Chapter 2
Dealing with a Complex World: Multiple Dimensions, Values and Scales

2.1 Complexity and Post-Normal Science

The world is characterized by deep *complexity*. This apparently unremarkable observation has important implications for the manner in which policy problems are represented and decision-making is framed. One may decide to adopt a reductionistic approach by tackling only one of the many possible dimensions or one may try to deal with the complexity of the real-world. This book adopts the latter approach. My firm conviction is that any representation of a complex system reflects only a sub-set of its possible representations. *A system is complex when the relevant aspects of a particular problem cannot be captured using a single perspective* (Rosen, 1977; O'Connor et al., 1996; Funtowicz et al., 1999).

To make things more difficult, systems involving humans are *reflexively* complex. Reflexive systems display two peculiar characteristics: "*awareness*" and "*purpose*", both requiring an additional "jump" in describing complexity. The presence of self-consciousness and purpose (*reflexivity*) means that these systems can continuously add new relevant qualities/attributes to be considered when explaining, describing or forecasting their behaviour (i.e. human systems are learning systems).

Moreover, the existence of *different levels and scales* on which a hierarchical system can be analysed implies the unavoidable existence of non-equivalent descriptions of it (Giampietro, 1994, 2003). Even a simple "objective" description of a geographical orientation is impossible without taking an arbitrary subjective decision on the relevant system scale. In fact, as shown in Fig. 2.1, the same geographical place, for example, in the USA, may be considered to be in the north, south, east or west according to the scale chosen as a reference point (the whole USA, a single state, etc.)[1](Giampietro and Mayumi, 2000a,b). Therefore, the problem of *multiple identities* in complex systems cannot be interpreted solely in terms of *epistemologi-*

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[1] These multiple-identity/multiple-scale systems can be defined as "*Learning Holarchies*". A "*holon*" is a whole made of smaller parts (e.g. a human being made of organs, tissues, cells, atoms) which at the same time forms a part of a larger whole (an individual human being is a part of a household, a community, a country, the global economy) (Koestler, 1969).

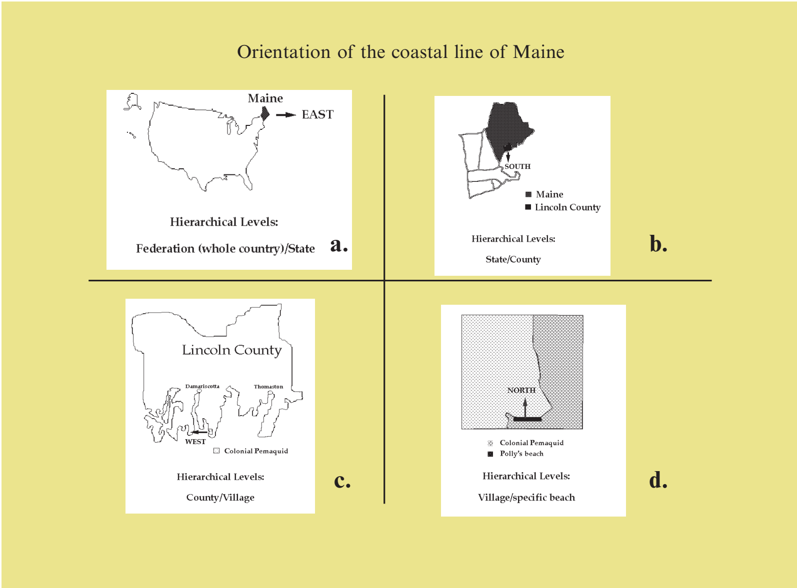

Fig. 2.1 An example of multiple identities according to the system scale (Source: PowerPoint Presentation by M. Giampietro)

cal plurality (non-equivalent observers), but also necessarily in terms of *ontological characteristics* of the observed system (non-equivalent observations).

The implications of scale for multi-criteria evaluation are very important. For example, in generating evaluation criteria (e.g., when evaluating the impacts building a skiing infrastructure in a mountain region, who are the relevant social actors? The inhabitants of the mountain region, the potential users in urban areas or even the ecological preservationists all around the world?), in computing impact scores (e.g., should a contamination indicator be computed locally, or at a larger scale? The use of hydrogen cars in cities is clearly good at local level, but not necessarily at global level, where the emissions depend on the technology by which hydrogen is produced –since hydrogen is an energy carrier and not an energy source.).

A consequence of the extreme subjectivities involved is that in any normative exercise connected with a social decision problem, one has to choose an operational definition of "*value*", in spite of the fact that social actors with different interests, cultural identities and goals all have different definitions of "value" (O'Neill, 1993). That is, to reach a ranking of policy options, there is a prior need to decide *what is important* for different social actors as well as *what is relevant* for the representation of the real-world entity described in the model.

Sustainability policies deal with reflexive phenomena. Because an effective assessment, in order to be realistic, should consider not merely the measurable and contrastable dimensions of the simple parts of the system, which even if complicated, may be technically simulated, it should also deal with the higher dimensions of the system: those dimensions in which power relations, hidden interests, social participation, cultural constraints, and other "soft" values become relevant, and unavoidable variables that strongly, but not deterministically, affect the possible outcomes of the strategies to be adopted.

No mathematical model, even if legitimate in its own terms, can be sufficient for a complete analysis of the reflexive properties of a real-world problem. These reflexive properties include the human dimensions of e.g. the ecological change and the transformations of human perceptions along the way. The *learning process* that takes place while analyzing the issue and defining policies will itself influence perceptions and alter significantly the decisional space in which alternative strategies are chosen. At the other end, *institutional and cultural representations* of the same system, while also legitimate, are on their own insufficient to define what should be done in any particular case.

The various dimensions are not totally disjointed; thus the institutional perspective can be a basis for the study of the social relations of the scientific processes. To take any particular dimension as the true, real or total picture amounts to *reductionism*, whether physical or sociological. As a consequence, any attempt to fit the real world into a closed model leads to a simplification, which does violence to the description of reality. In most cases the dimensions sacrificed are precisely the reflexive properties of the systems. These characterize the problem in a fundamental way but are difficult to identify or measure.

In general, these concerns were not considered very relevant by scientific research as long as time was considered an infinite resource. On the other hand, the new nature of the problems faced in this third millennium (e.g. mad-cow disease, genetically modified organisms, etc.) implies that, when dealing with problems that may have long term consequences, we are confronting issues "*where facts are uncertain, values in dispute, stakes high and decisions urgent*" (Funtowicz and Ravetz, 1991, 1994).

Scientists cannot therefore provide any useful input without interacting with the rest of society while the rest of the society cannot make any sound decision without interacting with scientists. That is, the question of "how to improve the quality of a policy process" must be put, rather quickly, on the agenda of "scientists", "decision-makers" and indeed of society as a whole. This extension of the "peer community" is essential for maintaining the quality of the process of decision-making when dealing with reflexive complex systems. In relation to this objective Funtowicz and Ravetz have developed a new epistemological framework called "*Post-Normal Science*", with which it is possible to deal better with two crucial aspects of science in the policy domain: *uncertainty* and *value conflict*. The term "post-normal" signals a divergence from the puzzle-solving exercises of normal science, in the Kuhnian sense (Kuhn, 1962).

Post-Normal Science can be characterized in relation to other, complementary, scientific strategies according to the diagram in Fig. 2.2, which is based on two axes: "*systems uncertainties*" and "*decision stakes*". When both uncertainty and stakes are low, we are in the realm of "*normal academic science*",[2] where it is safe

[2] Funtowicz and Ravetz use the term "applied science". I prefer the more general category of "academic science".

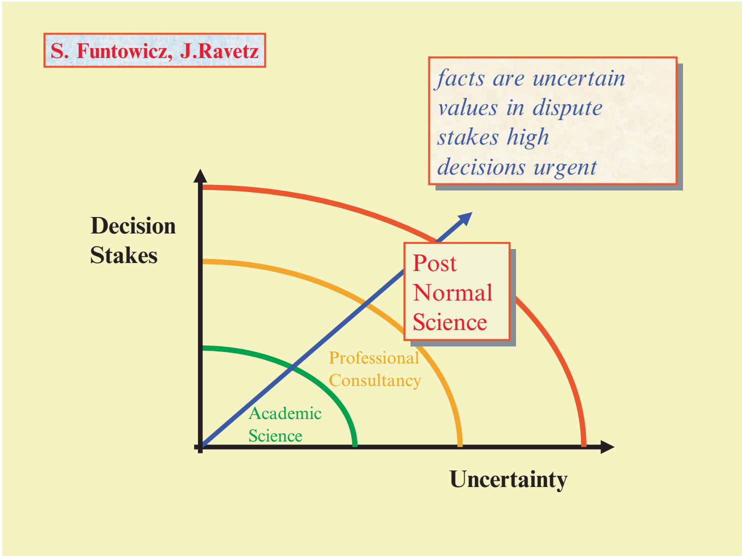

Fig. 2.2 Graphical representation of post-normal science

to rely on "codified expertise". When either uncertainty or stakes are in the medium range, then the application of routine techniques and standardized and generalized knowledge is no longer enough. In these cases, skill, judgement, and sometimes even courage, are required to adjust the "general knowledge" available to the "special situation". Funtowicz and Ravetz call this "*professional consultancy*", with the examples of the surgeon or the senior engineer facing a critical situation. Finally we arrive at cases, in which conclusions are not completely determined by scientific facts; inferences will (naturally and legitimately) be conditioned by the values held by the agents. When the stakes are very high (as when an institution is seriously threatened by a policy) then a defensive tactic will involve challenging every step of a scientific argument (this applies even to those cases in which system uncertainties are actually small). Such a tactic should be considered wrong only when is conducted covertly, as by scientists who present themselves as impartial judges when, in reality, they are actually committed advocates of a particular view. When legitimate contrasting views are openly used to challenge scientific arguments, we are in the realm of "*Post-Normal Science*".

There are now many initiatives constantly increasing in number and significance, for involving wider circles of people in decision-making and implementation on environmental issues. Examples of "Post-Normal Science" are to be found wherever local communities engage in scientific research and dialogue on the state of their personal and environmental health; one important case is the "popular epidemiology" movement connected to the Environmental Justice movement in the United States (Novotny, 1994). A number of grass-roots movements struggled for years against all official agencies, including academics, to try to establish the fact that their communities were being harmed. The most famous was a case where the authorities were eventually forced to admit that a collection of symptoms was the manifestation of a real condition, thereafter known by the town's name as Lyme Disease.

2.2 The Incommensurability Principle

The previous discussion can be summarized by using the philosophical concept of *weak comparability* (O'Neill, 1993; Martinez-Alier et al., 1998). From a philosophical perspective, it is possible to distinguish between the concepts of *strong comparability* (there exists a single comparative term by which all different actions can be ranked) implying *strong commensurability* (a common measure of the various consequences of an action based on a cardinal scale of measurement) or *weak commensurability* (a common measure based on an ordinal scale of measurement), and *weak comparability* (irreducible value conflict is unavoidable but compatible with rational choice employing, for example, multi-criteria evaluation).

In terms of formal logic, the difference between strong and weak comparability, and one defence of weak comparability, can be expressed in terms of Geach's distinction between *attributive and predicative adjectives* (Geach, 1967). An adjective *A* is predicative if it passes the two following logical tests:

(1) If *x* is *AY*, then *x* is *A* and *x* is *Y*;
(2) If *x* is *AY* and all *Y*'s are *Z*'s, then *x* is *AZ*.

Adjectives that fail such tests are attributive. Geach claims that "*good*" is an attributive adjective. In many of its uses it clearly fails (2): "*X is a good economist, all economists are persons, and therefore X is a good person*" is an invalid argument. The fact that a comparative holds in one range of objects does not entail that it holds in the wider range. Given a claim that "*X is better than Y*" a proper response is "*X is better what than Y?*" Similar points can be made about the adjective "*valuable*" and "*is more valuable than*". If evaluative adjectives like "good" and "valuable" are attributive in standard uses, it follows that their comparative forms have a limited range. That does not however preclude the possibility of rational choices between objects that do not fall into the range of a single comparative. Weak comparability is compatible with the existence of such limited ranges.

It is in terms of such descriptions that evaluation takes place. A location is not evaluated as good or bad as such, but rather, as good, bad, beautiful or ugly *in relation to different descriptions*. It can be at one and the same time a "*good W*" and a "*bad X*", a "*beautiful Y*" and an "*ugly Z*". The use of these value terms in such contexts is attributive, not predicative. Evaluation of objects relative to different descriptions invokes not just different practices and perspectives, but also the different criteria and standards for evaluation associated with these. It presupposes value-pluralism. An appeal to different standards often results in conflicting appraisal of an object: as noted above, an object can have considerable worth as a *U, V*, and *W*, but little as an *X, Y* and *Z*.

In conclusion, weak comparability implies *incommensurability* i.e. there is an irreducible value conflict when deciding what common comparative term should be used to rank alternative actions. Remembering that the presence of multiple-identities in complex systems can be explained in terms of the *epistemological plurality* and *ontological characteristics* of the observed system, I think that it is possible to further distinguish the concepts of social incommensurability and technical incommensurability (Munda, 2004). *Social incommensurability* can be derived from the concepts of reflexive complexity and Post Normal Science and refers to the existence of a multiplicity of legitimate values in society, that is, in one word, to democracy. *Technical incommensurability* comes from the multidimensional nature of complexity and refers to the issue of representation of multiple identities in descriptive models.

At this point, if we accept that real-world systems are multi-dimensional in nature, we also have to accept that the evaluation of public plans or projects has to be based on procedures that explicitly require the integration of a broad set of various and conflicting points of view. Consequently, multi-criteria evaluation is in principle an appropriate policy framework. It is interesting to note that analytic philosophy, theories of complexity, post-normal science, recent theories of rationality and modern public economics lead with different trajectories to the same conclusion, i.e. policy problems can be operationalized through a consistent multi-criteria framework.

The arguments developed in this section imply that there could be at least two different compromise solutions: a *social compromise solution* originating in value conflicts and a *technical compromise solution* for conflicting non-equivalent representations of the same policy options.

At this stage, the basic questions to be addressed are:

1. How is it possible to deal with technical incommensurability?
2. How can we deal with the issue of social incommensurability?
3. Which are the main consequences of technical and social incommensurability in a SMCE framework?

Answering these questions will be the subject of the rest of this book.

2.3 Reductionism "Must" Be Avoided

2.3.1 An Example of Ecological Reductionism: Carrying Capacity and the Ecological Footprint

Sustainable development clearly has a global dimension. However, the existence of interactions between local and global processes is also increasingly recognized. In particular, cities are open systems which impact on other physical areas and on the earth as a whole.

In the European context, for example, the reinforced focus on the city seems warranted as European countries face into a period of dramatic restructuring and transition (Nijkamp and Perrels, 1994; Cocossis and Nijkamp, 1995). The aim to make Europe economically more competitive has to be reconciled with the issue of environmental and cultural sustainability. At the institutional level for instance, EUROSTAT proposes a set of urban pressure indicators to deal with the urban sustainability issue (European Commission, 1996).[3]

It might be asked, for what reason so many different indicators should be introduced, when a unique physical *index* of human impact on the environment could be constructed simply from the concept of "carrying capacity". *Carrying capacity*, as defined in ecology, is the maximum population of a given species (frogs in a lake, for instance) that can be supported indefinitely in that given territory, without spoiling its resource base. Begon et al. (1996) clearly state that, even for animals, carrying capacity is "*an idealized concept not to be taken literally in practice*".

Authors with a background in biology and with an interest in population growth, such as Paul Ehrlich and his collaborators, have over the years become aware of the shortcomings of the idea of carrying capacity as applied to humans. This is why they proposed the formulation ***I = PAT, I*** standing for human impact on the environment, ***P*** for human population, ***A*** for affluence, and ***T*** for technology.

The definition of carrying capacity is irrelevant for humans for several reasons. First, the human ability to establish large differences in the *exosomatic use of energy* and materials points to a crucial question: at which level of consumption should the maximum population be established? Second, *human technologies* play a paramount role. To give an example transport is essential for determining urban carrying capacity because it influences the number of people which can enjoy a reasonable quality of urban life. Third, the *territories* occupied by humans are not given. We compete for them with other species as well as with other humans, whereby the concept of territory is socially and politically constructed. There is yet another reason why the notion of carrying capacity is not directly applicable to humans in any particular territory: *trade* may in fact be interpreted as the appropriation of the carrying capacity of other territories.

Urban growth rests on a trade-off between agglomeration economies (notably economies of scale and scope including higher wages) and diseconomies (e.g. population density and environmental decay). It is likely that environmental quality

[3] These indicators are: population density per area, land consumption, roads and parking areas, mono-functional areas, derelict areas, inhabitants per green area, accessibility of green areas, emissions of CO2, emissions of SO2 and Nox, emissions of VOC, emissions of PM10, emissions of lead, water consumption per capita, COD/BOD through (non-treated) waste water, non-treated waste water, non-treated waste water discharges to urban surface waters, soil contamination, municipal waste per capita, non-recycled municipal waste, household hazardous waste, energy consumption, share of private car transport, registered motor vehicles, traffic accidents with victims (injured and/or dead), mileage of commuters, people endangered by noise emissions, noise emissions of industry, noise levels of vehicle fleet.

problems may become more severe with urban size; however, factors such as land use, transportation system and spatial layout of a city are also critical factors in determining the "urban environmental carrying capacity".

Another indicator related to the idea of urban carrying capacity is the *ecological footprint index*. Ecological footprint overcomes some of the difficulties of traditional carrying capacity simply by inverting the usual carrying capacity ratio. In short, the ecological footprint measures land area required per person (or population), rather than population per unit area (Wackernagel and Rees, 1995; Folke et al., 1996).

The ecological footprint starts from the *assumption that every category of energy and material consumption and waste discharge requires the productive or absorptive capacity of a finite area of land or water*. If one sums up the land requirements for all categories of consumption and waste discharge of a defined population, the total area represents the ecological footprint of that population whether or not this area coincides with the population's home region.

More precisely, the ecological footprint of a specified population or economy can be defined as the area of ecologically productive land (and water) that would be required on a continuous basis:

(a) To provide all the energy/material resources consumed
(b) To absorb all the waste discharged, by a given population in a given area

From an operational point of view, the main categories of land use for the calculation of the ecological footprint would be the following:

1. Crop and grazing land required to produce the current diet (the sea area could also be included)
2. Land for wood plantations for timber and paper
3. Land occupied or built-over, as urban land
4. Land needed to absorb CO_2 emissions through photosynthesis, or alternatively land required to produce the ethanol equivalent to current fossil energy consumption

In Rees' hometown of Vancouver, the respective figures for these four items, per person, would be 1, 0.6, 0.2, and 2.3 ha (of middle-aged Northern temperate forest), i.e. over 4 hectares per person. One should note that only CO_2 is translated into a land requirement, and not other wastes, such as domestic waste, or other greenhouse gases, or radioactive waste; this is so because of difficulties of computation. The water catchment area and the waste water disposal area are not included either.

Of course, when considering the urban population, it is particularly important to acknowledge the existence of physical constraints on matter and energy flows, which are determined by the particular type of social structure. The *structure of a society* has huge relevance in determining the consequential ecological footprint for the same unit of human mass sustained, energy consumed or waste generated. Let us consider the case of food supply. A kilogram of grain consumed per person can have a cost of 2,000 kcal (in a poor society) or 35,000 kcal (in a rich society) according to the characteristics of the society. A rich society can be defined by the average need to produce food using only 5% of the available work force in agriculture (to produce grain at a throughput of 700 kg of grain per hour of labour). On the contrary, the situation of a subsistence society is far more "energy efficient". This is caused by a very low productivity of labour e.g. 10 kg of grain per hour of labour (the population is mainly composed of poor farmers). The same applies to the amount of land available (Giampietro, 1997).

What I want to emphasize here is the *problem of aggregation* (i.e. the somewhat mysterious convention that one needs to transform all the dimensions of ecological sustainability in a common measurement unit in terms of space connected to ecological footprint) and the necessary *reductionism* implied by the use of this index.

From a *land-use policy perspective*, the urban management suggestions arising from the computations of the ecological footprint can be misleading. Given that ecological footprint considers the land used to produce the current diet, this could imply an incentive towards intensive agricultural production systems. These systems will reduce the virtual space occupied by a city but at the same time will imply the use of much more energy and loss of biodiversity, due to the use of fertilizers and pesticides and the introduction of exotic species. It is true that to a certain extent these consequences will produce an increase in the land needed to absorb CO_2[4]. But what is the rate of compensability implied by these transformations? Are we sure that the decrease in the ecological footprint implied by a more energy intensive agriculture will correspond to an equal increase for the land needed to absorb CO_2?

Technically speaking, this will depend on the assumptions about the elasticity of substitution assumed between the different environmental pressures[5]. Unfortunately, in the computations of the ecological footprint index no specification of this elasticity is made and thus the compensation implied is completely unpredictable and non-transparent. Furthermore, even if the elasticity could be specified, what kind of biological productivity are we considering? What kind of soil? What kind of trees and of which age?

To give another simple land-use policy example, let us consider the issue of urban form. There is consensus that a *compact city* has less environmental impact than a *decentralized city* (see e.g. Frey, 1999). If there is high population pressure, taking only the environmental point of view into account, it would be better to have the people live in compact cities than spread out over the regional territory. But the ecological footprint index, will surely be very high for a compact city and on the contrary quite unpredictable in the case of a decentralized city. In this latter case the computations will depend crucially on what is defined as a homogeneous metropolitan area.

As we have previously seen, when dealing with complex systems operating on several hierarchical levels, the simultaneous existence of contrasting but "correct"

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[4] This point was put to me by Joan Martinez-Alier.

[5] This is the same issue connected to the use of economic production function measured in monetary terms. In this case, the elasticities of substitution between different production factors are always clearly specified, e.g. a Cobb-Douglas type.

scientific assessments has to be accepted. Complex urban systems are entities which change their identity according to the particular hierarchical space scale at which they are described. A study of a block inside a city, of the administrative unit constituting a "Commune", or of the "metropolitan area" is likely to give completely different and contrasting views and policy suggestions. And so, if we take the example of the hierarchical level of the "Commune of Barcelona", the claim that the quality of life is steadily increasing seems to be correct (or at least this perception is shared by most of its inhabitants). If we look at the whole metropolitan area, the same statement appears less convincing in the light of one problem: the transfer of most of the polluting activities from the city centre to the periphery.

This is the reason why the ecological footprint is often computed for regions or countries. This leads us to another question: are political territories also relevant in ecological terms? And what about trade? The latter issue has been addressed intensively by van den Bergh and Verbruggen (1999). A discussion of the pros and cons of this index is also available at the "Forum on the ecological footprint" in Ecological Economics (2000).

In conclusion it should be emphasized that computing the inverse of the concept of carrying capacity will not help to eliminate its shortcomings. Indeed, by definition an inverse retains all the properties and limitations of the original concept, as this has become evident in the discussion above.

It is impossible to find scientifically sound conversion factors that can transform all ecological, economic and social dimensions in land as well as in energy, money and similar. The concepts of urban environmental carrying capacity and ecological footprint are examples of *ecological reductionism*, i.e. socio-economic and cultural aspects are completely neglected (e.g., transforming the Colosseum into a wooded area would theoretically improve the ecological footprint of Rome).

There have been various attempts to develop multi-dimensional systems of urban sustainability indicators (e.g., CEROI, ICLEI, and many others), without producing any consensus on the pros and cons of any specific system. However, I would like to address another issue here, relevant for the policy-making process and connected to the simultaneous use of various indicators: often some indicators improve while others deteriorate when computed for a specific city. How might such indicators be aggregated? As we know, multi-criteria evaluation is clearly relevant[6].

2.3.2 An Example of Economic Reductionism: The "Fetishism of Fictitious Commodities"

The starting point here is that it is impossible to deal with the concept of "economic value" (and connected economic policy instruments) as an *objective, value-free*

[6] See Munda and Nardo (2007) for a more formal analysis.

category. Economic development implies the creation of new assets in terms of physical, social and economic structures. In a process of "creative destruction" traditional environmental, social, and cultural assets owed to our common heritage may disappear.

Indeed, as discussed in Chap. 1, the key question is *value for what and for whom?* For example, if the objective is to reduce the tourist pressure on Venice, one might conceive of limiting the number of visitors by imposing an entry fee and using the money collected to maintain the city's cultural heritage. However, one could argue that due to the "relative scarcity" of an economic good such as Venice, people will be quite willing to pay the price of an entry ticket. Thus, the economic instrument "entry ticket" will be useful for collecting money, but not for reducing the tourist pressure. As a consequence, the maximum number of visitors allowed per day should be clarified, and this can only be done on heuristic grounds since tourist carrying capacity can hardly be computed precisely.

Let us now move to a more fundamental question: people who do not visit Venice have an interest in its preservation? If the answer is yes, the concept of "total economic value" (see Box 2.1) immediately becomes relevant. To attribute monetary values to the historical heritage implies capturing *user* (actual, option and bequest) and *non-user* (existential, symbolic, etc.) *values*. Of course, to compute total economic values has nothing to do with the "true" or "correct" value. All monetary valuation attempts will suffer deep uncertainties such as: which monetary

Box 2.1 Total economic value

A fundamental concept in defining a value for non-market goods and services is the concept of *total economic value* (TEV). The TEV is the sum of four elements: the actual use value, the option value, the bequest value and the existence value. The *actual use value* is the value derived from the actual use of the good, e.g. an environmental space for recreation. The *option value*, instead, is the value derived from a possible use of it in the future by the current generation. Both of them have to do with individual preferences and the willingness to pay to conserve for example an ecosystem or a monument or the willingness to make use of it. Given the uncertainty about future uses, the option value is likely to be positive, indicating an interest in preserving the resource for the future. The *bequest value*, instead, implies an intergenerational dimension: it is a willingness to pay to preserve the good for the use of future generations (and not only for the future use of the current generation). Finally the *existence value* has to do with "the concern for, the sympathy with, and the respect for the rights or welfare of no- human beings" (Turner et al., 1994, p. 113).

valuation technique should be used[7]? Which time horizon should be considered? Which social discount rate?

Moreover, c*an we use money values as a social decision tool for sustainability policies?* If the answer is affirmative a measurement of social costs and benefits should be made on the basis of the so-called "*compensation principle*" (usually associated with the names of Hicks and Kaldor). According to this principle, the social cost of a given event is defined as the sum of money paid as compensation to those who have suffered injury. The level of utility[8] that the damaged people had before the event took place should determine the amount of compensation to be paid.

The general economic foundation of monetary compensation to the victims of an environmental or whatever else destruction is the concept of negative externalities. According to Baumol (1969) the relevant aspect of externalities is that *the activity of a subject negatively interferes in the utility function of another subject without an economic transaction between them*. We experience negative externalities in our everyday life: a barking dog at night, the smoke of a neighbour in a restaurant, the volume of teenagers' music, are a few examples. In many cases related with the environment this interference is in the utility function of a whole community, like for example the case of waste residuals or the pollution of a water source or costal zones.

Sustainability policies based on principles of compensation and substitution might sometimes be operable, but one should be very cautious *in applying such principles as a general rule*. The difficulties in substituting for the loss of environmental goods such as biodiversity (which is not even inventoried), or in compensating future generations for the uncertain, irreversible negative externalities we are causing today should be explicitly considered. These are allocations without any possibility of transactions in actual or fictitious markets. Who would be willing to accept compensation for the destruction of the "Sagrada Familia", the "Statue of Liberty" or the "Colosseum"? We could argue that, the presence of irreversibility and uncertainty urges us to transform the compensation principle into the *precautionary principle*[9] (it is more prudent a social conservationist attitude).

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[7] Valuation techniques try to derive willingness to pay for a good or service by using the concept of consumer's surplus. Consumer's surplus is the difference between what an individual has to pay for a good (the market price) and what an individual would be willing to pay for each unit of the good rather than to go without it. Hence consumer's surplus is defined as the area below the demand function and above the price line. For environmental and artistic goods and services, which have no market price, the consumer's surplus is defined as the area below the demand function (and above the zero price line). A necessary condition for an effective calculation of the aggregate consumer surplus is knowledge of the demand curves for the elements of the targeted project.

[8] Historically, the word "utility" was used in economics to denote the subjective sensations which are derived from consumption. The economists of the late nineteenth century, who were concerned with constructing a theory of consumer choice, regarded utility as something which could be measured as an absolute quantity. They thought it possible to speak of the total quantity of utility derived from consuming a given bundle of goods, of subtracting such quantities from each other, and discussing how these differences changed as consumption varied (Gravelle and Rees, 1992, p. 74).

[9] The definition of the precautionary principle given at the Bergen Conference on Sustainable Development (1990) is the following: "*It is better to be roughly right in due time, bearing in mind the consequences of being wrong, than to be precisely right too late*".

Of course, this principle implies that the majority of society, mainly non-experts outside the economic system (i.e. outside market mechanisms), would decide the "amount" of cultural or natural capital desired. This becomes evident when talking about the "Sagrada Familia" (a church designed by Gaudí in the nineteenth century, still under construction in the city centre of Barcelona). Although some "experts" agree in that it should not be completed, society at large feels a strong commitment to and involvement in its construction. One reason might be found in its symbolic value for Catalan identification (Catalunya is a region in the north-east part of Spain characterized by a strong nationalistic feeling).

In this context, from an economic point of view the only instrument left is "*cost-effectiveness*"; that is given a certain "physical" target (e.g. the amount of cultural heritage to be preserved or the amount of contamination to be accepted), it is rational to try to achieve it by means of the lowest possible use of resources (i.e. at the minimum social cost). Obviously there are several possible targets. This is explicitly acknowledged in many instances of environmental management, such as water quality standards (Funtowicz et al., 1999).

In general two rankings are possible:

1. According to cost
2. According to physical target (e.g. the more monuments preserved, the better)

An inclusive debate might lead to the conclusion that the improvement of a physical target score would worth the extra economic cost, but equally the opposite judgement could be reached. In both cases we would have an ordinal ranking of alternatives and "cost-effectiveness" would "fall down" into "weak comparability" operationalized by multi-criteria evaluation, i.e. two criteria and two different rankings must be dealt with explicitly.

From the discussion above the following conclusion can be drawn: to attach prices to non-market assets (such as most of environmental and cultural ones), gives a positive signal to society and may contribute to a more rational use increasing the chances for a better conservation. When one wishes to preserve a monument or a natural area, a fundamental question is: is there any resource, which society is willing to assign to this objective? To answer this question the use of monetary techniques such as hedonic prices, travel costs or contingent valuation is desirable and useful[10].

[10] In the framework of the famous debate of the 1920s and 1930s on economic calculus in a socialist economy Hayek, replying to Neurath wrote (1925, p. 31): "Neurath was quite oblivious of the insuperable difficulties which the absence of value calculations would put in the way of any rational economic use of the resources…". Or, as Von Mises had put it (Von Mises, 1920, in Hayek, ed. 1935, p. 111), "Where there is no free market, there is no pricing mechanism; without a pricing mechanism, there is no economic calculation". Certainly, the market would sometimes fail to give economic value to environmental amenities, thus, the calculation of the profitability of a hydroelectric scheme would not include "the beauty of the waterfall which the scheme might impair", except that attention could be paid "to the diminution of tourist traffic or similar changes, which may be valued in terms of money" (Von Mises, in Hayek, ed. 1935, p. 99). Through what is now called the "travel-cost method", or similar methods, the market mechanism could be extended in a capitalist economy to positive or negative externalities.

However, one should remember that the market alone may be successful in efficient allocation of resources, but it does not give any guarantee at all for preservation of the cultural or natural heritage. Once something is on the market, it can be bought or sold, and so the willingness to accept and the compensation principle may easily cause the destruction of any asset. Monetary compensation is without a doubt the only possible tool when irreparable and irreversible damage occurs. This way, if an accident causing serious contamination occurs – as in the case of Seveso in Italy (1976), Bhopal in India (1984), the Exxon Valdez in Alaska (1989), or more recently the oil-tanker Prestige off the coasts of Galicia (2002) – it seems correct and appropriate to indemnify the victims.

It remains to be verified whether in the long run, compensation is an effective tool to prevent contamination, given that it does not guarantee the preservation of natural or artistic goods. Take the case of Catalan aquifers. In Catalonia ("*Catalunya*" in the Catalan language) there have recently been serious problems of contamination of the underground aquifers. The damage has been attributed to pigs which are imported from Holland, raised in Catalonia and subsequently sent back to Holland for slaughter. The Dutch like this solution because in their country there are serious problems of ground contamination and pig-breeding has become practically impossible. Who profits from this? Obviously, the Dutch and some Catalan families who owe their economic prosperity to this activity. Who pays the costs? Catalan society as a whole to which the Dutch have succeeded in transferring the environmental costs, and which is losing a resource of such vital importance as drinkable water. Private costs born by breeders are thus very different from those born by the whole Catalan community. Whenever monetary compensation to victims was paid, this did not necessarily bear any positive consequences for either the environment or, in the long run, the inhabitants of the region left without drinking water.

Economic value is different from environmental or artistic-cultural value. If we had to decide whether to save the Galapagos Islands or the inside sea in Holland, which value should one use? The economic would favour the inside sea, which, since totally eutrophized, represents an important economic service receiving all the nutrients coming from human activity. The ecological would obviously favours the Galapagos Islands. The choice of the values to be considered as socially predominant is a scientific or socio-political issue? Again, the issue of incommensurability of values becomes relevant.

The application of the precautionary principle introduces some elevated costs, but how much would its non-application cost? The burden could be enormous, as admitted by the European Environment Agency. Even the Economist (certainly a magazine well distant from being environmentalist) has recently suggested as a possible positive consequence of the accident of the Prestige (a ship which heavily contaminated the coasts of Galicia in northwest Spain) a stiffening of the European legislation on the subject of maritime transport (The Economist, November 23–29, 2002, p. 79). When we abstract from myopic logics, there is no doubt that for society it is ecologically and economically more convenient to apply the precautionary principle than to suffer a series of disastrous accidents. For this reason, when uncertainty and irreversibility are present, it may be prudent to exchange the compensation principle for the precautionary one.

Summarizing this discussion, we can say that to "*internalize*" externalities into the price system might in general have positive consequences from a sustainability perspective. But one should not forget the uncertainties and complexities which make it difficult to give physical and economic measures for externalities. Moreover, it is worth remembering how economic values depend on inter- and intra-generational inequalities in the distribution of the burdens of pollution and in access to natural resources. Thus externalities can be seen as "*cost-shifting*" or as "*ecological distribution conflicts*" (Martinez-Alier and O'Connor, 1996). In general, if the injured parties are poor (or even not yet born), the cost of the internalization of the externality will be low. This is why a lot of multinationals locate particularly dangerous production plants in developing countries where, in the case of accidents, they are generally forced to pay much lower monetary compensations than in western countries. The accident of the chemical plant of the Union Carbide in Bhopal, India, in 1984, is a sad example (Jasanoff, 1994; Rajan, 2002). Obviously, the institutional and juridical context is fundamental. In the case of the oil contamination caused by Texaco in Ecuador (with serious consequences for human health) the point in the trial was deciding whether the competent court should have been in the USA or in Ecuador. Texaco naturally insisted on having the trial held in Ecuador… (Martinez-Alier, 2002, pp. 102–107).

Accepting low values for a negative externality that has negative impacts on a poor community is a "political decision", that is far from being ethically neutral. Some years ago, an internal document of the World Bank, subsequently made public, suggested that toxic waste should be stored in Africa, since the cost of compensation would be extremely low and would therefore have to be considered as the most efficient solution (it is interesting to remember that the World Bank is supposed to be working on behalf of poorer countries).

Allen et al. (2003) summarize the basic sustainability issues in the following questions.

Sustainability of:

1. What?
2. For whom?
3. How long?
4. At what cost?

It is clear that economic instruments are designed to answer only the fourth question, they thus need to be complemented with other approaches if one wishes to deal with sustainability in a comprehensive manner. Monetary valuation methods are based on phenomena such as consumer's surpluses, market failures and demand curves which are only a partial point of view, since connected *with one institution only: markets*. From a sustainability point of view, issues connected with actions outside the markets and as well as behaviour of people different from the class of consumers should also be taken into account (Duchin and Lange, 1994). As noted by Funtowicz and Ravetz, (1994, p. 198), "the issue is not whether it is only the marketplace that can determine value, for economists have long debated other means of valuation; our concern is with the assumption that in any dialogue, all valuations or "numeraires" should be reducible to a single one-dimension standard". I would like to stress that incommensurability of values does not imply a hierarchy of values. "Intrinsic" value (or "end value" (Lockwood, 1997)) is sometimes considered "superior" to economic value, this is not the position I am defending. Beckerman and Pasek (1997, p. 65) rightly note that: "the frequent claim that the environment has some unique moral intrinsic value is unsustainable, its preservation often raises ethical and other motivations that are not commensurate with the values that people place on ordinary marketable goods".

I reiterate that I am not opposed to putting economic values on natural resources, to environmental sinks, to natural spaces or to cultural heritage. A location may be valuable for its biodiversity (measured in richness of species or genetic variety), and also as a landscape, yet also have economic value (measured by differential rent or by the travel cost method, or contingent valuation). These are different types of value. The point is that it is misleading to take sustainability decisions based on only one type of value. The "*fetishism of fictitious commodities"" and "energy myths*" must be avoided. Thus, instead of focusing on "missing markets" as causes of allocative disgraces, or trying to explain economic values by means of energy measures (clearly a non sense from an economic point of view) we should focus on the creative power of missing markets, because they push us away from economic commensurability, towards multi-criteria evaluation of evolving realities.[11]

The next chapter gives some guidelines for the real-world treatment of both technical and social incommensurability.

[11] "There is great pressure for research into techniques to make larger ranges of social value commensurable. Some of the effort should rather be devoted to learning – or learning again, perhaps – how to think intelligently about conflicts of value which are incommensurable" (Williams, 1972, p. 103). A call for dealing explicitly with incommensurability can also be found in Arrow (1997).

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