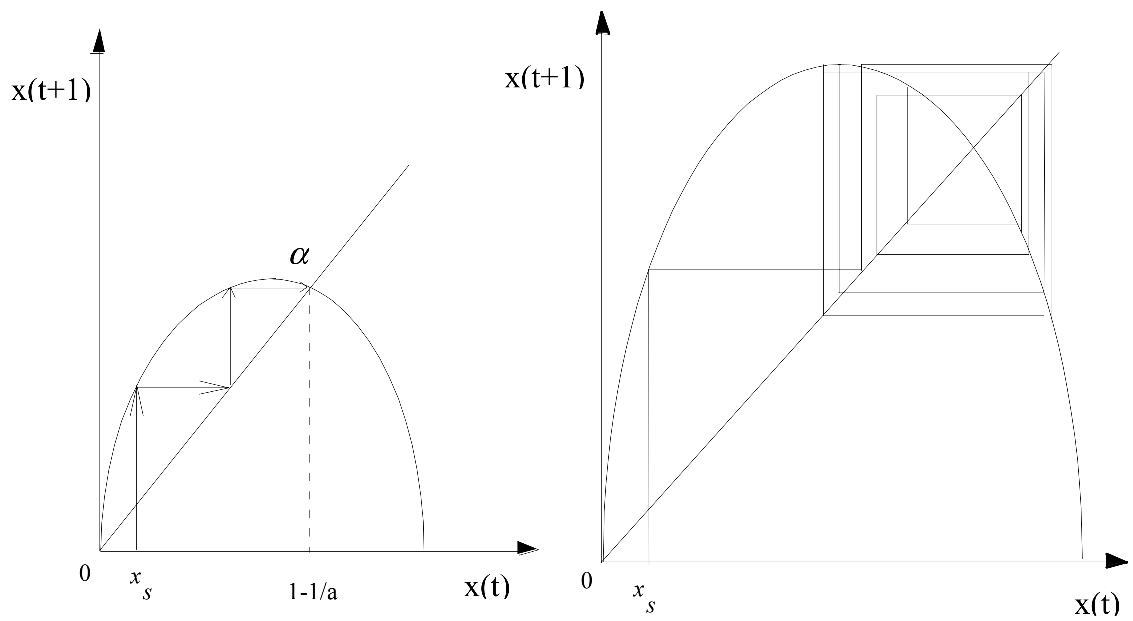
A dynamic system can be represented as a set of differenzial equations. It is well known that systems of differential equations and systems of non-linear difference equations can generate very complex time-paths that can seem random but instead they are chaotic. We will examine a dynamic system with a simple first-order difference equation:

$$X_{t+1} = aX_t(1 - X_t) \qquad (1)$$

This equation in literature is known as "logistic map"[4] and it has been used by May for modelling the dynamic of population. The equation (1) has been largely discussed by May and subsequently by many other authors such as Baker and Gollup (1990), Baumol and Benhabib (1989), Frank and Stengos (1988) and Kelsey(1988). In this equation the parameter "a" is crucial to put in action feed-back behaviours. The equation (1) has two solutions, or stationary solutions in which $x(t+1)=x(t)$ so $x(t)=0$ e $x(t)=1-(1/a)$ the values of the endogenous variable can fluctuates between 0 and 1. The equation arises a curve known as phase curve and it can to create different dynamic behaviours that may produce complex effects. More precisely we will have:

- If at the beginning, the parameter is $0 \le a \le 1$ the system tends to zero, so a growth of economic development rate does not have any effect on the ecological system.
- If we suppose instead that the parameter is $0 \le a \le 3$ the system tends towards a point of stable equilibrium that in the fig. 1a is represented by the point α. It is easy to observe that the system moves away from the point x_0 and is attracted to a fixed point $x_t = 1 - \frac{1}{a}$, so the dynamic of the system seems to be rather foreseeable. The point α is an attractor point.

Eventually if “a”is gradually increased till reaching values higher than a *sustainable threshold* the fixed point 1-1/a becomes instable. The behaviour of the system at the beginning will be oscillatory with periodic cycles (see fig.1 b) and afterwards the cycles will be not identifiable anymore and the path will arise in a chaotic way. Consequently it will became impossible to do any forecast about the pathway of the system.



a) b)

Fig. 1

3.2 A systemic approach

In order to globally interpret the existing interrelations in the system *economy-tourism-environment* and above all to verify the degree of stability it seems interesting to adopt and approach that is able to comprehend all the elements produced, i.e., from the dynamics of the interconnections between the vital elements of the whole system. According to a systemic view the interventions occurring in one sector may affect other sectors and the way in which these sectors are interlinked and the possible effects produced are in many cases not at all predictable[5]. Complex systems analysis has been useful in the fields of economics, ecology and others to interpret phenomena when the exact intensities of the interconnections are unknown. Therefore, through the development of this model an attempt is made to interpret the relations and changes over time of the main variables present in the system analysed.

3.3 Elements of the model

The model was developed in the STELLA™ modelling environment based on system dynamics. The system created was subdivided into three interacting sub-systems: economic, tourist population and environmental resources (see fig. 2).

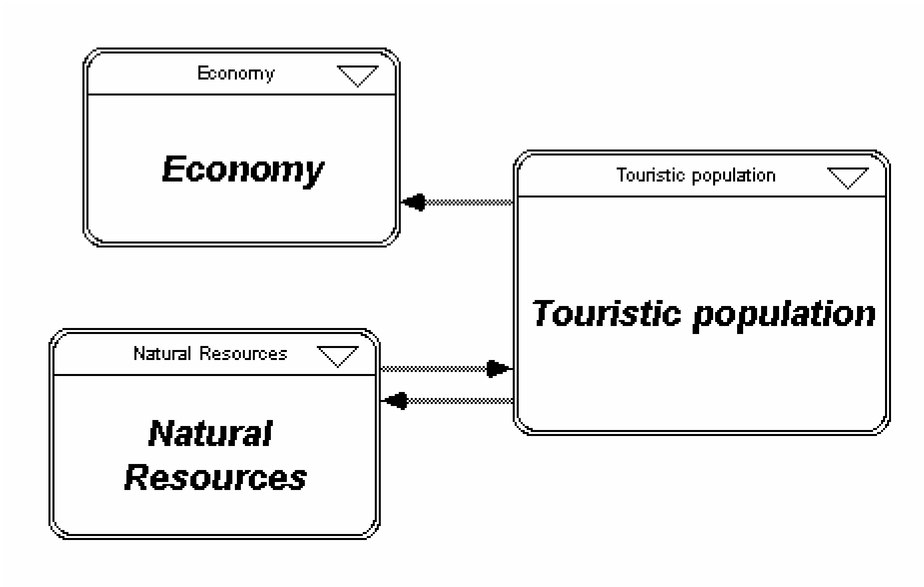


Fig. 2 Interactions of the system

An analysis of all the elements of the three sub-systems making up the model was developed as follows[6] (see fig. 3):

- In **sub-system (a)** the local economy is presented as a stock (**Local Economic**) the growth of which is strongly influenced by the presence of tourists (and all derived from this) and by the rate of local growth (**Lgrowth**), i.e. the ability of the local population to create added value. The hypothesis is considered of introducing a tax (**Tax**) to levy on tourists who decide to go to the island; the yield is calculated on the basis of the rate (**Rate**) set by the authorities (see below).
- The second **sub-system (b)** (population) relates to the size of the tourist population that influences the environmental sub-system. The most important variables, which in this model regulate the size of the tourist population, are represented by[7]: ($\mathbf{E_a}$) *environmental attractions*, this variable takes account of all the aspects linked to the quality of the environment: coastal roads, the sea, parks, cultural and architectural wealth, the landscape, in other words those elements that combine to make a tourist resort an attractive choice; ($\mathbf{P_t}$) *promotion of tourism*, refers to all the initiatives aimed at promoting an influx of tourists (cultural displays, festivals, etc); ($\mathbf{A_t}$), a*ccessibility*, this is a global measure of the number and frequency of maritime transport to ship people from the mainland to the islands; ($\mathbf{R_t}$) r*eceptivity* represents the supply of hotels and (**Rh**) the number of rooms available; and lastly ($\mathbf{C_v}$) is the cost of living that is the price levels of goods and services offered on the island. If we observe fig. 3, the flow which increases the tourist population stock (**Touristic Population**) is governed by the variables Ea, Pt, At, in other words its increase is strongly influenced by environmental attractions, easier access from the mainland and promotions; on the contrary the outflow is regulated by the local cost of living ($\mathbf{C_v}$) and limited availability of accommodation (**Rt**).
- **Sub-system (c)** represents all the elements relating to natural resources and the main types of environmental damage. There is a stock of natural resources (**Natural Resources)** whose level of is governed by tourist population consumption (**Ctp**) and environmental load mainly influenced by the amount of wastes produced (**Waste)**, and seawater pollution caused by motorboats **(Poll)**, and by problems caused by overcrowding (n. cars). The environmental load is however lightened by the *resistance* and *resilience* of the local environment **(R&R)***;* i.e. by reaction mechanisms and therefore adaptation to external changes with which the system itself is equipped.

3.4 Interactions and effects of feedback

As can be seen from the model shown in fig. 2 the main interactions are recorded between system (b) and system (c). Let us try to analyse the strategic points of the model that influence the results of the simulation exercise:

- The tourist population consumes a certain amount of resources (fresh water, energy, etc.), thus it affects, together with the consumption per stock unit (**C_{us}**), the stock level of natural resources.
- The environmental load **(Env Load)**, in the most general sense, depends on the level of waste produced, marine pollution caused by motorboats, and by problems of traffic congestion. These correlated elements produce a behaviour (see fig. 3) that is strongly influenced by resilience, **(R&R)**, which plays a strategic role in the overall dynamics of the system.
- The stock (Touristic pop) interacts positively with the local economy due to the fact, as mentioned above, that tourism represents the driving force of the local economy. The rate of flow could be influenced by a tax imposed on tourists.

The points of overlap of the elements described generate a complex pattern to be interpreted globally. Therefore, a series of simulated trials of the model were carried out and these produced rather interesting results which are described in the section below.

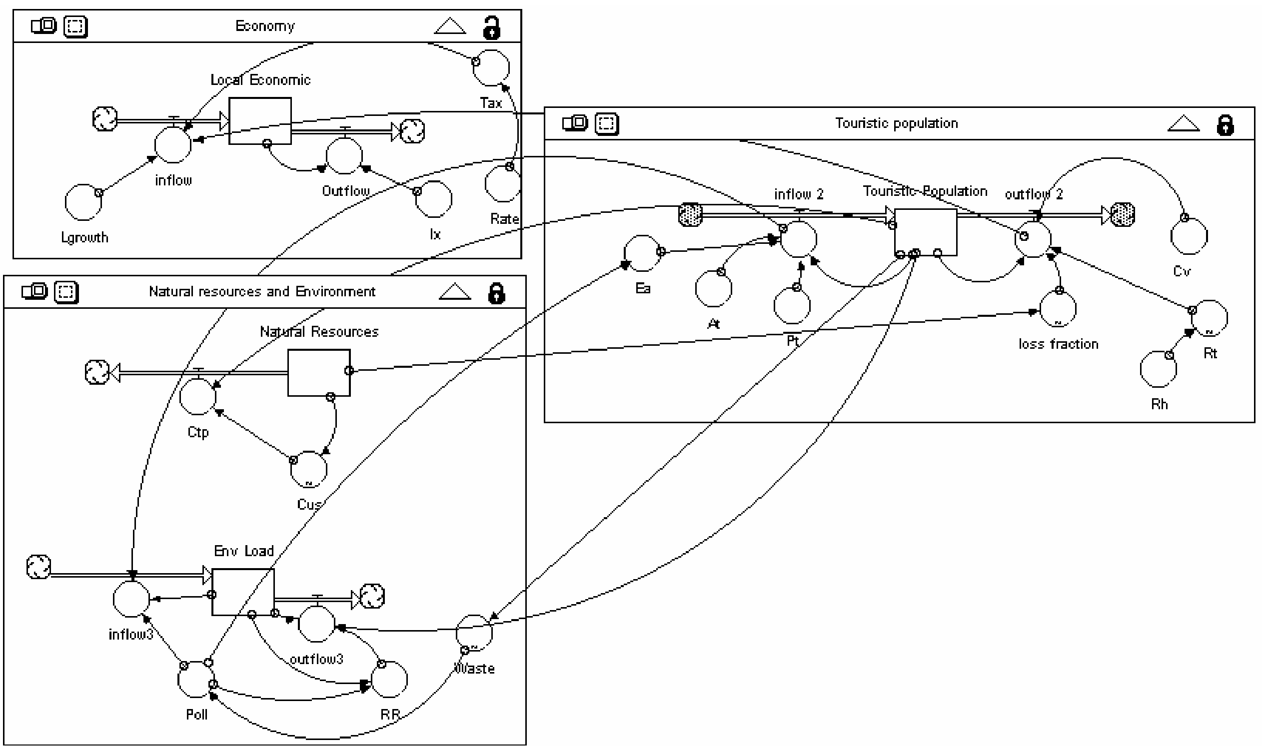


Fig. 3 Tourism-Economy-Environment

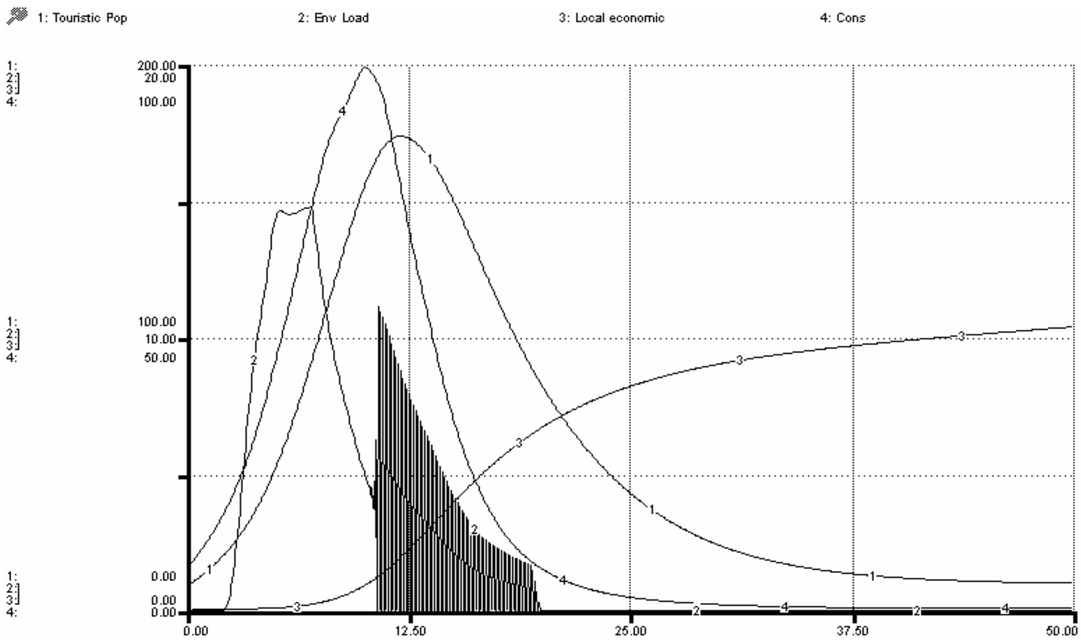
4. SIMULATION RESULTS

4.1 System dynamics and trajectories

Fig.4 shows the results obtained from the simulations performed using the model developed. As can be seen from this fig., several curves are plotted to show the patterns of the four different parameters considered. The time period of reference is the typical summer season lasting about three and a half months (June to September). Curve (**1**) represents tourist population movements and has a typical bell-shape. The number of tourists on Salina (like many other tourist resorts) starts to be recorded towards the middle of June and gradually increases to reach a peak in August. After that the curve gradually falls until it reaches a level of almost nil (winter season). The (**4**), showing the movements in consumption of natural resources, has a very similar shape to (**1**) as its plot is highly dependent on the size of the tourist population (consumption of fresh water and energy).

In contrast, the local economy traced in curve (**3**), first rises, due to the cash inflow directly linked to the tourist presence, and subsequently seems to stabilise at a steady level. This can be explained by the fact that a residual economy remains even when the summer season has finished and there are no longer any tourists. This is basically due to ordinary maintenance work on holidaymakers' second homes. Construction work, together with related activities, is the local population's income source during the winter season. The plot shows a non-linear path and seems to be the parameter that reflects the environmental load level (**2**). As can be seen from the figure, the (**2**) shows a sudden rise despite the fact that the tourist population initially grows only gradually; this reflects the fact that at first, the environment does not react promptly to an exogenous perturbation (tourism) and as a result the environmental load curve rises. Subsequently the (**2**) remains at a constant level very briefly and then plummets. This sharp fall is due to the resilience effect.

Fig. 4 Simulation results (a)



But, just when it seems that the system has *self-regulated*, it suddenly moves towards an unstable equilibrium making the system behave chaotically. This behaviour observed therefore makes it impossible to forecast the evolution of future system behaviour. The instability of (**2**) is recorded when the tourist population reaches its peak (presumably in August) and then becomes stable when the density of tourists reduces to such a level that it no longer influences environmental balance.

4.2 Simulation with hypotheses of controlled and planned flows

Following the analyses carried out in the previous paragraph we wanted to measure the level of sensitivity and equilibrium of the system when altering some parameters held to be strategic to the model. A number of interventions and planned actions that tend to influence the level of the tourist population were introduced and the consequences of these were studied. Details of the interventions hypothesised are as follows:

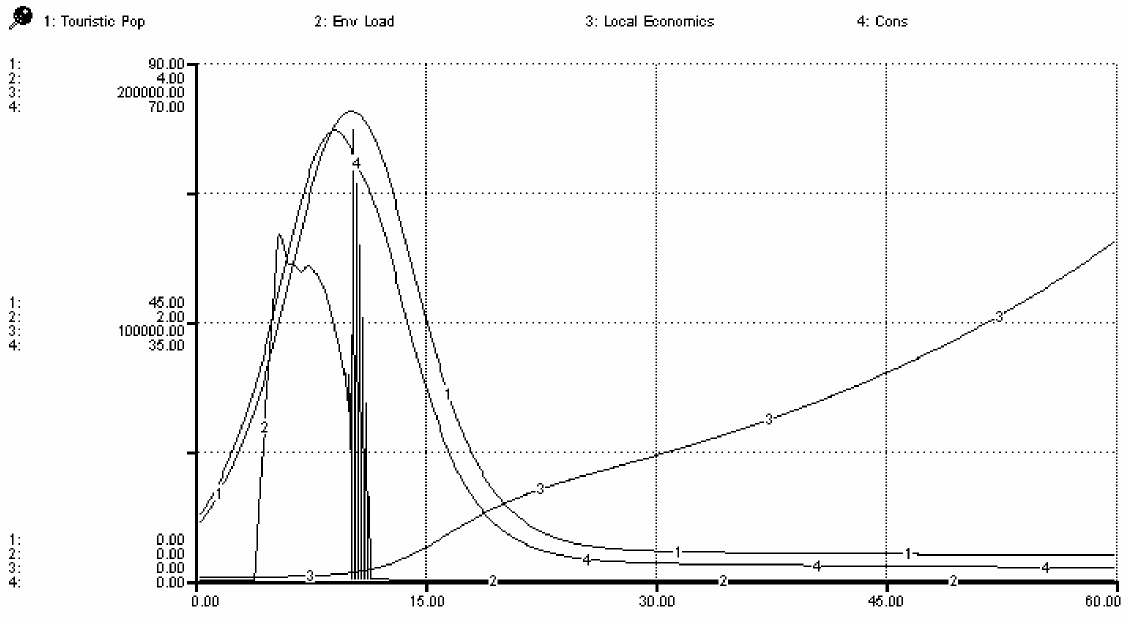
- The introduction of an "*entrance tax*" payable by tourists intending to visit the island. This restriction could represent a means to regulate the flow of people in quantitative terms, providing an incentive to environmentally driven quality tourism. In the model the tax yield, indicated by the variable **(Tax),** is determined by the rate set by local authorities. It is obvious that the size of this variable could in some way influence the flow of tourists. It was hypothesised that the entire sum of the tax collected, deposited in the coffers of the local administration, would be used exclusively to diminish the externalities suffered by the local population by the tourist industry. In other words, the total financial sum would be reinvested in environmental recovery activity and to protect eco-systems.

- Reducing *accessibility* (**At**) (reducing the frequency and number of ferries and hydrofoils between the islands and the mainland) in such a way as to limit the number of tourists "just passing through" while improving the quality of transport services;
- Reducing the level of mass *receptivity* (**Rt**) (big hotels, campsites etc) while favouring the rebuilding of local houses conforming to the original style and architecture but fitted out, however, with various comforts.

As can be seen from figure 5 the pattern of the main variables under scrutiny does not differ substantially from the behaviour described in figure 4. Curves (**4**) and (**1**) are typically bell-shaped and, are very similar in both figures, although in simulation (fig. 4) the peak of the (**4**) was distinctly lower. The most evident differences are to be found when analysing the (**2**) and (**3**), i.e. environmental load and economy. Curve (**2**) shows less chaotic behaviour for a more limited duration, while the (**3**) climbs rather steeply. The different movement of these variables can be attributed to the manoeuvres hypothesised regarding the introduction of an entry tax and the altered levels of accessibility and receptivity.

The shrinkage caused by the latter two variables certainly modifies and controls the tourist population stock and thus lightens the load on the environment as shown in fig. 5. Curve (**4**) relating to the economy seems to show rather anomalous behaviour thus leaving a margin of uncertainty. Even considering that collection of taxes paid by tourists benefit local finances (by indirectly creating wealth in the local community) the exponential growth shown by the (**4**) appears excessive compared to the typical effects arising from the application of a tax on an economic system.

Fig. 5 Simulation results (b)



5.CONCLUSIONS

The first results of the model developed showed that the environmental system is clearly sensitive to the pressures arising from the influx of tourists, above all in small areas like the minor islands. It is necessary to take into account all those signals received from environmental systems that endogenously produce new levels of equilibrium after a series of fluctuations. The model presented provides some data and elements to reflect on. In the case examined these basically affirm the principle that the *uncontrolled* flow of tourism is environmentally unsustainable in the long term and is of limited benefit to the development of the local economy.

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[1] See Candela G., Fabbri P., Cardini F., (1995) I programmi di un'economia sostenibile in *Rivista di Politica Economica,* n.2;

[2] The idea of stability in our system is commonly meant as a concept which includes *resistance* and *resilience.* Resistance is the tendency of the values of the parameters of a system to remain within the same bounds when the system is subject to perturbation, resilience is the speed with which a system returns to its original state following perturbation (Hollings C.S., 1973 - Smith F, 1996);

[3] See Baumol W.L., Benhabib J.,(1992), Nijkamp P., Reggiani A., (1992), Nijkamp P., Reggiani A., $(1992)_b$, for discussion of this argument;

[4] See Baumol W.L., Benhabib J.,(1992) Parker d.-Stacey R., (1994);

[5] See Forrester J.W. (1968), Ruth M., Hannon B., (1997), Odum H.T., (1987);

[6] The words inside the brackets are riported in the fig. 3 that represents the model;

[7] Some of the variables selected in this model are dealt with by Puccia *et al.* (1988).

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