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ECONOMIC THEORY AND ENVIRONMENTAL DEGRADATION: A SURVEY OF SOME PROBLEMS*

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Abstract:

Both market and policy failures can lead to environmental degradation. Considerable progress has been made in the area of project evaluation and the valuation of environmental effects. On the other hand the analytical tools to study the effects of policy failures –the impact of taxes, prices, exchange rate and incentives– are more limited. The correct handling of uncertainty also remains a major issue. The analysis of international environmental problems, such as acid rain or CO2 buildup, may benefit from the application of game theory approaches and the use of revelation mechanisms designed for public goods.

Externalities, Economic Growth and the Material Balance Principle

In elementary textbooks, environmental degradation is usually given as an example of a negative externality. An externality is usually defined as an unintended side effect of a decision, that has not been included in the basis for the decision simply because the effect will not affect the decision maker. It is noted that when externalities are present, the market will not be able to allocate resources efficiently and there is a need for some policy interventions. However, in some presentations, it is said that the real reason for the lack of concern for these externalities is transaction costs, and as the government can not reduce the transaction costs, it is as well to leave the externalities aside, because they have been and still are being presented as curious exceptions to the general blessings of the market.

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One could, however, make a very strong point that negative externalities are pervasive, that material production must necessarily be connected with such externalities. According to the first law of thermodynamics, the total energy and the total mass in an isolated system must be constant. But that means that the mass of all the resources that is extracted from our natural environment must ultimately be discharged back into the environment, and the higher the economic activity, the more resources are extracted and therefore more residuals or waste have to be discharged back to the environment[1]. Thus, the importance of the externalities will be accentuated by economic growth unless they can be internalized in one way or another. The market failures from the existence of negative externalities will therefore be potentially more severe in the future (if we are optimistic about future growth rates) than they have been in the past.

Thus, market failures play a very important role in trying to explain the growing seriousness of environmental degradation. Not only pollution but also other types of environmental degradation is due to market failures. For example, free access common property resources, such as international fisheries, common grazing land, communal forests, etc. tend to be over exploited. Basically, because of the lack of well defined private property rights, the basic incentive structure will give the wrong signals on the use of many environmental resources. However, market failures are not the only reasons for biases in the incentive structure that lies behind and below unnecessary destruction of environmental resources. Quite often, government policies on taxes, subsidies, exchange rates, prices, etc., create incentives that will lead to inefficient management of natural resources. In my own country, the heavy subsidization of construction of roads in order to keep employment up have led to widespread clear cutting of mountain forests, which otherwise would not have been profitable to harvest. One may be inclined to infer that the problem is one of conflict between preservation of these forests (with a regenerative time of 2-5 hundred years) and the objective of reducing unemployment. However, that is not the issue as the employment could be increased by other policy measures –for example by using marginal employment subsidies. Instead, this is a case when one policy has unintended side effects on the environment.

Dennis Mahar (1989) and Hans Binnswanger (1989) have shown quite clearly and convincingly in a couple of reports from the World Bank that the present process of deforestation in the Amazon has its roots in government policies, and in particular in the tax- and subsidy-policies together with existing system of land tenure in Brazil. Whatever the reasons behind these policies may have been, they did not have as an explicit objective the deforestation of the Amazon. Moreover, it seems to be quite clear from their reports that the incentive system not only destroy the resource base but does not even produce a net benefit to the rest of the Brazilian economy. Therefore, it remains to explain the reasons for such policies. I believe that public choice theory can offer quite interesting analysis of the background. Unfortunately, very little has been accomplished to date.

These examples are not unique. It is too easy to find too many examples where government policies have had similar destructive consequences[2]. There is thus two broad types of failures in the incentives system that will bring about inefficient resource management - market failures and policy failures. While we have developed quite sophisticated methods of dealing with the first type of issues - market failures, we have much more to learn on how to identify, how to predict, and how to resolve policy failures. A few attempts are under way to develop computable general equilibrium models that would link environmental resources to economic activities and by that enable the researcher to forecast impacts on environmental resources from policy changes. It is too early to judge

the success of these developments. Moreover, public choice theory must be developed in such a way that the mechanisms behind these for the environment destructive policies can be understood better.

These market and policy failures leads naturally to the question of how the desired development should look like - which development with regard to the management of environmental resources is desirable and sustainable.

Sustainable Economic Development

Since the publication of the report from the World Comission on Environment and Development - the Bruntland commission, the concept of sustainable development has become a hotly debated concept. There is no consensus on what the concept stands for. Ecologists and anthropologists have their concepts and the economists have at least a couple of dozens different definitions. In this presentation, the following meaning of the concept will be used:

> By sustainable development is meant an economic development such that the welfare of future generations will not be impaired by actions taken today.

This is nothing but the standard Pareto criterion, adapted for an intertemporal allocation problem. The criterion implies that

i) The damage to future generations from present resource use (depletion of non-renewable resources, degradation of renewable resources, etc.) must be quantified and valued.
ii) Incentives must be designed so that only those projects are undertaken whose present value of the future demage don't exceed the present benefit of the projects.
iii) Investments in other assets (other environmental resources or physical reproducible capital or human capital) must be done in order to compensate future generations.

Valuation[4]

Basically, the value of a change in an environmental resource is defined as the compensated or equivalent variation of that change[5]. For the rest of this presentation, the consumer surplus measure will be used as an approximation to these two concepts[6]. Two different approaches are being used to value changes in environmental resources:

A. Contingent valuation
B. Production function valuation

A. Contingent Valuation

By contingent valuation is meant a rather sophisticated system of asking persons about their valuation of resource change. The use of contingent valuation techniques has become widespread, and it seems that its role in industrialized countries will increase in determining resource policies[7]. In the US, these techniques have been used in court cases for determining the liability from having surface water being polluted from mine tailings and for determining the liability of polluting ground water[8]. The main problems with contingent valuation tehcniques seems to be that individuals are being put in a hypothetical situation and essentially asked about their willingness to pay for preventing a change or for obtaining a change. Obviously, being in a hypothetical situation, the individual may not consider the decision situation as much in depth as he would if it was an actual decision making situation. However, studies have shown that the results obtained with contingent valuation methods are roughly compatible with results from using other, quite different techniques[9].

B. Production Function Valuation

Let $X_1, X_2, ..., X_k$ denote inputs of goods and services that can be bought on a market and let Q be the input of an environmental resource that is not priced on market. Consider the following production function

$$y = \varphi(X_1, ..., X_k, Q)$$

y is the output which can be a commodity that is bought and sold on a market, or can be a physical commodity which is not marketed or it can be a direct input to consumption in which case it can not be measured directly. In this latter case, φ is usually described as a household production function. If we know φ and if we can measure y and its unit value, it is obvious that we can calculate the value of the resource Q directly. This has been done in a number of studies on the value of certain recreational facilities where the output is number of visitor days, on soil erosion and agriculture output, on reforestation and agriculture output, on pollution and agriculture production, etc. The main problem here is how to describe the production function.

Sometimes, y cannot be measured but there is a perfect substitute that can be measured. For example, when air pollution is a threat to health, the value of that threat may be inferred from values of similar threats in other circumstances. For example, wage differentials due to differential occupational risks may be used to value similar risks from air pollution[10].

When y cannot be observed and when there does not exist a perfect substitute, the value of Q may still be inferred from information on the other inputs. If Q is a perfect substitute for an input that can be bought on a market (or even a "weak" substitute, see Maler 1985), it is clear that the price of that input will also reveal the value of the resource.

Sometimes it may be possible to assume that Q is a complement to a purchased input. Then the value of Q is dependent on the price of the complementary input. A more general and very useful case is when Q and a purchased input are weak complements. X_1 and Q are weak complements if the valuation of Q is zero if $X_1 = 0$. If an individual is not using a lake for recreation, he may not be interested in its water quality and consequently, his valuation of that quality is zero. If an individual is interested only in the air quality in the area in which he lives, we have another case of weak complementarity. It is possible to show rigorusly that if the resource is a weak complement to a purchased input, the value of the resource can be inferred from an estimated demand curve for the purchased input. Basically, if the resource change, the demand curve will shift, and the change in consumers' surplus from that change is a measure of the value of the resource change. Moreover, if the purchased input has an inelastic supply, one can assume that the change in the resource will be capitalized in a change in the price of the purchased input. If the shift in the demand curves is a parallel one, one can show that the change in the price will reveal correctly the value of the resource change. The main application of this idea is to the study of property values. It is assumed that land is in fixed supply and that changes in say the air quality in an area will show up in changed land prices. In order to guarantee that the shift in demand curves is a parallel one, economists have introduced various assumptions, such as an assumption that either there is a continuum of identifical households or that each community consist of homogenous households. By studying the

empirical relation between land prices and air quality, the researcher is then in a position to estimate the value of the air quality.

Finally, by specifying the functional form of the production function (or the indirect utility or the profit function) and then estimating the derived demand functions, the parameters in the production function determining the value of the resource may be identified.

Thus, there are a number of different techniques available for estimating the value of environmental resources. However, the techniques described under the heading of production function valuation will only provide estimates of what is known as the use value, that is the value associated with the actual current use of the resource, the expected future use value, but not the value from the knowledge that the resource is there. The preservation of bio-diversity gives an example. We may be able to use species in the future for commercial purposes but we do not have the knowledge to do that today. How do we asses that expected future use value, and in particular take into consideration that our information will shift over time. In order to make a rational decision today, we must develop a theoretical framework that can be used for that purpose. Some has already been accomplished. For example, it has been shown by C. Henry (1974) and by K. Arrow and A. Fisher (1974) that if a decision implies an irreversible change in a resource and if new information on the expected future benefits from the resource will be forthcoming, there is an extra value in postpoing the irreversible change. This extra value is known as the quasi option value. It corresponds to the conditional expected value of the forthcoming information. Thus we should not only take the expected future value into account from preserving the biodiversity but also include the quasi option value.

Moreover, even if we know that some individuals now or in the future will never be using the resource physically, they still may put a positive value on the preservation of the biodiversity. This is the existence value. Thus we end up with a total economic value consisting of present use value, future use value, quasi option value and existence value. The techniques described above under the heading of production function can only be used for assessing the three first kinds of values. On the other hand, contingent valuation studies may be used to capture the total economic value. Some of the valuation issues are discussed in the paper by Dixon in this volume.

Environmental Resources as Assets

Assume now that we can do the valuation of resources correctly. We can then redefine the concept of sustainable development in a slightly different but equivalent way. Let us look at all the assets of an economy, net financial assets (which of course will add to zero in a closed economy), physical real capital, human capital, non-renewable resources and renewable resources. By the valuation procedure, we can define values for all these assets and therefore calculate the total value of the assets. It is possible to show that if the competitive rents from environmental resources are invested in physical capital, then this stock of capital will remain constant over time[11].

Moreover, Robert Solow (1986) has shown that the sustainable consumption can be thought of as the return on this capital. Thus sustainable development as it has been defined here (and there is a large number of competing definitions) is the requirement that this total stock of assets never will be allowed to diminish. Thus, a reduction of one asset must be accompanied by an increase in some other assets. A reduction in an environmental resource must therefore be accompanied either by an increase in the asset of some other environmental resource or by investments in physical or human capital, in order to keep the total value of hte stock of assets non-decreasing. Hartwick's rule then says that the necessary investments is given by the rents from the natural resources.

However, this is based on the assumption that we know with certainty the size of these assets and their values. In reality, we are far from that situation. Uncertainty is pervasive with respect to environmental assets and that uncertainty must be coped with. A substantial literature on the problems of risk and environmental resources is now available, and a common conclusion is that one should be cautious in exploiting the environmental resources and in particular if the exploitation will bring about irreversible changes[12]. One practical conclusion that can be drawn is simply that for such environmental resources that are judged to have a high but uncertain value, the resource should never be allowed to be depleted or degraded. These are the critical ecosystems that are necesary for human life. However, for most of the environmental resources, there are substitutes available which imply much lower values of the resources and means that trade-offs are posible between physical capital and environmental resources.

In order to be sure that the economy is on a sustainable development path, a monitoring system is needed. The most used monitoring system is our national income accounts. However, these accounts do not take into consideration the depletion of non-renewable resources or the degradation of renewable resources. There is therefore a strong need for modification of the present system for national accounts. In particular, it is of great importance that the value of all relevant assets is included in the balance sheets, in order to test the sustainability of the development. This is covered in more detail by El Serafy and Lutz in this issue.

Incentives

Assume we have solved the valuation problems and want to pursue a sustainable development. In order to do that, the basic incentives in the economy must be modified. First of all, the badly designed incentives in public policy should of course be corrected. Second, incentives designed to counteract the market failures should be implemented. There is no reason here to go into a discussion of general public policy, so the discussion will be limited to market failures.

The conventional way of designing incentives for environmental policy in industrialized market economies is paradoxically by using command and control instruments. Through legislation, firms have to have permit for certain activities and their use of environmental resources such as air and water is regulated. However, it is now well known that this command and control approach is inefficient and ineffective. It is inefficient because it cannot accomplish the desired improvements in the environment to lowest social costs and it is ineffective because, quite often, it cannot achieve the desired environmental improvement at all.

Economists have since the days of Pigou recommended the use of taxes in order to provide the correct incentives. The idea is of course to tax excessive use of an environmental resource in order to make it more expensive to use that resource. As all users will have to pay the same tax, their marginal benefit from using the resource will in equilibrium be the same, and economic efficiency will therefore be attained. However, in spite of this nice property, applications of such taxes are very rare. There may be many reasons for that. In particular, it seems that regulators are more fond of command and control measures as they are much more concrete than the abstract reasoning of the economist.

However, there may also be theoretical advantages of using a command and control approach. Let us consider pollution abatement. Assume there is one polluter and that he knows the cost of controlling pollution with certainty. Assume also that there are pollution damage. If the regulator knows the cost of pollution control and the damage cost, he could calculate the optimal regulation or the optimal tax, and the outcome would be the same. However, if the regulator is uncertain about the cost of control and uncertain of the damage cost function, the situation is different. This is a principal-agent problem, which was first analyzed by Martin Weitzman (1974). When both control costs and damage costs are uncertain, it is obviously impossible to find the ex post optimal tax rate ex post optimal regulation. What one should aim at is to minimize the expected ex post losses. It now turns out that if the marginal control cost function is less steep than the corresponding marginal damage cost function, the command and control approach will have smaller expected ex post losses while the taxation approach should be chosen if the opposite was the case. It seems that for many environmental problems, the marginal damage cost function has steeper slope than the marginal cost of control function, so that a regulatory approach is to be preferred.

However, this neglects the case when there are many sources. The command and control approach will in general not be able to allocate a pollution restriction among the sources efficiently. Therefore, tradeable quotas or permits have been introduced in order to combine the command and control approach with market mechanisms. This was first proposed by Dales (1968) and has recently been applied in the US[13]. It is now possible in some areas and for some pollutants to trade emission permits among sources. Not only trade between different sources but also trade between different periods of time have been permitted in the general approach of using market mechanisms to ensure efficiency in pollution control while simultaneously keeping a regulatory mechanism to ensure that the desired environmental goals are achieved. In president Bush's recent proposal to amend the clean air act, trade between different sources for sulfur emissions plays an important role.

In principle, this application of tradeable permits means that new property rights are established - rights that can be transferred from one economic agent to another. This approach can be used in other cases of market failures too. One problem plaguing several tropical countries is overgrazing due to the fact that the grazing lands are free access common property resources. This, we know will eventually lead to overgrazing and ensuing environmental degradation. However, by introducing certain forms of property rights - not necessarily individual rights-better management of the grazing range can be expected.

In international fisheries, the establishment of property rights have very frequently been the key instrument to secure sustainability of the fisheries.

International Environmental Problems

The single most important characteristic of international environmental problems, like transboundary pollution problems, is the absence of a legal framework that can define and enforce property rights. Instead, all property rights must be negotiated and agreed upon by the countries involved. However, in order to be agreed upon, all countries must benefit in the long run from the agreement. It is easy to imagine situations where some countries may not benefit from an agreement that would make economic sense. If one country is upstream and polluting the flow of water, and another country is downstream, there is an obvious externality, and economic efficiency would require that the upstream country reduces its pollution. However, that means that the downstream country would gain while the upstream country would lose. Why should the upstream country agree to such a measure? It seems that the downstream country must compensate the upstream country for the increase in abatement costs in order to make an agreement possible. Thus there is a need for international transfers in order to solve international environmental problems. OECD (1981) has recognized this need and in one document concluded that international financial transfers may be necessary to solve transboundary problems. However, such transfers have in practice hardly been used. There are a few examples where international transfers have taken place, but these are exceptions. There may be three explanations to this. The first is that very few transboundary problems have been solved, the second that countries do not act only in self interest but have other objectives too and the third that transfers take place, but not as financial transfers but transfers in kind. Countries act in a web of economic, environmental, cultural, military and other relations and one should view transboundary environmental problems in view of this web. Allen Kneese has argued forcefully that the concession on the part of US to construct a desalinization plant where Colorado river enters Mexico should be seen in view of what US was expecting from Mexico in terms of military concessions and in influence over Mexican oil. Likewise, John Krutilla has argued that the agreement between the US and Canada on Columbia river must be seen in view of the overall relations between the two countries.

If these observations can be generalized, it is clear that transfers take place but not necessarily in cash. The objective of these transfers is simply to make an agreement possible y ensuring that no party is loosing from the agreement.

However, even if we can guarantee that no country would be loosing from international environmental problems, there remains the important problem of incentives to cooperate. About 45 countries has signed the protocol regulating the discharge of CFC's in order to protect the ozone layer. This is in accordance with standard theory on industrial organization, as one should expect according to some results in that theory that only a group of countries would sign the protocol while the others would benefit from being free riders. The same is true with respect to acid rains in Europe.

Although countries would gain substantially from cooperating, each individual country would gain more from being a free rider. Therefore, in the short run, one would not expect a satisfactory agreement on reduction of sulfur and nitrogen emissions (although there is a non-satisfactory agreement to reduce the sulfur emissions with 30%). However, if one model this as a differential game, one is able to show that in the long run cooperation may evolve if an effective monitoring system can be designed. It is also possible to show that such cooperation may take the form of establishing new property rights which can be transferred between countries, and also that such a system will eventually lead to a second best equilibrium which will approximate an efficient outcome reasonably well[14].

In view of the threats from the emission of greenhouse gases, it quite clear that here the problems are much greater. Obviously, we must be able to define a system of property rights to net emissions of greenhouse gases (meaning that those who absorb carbon dioxide by photosynthesis will automatically get a corresponding credit) and design the initial allocation in such a way that all countries have incentives to cooperate. Unfortunately, very little has been accomplished to date on this issue.

One particular problem that has drawn the attention of economists is the problem of correct preference revelation. In the setting of international environmental problems, this problem has to do with information not only on costs and benefits in different countries but also information on the amount of pollutants actually emitted. The "30-club" is a group of North American and European countries that have agreed to reduce

their emissions of sulfur with 30% from the 1980 level. However, at least one country informed the other countries just before signing the agreement that their earlier measurements of emissions 1980 were in error. The number should be adjusted up with 30%. This shows that the problem of revelation of relevant information for international agreements is a very real one.

Quite a lot has been done in analysing this issue by using revelation mechanisms designed for public goods. It is interesting to note in this connection, that the celebrated Groves mechanism was first invented by H. Smets (1972), who was and still is working at OECD on questions of transboundary pollution problems. The objective of Smets' inquiry was to construct international institutions that could cope with international environmental problems.

Conclusions

Substantial progress has been made in environmental economics during the last 15 years. In particular, the field of project evaluation has developed quite fast. On the other hand, our analytical tools to study the effects of policy failures –taxes, agriculture pricing, exchange rates, etc.– are very limited. We also need to develop operational tools to deal with uncertainty and stop giving only lip service to this issue. We should devote our creativity to find new international institutions designed to cope with international institutions designed to cope with international environmental problems. Finally, we need a general theory of environmental policy instrument that takes into account the uncertainty of the cost of abatement and the cost from environmental damage and as well recognizes that in so many cases our monitoring possibilities are rather limited.

To close, environmental economists are facing some rather tough questions. However, the whole toolbox within the economic discipline has so far not been utilized fully. By using more of the results in industrial organization theories, game theory, public finance, etc. it is my conviction that environmental economics could make major advances.

Notes:

1 Ayres and Kneese (1969) were the first to use the idea of materials balance to study environmental pollution problems from an economic point of view. In d'Arge, Ayres and Kneese (1972) that study is carried further. Maler (1974) develops a Arrow-Debreu type of general equilibrium model to study the implications of the material balance approach.

2 For an overview of the role of public policies in the degradation of environmental resources, see R. Repetto and M. Gillis (1988). See also J. Warford (1987).

3 J. Pezzey (1989) has provided an interesting survey of various economic definitions of the concept of sustainable development.

4 Johansson (1989) contains an excellent survey of different valuation techniques. See also Maler (1989c).

5 CV or the compensating variation is defined as the change in wealth that would compensate an individual for a change in the resource. EV is the change in wealth that would be considered equivalent to the change in the resource by the individual. Both are description of the same underlying preferences. For a discussion of the use of CV and EV see Maler (1974) and (1985).

6 These concepts are rigorously defined in any textbook on microeconomics, f.e. Varian (1978). Varian also includes a very useful theorem by Willig (1976) which shows that in most cases, the compensating variation, the equivalent variation and the consumer's surplus are not very different numerically.

7 Mitchell, Carson (1989) give an excellent presentation of the contingent valuation techniques.

8 See Kopp, Smith (1989) for an interesting analysis of two court cases and the role of the economic valuation techniques.

9 There are many such studies. See Bojo (1985) for an investigation of the benefits from preserving a mountain forest in Sweden, which resulted in the same benefits being obtained by contingent valuation techniques as by a travel cost approach.

10 See Crocker *et al.* (1979), for an interesting application of this.

11 This is the Hartwick rule, see Hartwick (1977) and (1978). See also Solow (1986).

12 See Maler (1989a) and (1989b) for a rigorous analysis of these issues.

13 See Tietenberg (1984) for a survey of what has been accomplished in the US up to that year-by using tradeable emissions rights. For more recent experiences, see Tietenberg (1989).

14 See Maler (1989d) and (1989e) for a discussion of these issues in connection with the problem of acid rains in Europe.

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