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by

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Clem Tisdell*

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AQUACULTURE, ENVIRONMENTAL SPILLOVERS AND SUSTAINABLE DEVELOPMENT: LINKS AND POLICY CHOICES

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1. Introduction

Although aquaculture as been practised for many centuries, it was in the past on quite a modest scale and limited to a few species e.g. carp. However, in recent decades, aquaculture has shown very rapid expansion. This is partly because catches of wild fish have expanded at a slower rate than demand and many new scientific and technological advances have been made in aquaculture. Furthermore, by the mid-1990s evidence available to scientists indicated that catches of wild fish had either reached, nearly reached or even exceeded their sustainable limits (Williams, 1997). Consequently, according to Meryl Williams (1997, p.18), Director of ICLARM, now "aquaculture is the major, though not sole hope, for improving the world's fish production". Aquaculture, particularly marine aquaculture, has become a new economic frontier. Just as humankind in the past experienced the Agricultural Revolution it seems now to be starting on an Aquaculture Revolution. Naturally, this raises the question of how sustainable it will be.

The purpose of this article is to discuss the sustainability of aquaculture production. If expanded aquaculture production sets into motion forces that make it unsustainable, economic development based on it will be short lived. One should at least be aware how lack of economic sustainability of aquaculture production can arise, and be prepared to adopt policies to curb or prevent undesired trends in this.

In this article, it is pointed out that (a) factors endogenous to the productive unit and (b) factors exogenous to individual productive units (such as environmental spillovers or externalities) and result in the unsustainable development of aquaculture. However, most attention in this article is given to adverse environmental spillovers as a contributor to lack of sustainability of aquaculture. This is because lack of sustainability in the endogenous case results from the rational choice of businesses

involved in aquaculture whereas the outcome when externalities exist can be inferior from the point of view of all or from a social viewpoint. There is consideration of the relative sustainability of extensive aquaculture systems versus intensive ones, and of the impact of aquaculture on the sustainability of natural fish stocks. Policies for regulating environmental spillovers to achieve a social economic gain, and thereby in most cases promote greater sustainability of aquaculture, are outlined and discussed. By concentrating on a particular sector, it is possible to identify various policy issues raised by the quest for sustainable development that may be overlooked in a macroeconomic context.

2. Lack of Sustainability in the Absence of Market Factors

Even when markets work perfectly and market failures, such as may arise from environmental spillovers are absent, unsustainable income paths may be chosen by economic agents in preference to sustainable ones (for details see Tisdell, 1999). Profit-maximising or income-maximising behaviour by individuals or business need not result in paths of sustainable income or of sustainable economic activity being chosen by them. This is so even when they are fully informed and rational.

In Asia, for example, landholders often decide to farm shrimp knowing that this activity is unsustainable in the long run and that eventually their income will fall (Be, 1999; Alauddin and Tisdell, 1998). This choice can be illustrated by Figure 1. It is assumed that if only rice is grown on a farm that the net income path GCH will apply, This is a sustainable income path. If, on the other hand, shrimp is raised on the land the unsustainable net income path ABCDF applies. At time t_2, production of shrimp ceases because of falling shrimp yields for instance due to mineralisation in the fish ponds and the land may be then too barren to grow rice or other crops. But if the landholder discounts the future strongly enough because of uncertainty or a high interest rate, the net present value of the income from the unsustainable path may well be in excess of the from the sustainable path. Therefore, lack of income sustainability is chosen in preference to sustainability. This is even more likely if the land is not rendered barren by shrimp cultivation and so will still grow a crop, such as rice, when shrimp production stops, albeit with much reduced yield compared to the situation in which no shrimp cultivation occurs. In such a case, the alternative to the sustainable income path might be path ABCJ.

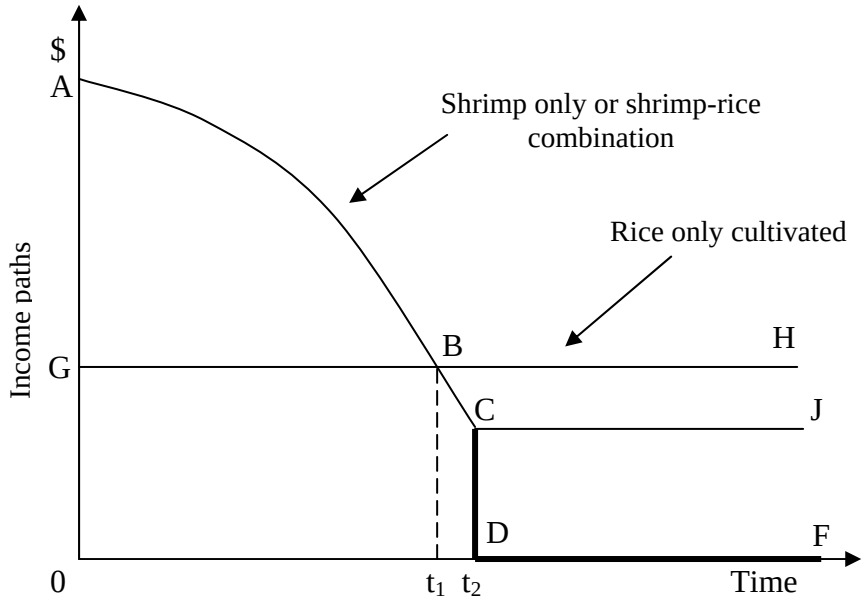

Figure 1 Rational individuals or businesses may choose unsustainable income paths in preference to sustainable ones in their use of land.

It seems that individuals are more likely to choose unsustainable paths for resource-use when they leave greater scope for mobility or access to markets. Subsistence villagers with virtually no access to markets and with little mobility are more likely to choose sustainable income paths as argued by Tisdell (1990, Ch.2). As outlined by Klee (1980, Ch.1), a similar point has been made by the geographer Raymond Dassman, namely that less sustainable systems are likely to be chosen as individuals change from a village to a global perspective as a result of the extension of markets.

But in any case, it ought to be clear that a perfectly working market system does not ensure sustainability of land use. Whether or not such sustainability is desirable is, however, a subject for debate. For example, sustainable income paths are more likely to be chosen if a zero or low discount rate is applied to future income, a policy favoured by economists such as Frank Ramsey and A. C. Pigou (Howe, 1979, p.156).

3. Environmental Spillovers as a Source of Inferior Sustainability Outcomes

As shown above, lack of economic sustainability in an industry or business program can even arise in the absence of market failures. But market failures can increase the likelihood of unsustainable economic outcomes (see Tisdell, 1999). More importantly they can result in unwanted lack of economic sustainability on the part of all, in

contrast to the case just discussed in which unsustainable income paths may be chosen rationally. Environmental spillovers or externalities, such as these arising in aquaculture, can be used to illustrate the matter.

Consider the case of unfavourable externalities or environmental spillovers. When these arise the private costs of producers such as fish farmers are less than the cost to society of their production. Consequently their private benefits from production exceeds its social benefits. This can result in private choices, by fish farmers in this case, resulting in an excessive level of economic production from a social economic point of view. This is illustrated in Figure 2. Te curve 0AB represents the private benefit or returns to fish farmers in a region and curve 0CDE indicates social benefits. Due to unfavourable externalities, curve 0CDE is below curve 0AB. The difference between these two curves measures externality costs. In the absence of control, fish farmers in the region will produce X_2 of farmed fish whereas X_1 is optimal from a social viewpoint. Market failure occurs and there can be a case for government intervention.

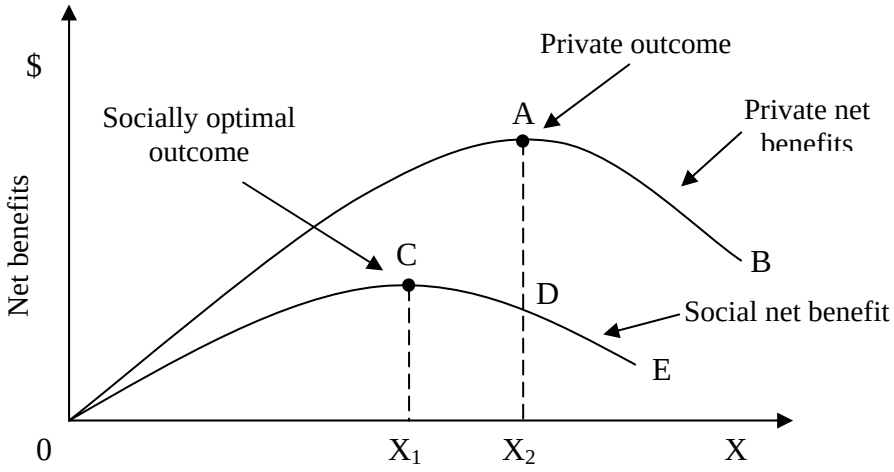

Figure 2 A case in which an unfavourable environmental spillover results in its market failing to bring about a social economic optimum.

While environmental spillovers in the above case reduce the attainable level of social economic welfare, in some cases they may still result in sustainable social economic benefit, albeit it at an inferior level. However, in many cases, environmental spillovers

result in individual producers not taking into account the full user costs of their actions, that is, their full impact on future incomes. For example, in drawing water from a shared water body or adding pollutants to it, each producer may consider his-her individual impact on the future availability of the water and it purity to be negligible. However, collectively this is not the case. Thus the natural resource may be utilized at an unsustainable rate. An unsustainable income path may be followed by all users of the resource that, from the point of view of each one, is less desirable than an available alternative involving greater prudence in their use of the resource. Hence, the presence of the environmental externality promotes lack of economic sustainability and result sin a Paretian inferior result. In game theory parlance, a prisoners' dilemma type of problem exist and the consequence is that a socially inferior Nash equilibrium eventuates.

This is illustrated in Figure 3. A community using a natural resource may have the possibility of following path I, a sustainable income path, or path II an unsustainable income path. All may prefer I to II. However, because of the presence of adverse environmental externalities resulting in inadequate consideration of user costs by individual producers, path II may be followed. Or, possibly the community has a third possible path that it prefers, marked III. Although this path does not result in a sustainable level of income, it sustains income at a higher level than path II. Nevertheless, the presence of externalities could still result in the private uncoordinated choice of path II.

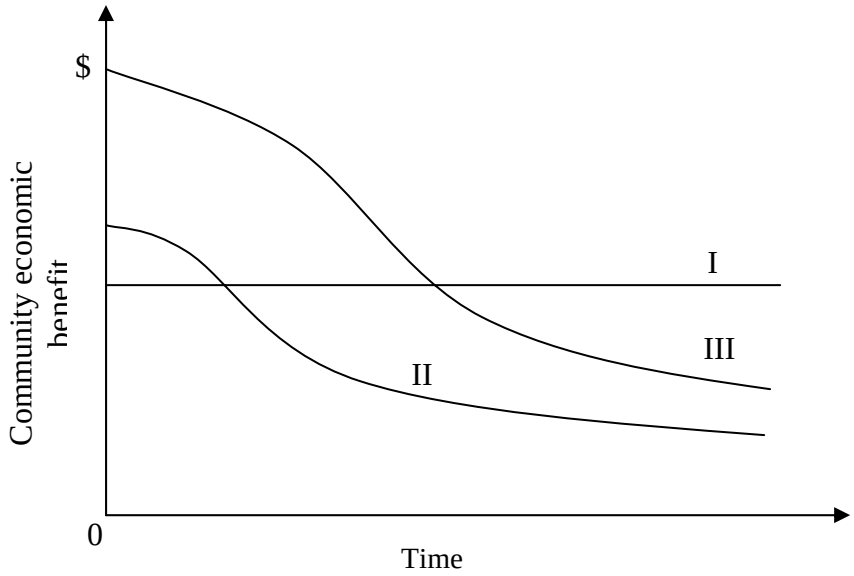

Figure 3 Environmental spillovers can result in less sustainable income paths and socially inferior ones being followed in a community.

Thus it is clear that the presence of adverse environmental externalities can both reduce social economic benefits and prevent the desired social sustainability of these benefits being attained.

4. Specific Observations on Environmental Spillovers, Sustainability and Aquaculture Development

Depending upon the type of aquaculture practised and other circumstances, aquaculture can have positive or negative environmental spillovers, or no significant spillovers. Table 1 lists some possible adverse environmental externalities from aquaculture. These range from pollution of underground and other water supplies, land subsidence due to withdrawal of underground water, reduced stocks of wild fish used for commercial or subsistence purposes, loss of recreational space, greater spread of diseases associated with farmed species and increased resistance of disease-causing organism as a result of medication e.g. antibiotics, used in aquaculture.

Table 1 *Types of agency and transaction costs involved in environmental regulations and the consequential economic impacts of such regulations*

POLICY FACTOR OR IMPACT	COMMENT
Agency and associated transaction-type costs	
1. Administrative outlays	Such as salaries for the general staff of the agency.
2. Monitoring or inspection costs	These policing costs can be high.
3. Enforcement costs	These include the legal costs of enforcement.
4. Political capture	The regulated may politically capture or influence the regulators. Regulators may prefer a quiet life and may not enforce the regulations rigorously.
5. Bribery	Regulators may take bribes and ignore infringements.
6. Imperfect information	Regulators have bounded rationality and thus have to act on imperfect information. Regulations may be inadequately drafted and values of policy instruments may be inappropriate.
7. Adaptability or flexibility of regulations	As economic and environmental conditions change, variations in policy may be necessary. Are the regulations adequate in that regard?
8. Uncertainty of regulations for the regulated	Uncertainty about the rights and obligations of the regulated and about enforcement of regulations may add to the costs of those regulated.
Transaction-type costs involved in private-property type of situations	
9. Negotiation costs	Note that many of these costs are similar in nature to those incurred by agencies but they fall on private individuals in this case.
10. Monitoring, inspection and enforcement costs.	
11. Imperfect information of the parties involved.	Asymmetry of information
Consequential economic impacts	
12. Allocative economic efficiency	To what extent do the regulations improve allocative economic efficiency, for example, bring private marginal cost into line with social marginal cost?
13. Change in income distribution	Different regulations have dissimilar impacts on income distribution. This should be taken into account.
14. Consequences for 'dynamic' efficiency - evolutionary impacts	How do the regulations affect technological progress, especially whether they encourage the development of technology for pollution abatement? Do the regulations encourage the development of environmental management skills?

In the light of the debate about strong or weak conditions for sustainable development, it is interesting to speculate about whether intensive or extensive aquaculture is likely to cause greater environmental damage. Intensive systems usually involve high man-made capital to land ratios and high man-made to labour ratios. It may also be that intensive systems are more likely to be closed or nearly closed so reducing their interdependence with natural environments. Thus, it is possible for intensive systems to be environmentally friendlier than extensive ones. In many cases, they probably have lower adverse environmental externalities for the same level of output. Therefore, in several circumstances, they could result in greater conservation of natural resources. For example, extensive farming of shrimp, as practised in Bangladesh and some other developing countries, although (appropriately) reflecting local relative abundance of man-made capital and labour, can be highly destructive of natural environments. Low-tech methods and methods with low man-made capital requirements in relation to other resources do not always foster sustainable development. Frequently these methods cause a high level of environmental destruction because they are actually require considerable utilisation of natural resource in relation to man-made capital. While superficially extensive production methods may at first seem to accord with strong conditions for sustainable development, in reality they often fall into the category involving weak conditions. While few natural resources may be converted directly into the man-made capital when using such techniques, the use of natural resource capital relative to man-made capital can be high when extensive production methods are employed because their adverse environmental spillovers seriously reduce natural capital stocks. However, as pointed out in Tisdell (1997a) the position is complex. Nonetheless, it is worthwhile linking macroeconomic requirements for sustainable development with microeconomic applications for it is at the microeconomic level that development policies are really put into practice.

I do not wish to give the impression that aquaculture is always environmentally unfriendly or that it always hinders sustainable development. In some circumstances, aquaculture can have very positive sustainability consequences. As Anderson (1985) points out aquaculture can increase the sustainability of wild stocks of fish and other gathered organisms by increasing supplies and reducing harvesting pressure. Such a favourable case is illustrated in Figure 4.

In Figure 4, the backward bending curve ABC represents the wild-caught supply of a fish species. It bends backward because, after some degree of harvesting effort is exceeded, available natural stocks of the fish fall significantly so increasing the per unit cost of their capture. The line DF represents the demand curve for this fish. In the absence of its aquaculture, market equilibrium is established at E_1 with the fish selling at P_2 per unit and with X_1 being supplied annually.

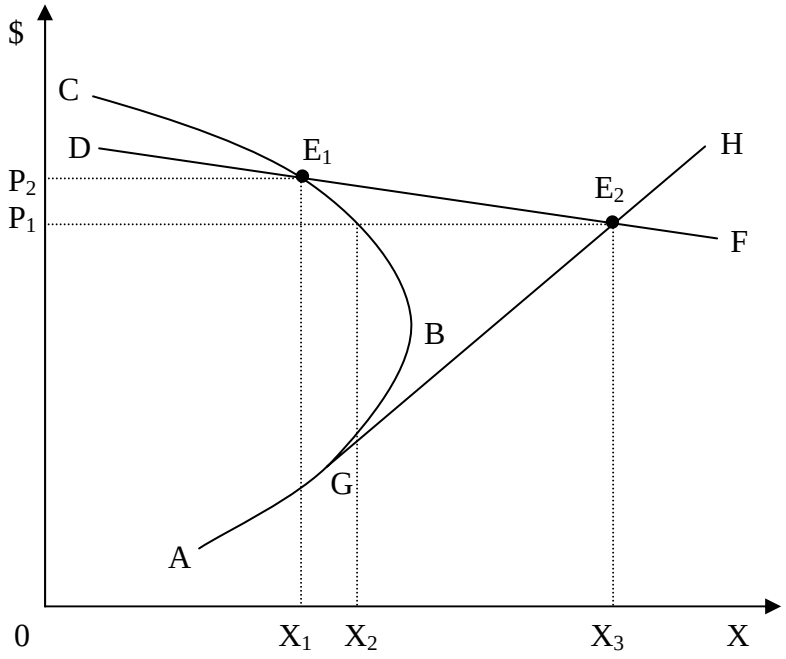

Figure 4 In some cases, farming or aquaculture favours the sustainability of the farmed species in the wild.

Now suppose that aquaculture of the wild-caught species becomes possible and that the total annual supply of it from farming and capture is as shown by AGH in Figure 4. If the captures and the farmed suppliers are perfect substitutes, a new market equilibrium is established at E_2. The market price of this farmed species falls from P_1 to P_2 and tis supply expands from X_1 to X_2. $X_3 - X_2$ of the increased supply is accounted for by aquaculture and $X_2 - X_1$ arises as a result of greater supply from the capture fishery. The latter occurs because a fall in market price reduces harvesting effort. Hence, natural stocks of the fish increase and per-unit and cost of capture declines. Thus in this case, the aquaculture is environmentally favourable.

However, the matter is much more complicated in practice, and in some cases an unfavourable environmental results eventuate from farming. This can occur via two different mechanisms. Aquaculture may stimulate the demand for the farmed species causing the market demand curves for supplies of the farmed species to shift upwards. Secondly, it may cause a shift to the left of the supply curve at wild-caught fish for reasons partly highlighted in Table 1. It may reduce the natural resources available to wild fish populations e.g. as a result of wetland destruction, lower their population by their capture at an immature stage to provide seedstock or fingerlings, and by other mechanisms.

This means that considerable care is needed in assessing each aquaculture situation for its sustainability implications. Hasty generalisation should be avoided.

Some other ways in which aquaculture can have positive environmental spillovers and add to sustainability might be noted. Fish farming is, for example, possible in conjunction with artificial wetlands. Such wetlands have been successfully used to reduce nutrient loads in water-bodies. Polyculture and appropriate combinations of agriculture and aquaculture can also be used to lower nutrient-loads entering common water bodies from private property. In Calcutta, fish aquaculture is engaged in in ponds and supplied with the city's sewage. Thus, aquaculture in this case assists with sewage-disposal and helps reduce biological oxygen demand in common waters. Furthermore, when agriculturalists engage in fish culture in farm ponds and dams, they are less likely to use dangerous agricultural pesticides and chemical fertilizers capable of adverse externalities on fish production. Scope exists for expanding the development of aquaculture for beneficial environmental spillovers but more research is needed in that regard. Since aquaculture includes botanic species, they should also be considered. In this respect, note that seaweeds and some molluscs can utilise the nutrients in nutrient-rich seawater and so could reduce dangers of red-tides and other unwanted environmental effects.

5. Regulating Adverse Environmental Spillovers from Aquaculture – General Considerations

Environmental externalities are generated by many social and economic activities, and aquaculture is both a source and a victim of several such adverse spillovers (Tisdell,

1994; Shang and Tisdell, 1997). As is clear from the above discussion, unfavourable externalities threaten sustainable development and are often sources of economic inefficiency and market failure. Their control can help to sustain economies development and improve the ability of economies to satisfy human wants.

Nonetheless, some caution needs to be exercised before deciding to regulate environmental spillovers from aquaculture. It should be borne in mind that economic regulation is not costless, is likely to be imperfect, and different policy instruments often have divergent side-effects, some of which may be unwanted. Furthermore, the economic impact of environmental regulation is liable to vary with the attribute of production to which the controls are applied. For example, impacts vary depending upon whether regulations are applied to inputs, outputs or emissions from productive activity.

In assessing alternative policy instruments for the control of spillovers from aquaculture, account must be taken of the comparative agency costs involved in each and limitations on the knowledge available to policy-makers. The relative adaptability of alternative policy instruments to changing circumstances also needs to be considered. As discussed here, these and other factors influence the practicality of using alternative policy instruments to regulate environmental externalities from aquaculture and achieve sustainable outcomes.

An economic system is only fully efficient if the relevant impacts of an economic agent's activities on others are fully priced. If this does not occur externalities or spillovers are said to occur. These unpriced economic effects result in the marginal private net benefits obtained by economic entities from their activities (for example, marginal profit of aquaculturalists) diverging from the marginal social net benefits of these activities. In all but very exceptional cases (Tisdell, 1993, Chs. 3 & 4), this causes economic inefficiency and a loss of economic welfare, assuming that economic entities act in their own self-interest to maximise their private welfare.

These externalities can in principle be addressed by policy measures in two general ways:

(i) Policy instruments such as emission taxes or trading in pollution rights may be used to price these thereby making them a part of the private costs or benefits of the economic entities involved. Economists describe this as internalising externalities.

(ii) Prohibitions or limits on environmental use may be imposed. Thus fiat, rather than guidance by means of pricing, is used to alter private behaviour

Sometimes a combination of pricing and prohibitory methods may be employed. For example, a tax on particular types of emissions such as nitrogenous and phosphorous emissions from artificial fishponds, and a ban on the use of particular chemicals or pharmaceuticals in fish farming may be simultaneously imposed.

Within the pricing and prohibitory approaches to regulating environmental spillovers, a variety of policies are possible. These will be discussed after the broad principles of evaluating policies for regulating environmental spillovers in aquaculture are outlined.

Broadly, economic assessment of the regulation of spillovers involves two parts:

(i) costs and problems involved in the administration of the regulations, often described as agency costs, and

(ii) consequential economic costs and impacts of the regulations.

Agency costs can be regarded as a form of transaction costs. Even when private property solutions of the type suggested by Coase (1960) are adopted with a view to eliminating externalities by negotiation, transaction costs are involved, particularly if agreements need to be enforced in the courts.

Policies for regulating environmental spillovers from aquaculture vary in terms of their agency and transaction-type of costs, and in terms of their consequential economic impacts. Both sets of factors must be taken into account in assessing environmental regulations; a holistic approach is needed. Table 2 summarises the type of factors to be considered in deciding on policies to control environmental spillovers. These are classified into considerations arising from agency and transaction-type costs, and consequential impacts. These considerations are quite general and apply not just to aquaculture but to all economic activities giving rise to environmental spillovers. Until recently, economists tended to concentrate on consequential impacts giving most of

their attention to item 12, impacts on allocative efficiency. However, with growing interest in institutional economics, the other aspects are getting more attention.

Table 2 *Types of agency and transaction costs involved in environmental regulations and the consequential economic impacts of such regulations*

POLICY FACTOR OR IMPACT	COMMENT
Agency and associated transaction-type costs	
15. Administrative outlays	Such as salaries for the general staff of the agency.
16. Monitoring or inspection costs	These policing costs can be high.
17. Enforcement costs	These include the legal costs of enforcement.
18. Political capture	The regulated may politically capture or influence the regulators. Regulators may prefer a quiet life and may not enforce the regulations rigorously.
19. Bribery	Regulators may take bribes and ignore infringements.
20. Imperfect information	Regulators have bounded rationality and thus have to act on imperfect information. Regulations may be inadequately drafted and values of policy instruments may be inappropriate.
21. Adaptability or flexibility of regulations	As economic and environmental conditions change, variations in policy may be necessary. Are the regulations adequate in that regard?
22. Uncertainty of regulations for the regulated	Uncertainty about the rights and obligations of the regulated and about enforcement of regulations may add to the costs of those regulated.
Transaction-type costs involved in private-property type of situations	
23. Negotiation costs	Note that many of these costs are similar in nature to those incurred by agencies but they fall on private individuals in this case.
24. Monitoring, inspection and enforcement costs.	
25. Imperfect information of the parties involved.	Asymmetry of information
Consequential economic impacts	
26. Allocative economic efficiency	To what extent do the regulations improve allocative economic efficiency, for example, bring private marginal cost into line with social marginal cost?
27. Change in income distribution	Different regulations have dissimilar impacts on income distribution. This should be taken into account.
28. Consequences for 'dynamic' efficiency - evolutionary impacts	How do the regulations affect technological progress, especially whether they encourage the development of technology for pollution abatement? Do the regulations encourage the development of environmental management skills?

Many methods traditionally recommended by economists for the control of environmental spillovers from economic activities are impractical or uneconomic for aquaculture, mainly because of the level of transaction costs involved. For example, where aquaculture is conducted in a shared water body, emissions from cages or plots for aquaculture are non-point and can be very difficult, if not impossible, to monitor. Even when aquaculture involves pond cultivation and water withdrawal from a common body of water with release of wastewater via a point outlet (or a few outlets), effective monitoring of the quality of the water released may be difficult or costly. Where will the aquaculture water samples be analysed, how quickly, how frequently will they be taken and when? Especially when small-scale scattered aquacultural enterprises are involved, as is sometimes so in less developed countries, the cost of sampling may be high. Furthermore, aquaculturalists may be able to time their noxious water releases so these do not coincide with the visit of a pollution-control inspector. Moreover, in some less developed countries, considerable scope exists for bribery, given prevailing socio-economic conditions.

6. Pricing and Market-Making Approaches to Environmental Regulation of Aquaculture

In regulating environmental spillovers from aquaculture, it is important initially to decide which aspect of aquaculture activity is to be controlled to address an environmental problem. For example, is the control designed to impact on the level of production, stocking rates, use of inputs, on emissions of pollutants, on location of activities or on use of particular technologies or farming methods? Depending upon where the controls are applied, they are liable to have different economic consequences. For instance, if the emission of a particular pollutant is the main problem, limitations on aquaculture production levels, on stocking rates, or on inputs containing the major source of the pollutant will reduce emissions of the pollutant but may fail to encourage development of techniques to reduce its emission. Thus, these policies may be ineffective in encouraging dynamic or evolutionary efficiency in pollution reduction. Nevertheless, agency cost, involved in regulating emissions directly may be so high that it is not economical to do this. Thus in Europe, stocking rates on fish farms are regulated in some countries and in Denmark, the nitrogen and phosphorous content of fish food is limited (New, 1995). However, taxation or charging for pollution emissions from many forms of aquaculture has proven to be impractical.

Economists have traditionally favoured pricing and market-making approaches to environmental regulation on the grounds of their allocative efficiency (Tisdell, 1993, Ch. 4). Unfortunately, as is clear from Table 2, the economic value of a policy cannot be judged solely from its ability to promote allocative efficiency or from its consequential economic effects. Furthermore, the simplicity of pricing-type policies is lost when environmental spillovers vary in their economic impact according to their location, as is mostly the case in aquaculture.

On the other hand, one should not be too ready to dismiss pricing approaches in favour of prohibitions. In some cases, very little extra cost is involved in adopting a pricing approach. Since it usually involves the 'user-pays' principle, the pricing approach can help fund the cost of administration of regulations and prevent this cost becoming an impost on the general state budget. Some also believe this approach is appealing because it can provide public funds for supporting research into methods of pollution reduction.

For example, instead of setting an administratively upper limit to the stocking rate on aquacultural farms, an alternative is to impose a tax or fee on this rate. The overall fee or charge should be determined to achieve the aggregate rate of environmental impact aimed for. This measure enables those farmers who find higher stocking rates to be more economical to have these, although they would have to pay extra for this. A disadvantage of this method from the point of view of the aquaculture sector is that (at least in the short term) it distributes income away from producers in this sector. Hence, this policy may be politically unpopular from the point of view of the regulated industry. Similarly, instead of regulating the maximum nutrient-content of manufactured fish food, one could impose a levy increasing with the nutrient-content of the this food.

Pricing and market-making approaches to control of environmental externalities may involve the following:

(i) The levying of taxes or charges on economic activities giving rise to environmental spillovers.

(ii) The payment of subsidies to producers to provide them with an incentive to reduce or refrain from activity resulting in adverse environmental spillovers.
(iii) The marketing of pollution rights or environmental-use rights. These may be transferable.
(iv) Extension of private property rights in an effort to eliminate the occurrence of the externality.

Subsidising pollution reduction is an alternative to taxing pollution creation, and in theory, it can achieve the same degree of allocative efficiency. However, in contrast to taxation, subsidisation involves a charge on the state budget. Moreover, it has the opposite income distribution consequences to taxation. Worrall (1995) argues that a subsidy to aquaculture, for example, for shrimp farming, may be justified because aquaculture is likely to reduce harvesting pressure in the capture fisheries. However, this is a controversial matter and it is clear that aquaculture does not always have this consequence (see Tisdell 1991, section 6.4). In fact, as pointed out above, just the opposite can occur.

Marketing of pollution or environmental-use rights has recently captured the interest of many economists. In theory, this policy approach can have similar allocative and dynamic economic consequences to the pricing control methods just mentioned. Nevertheless, actual schemes for marketing such rights can vary greatly. For example, depending upon how the rights are distributed, they may bring in little or no revenue for the state or considerable revenue. In this regard compare the policy which allocates initial pollution rights free to existing stakeholders in the industry and allows recipients to market these with the method by which the state auctions or sells rights (available only for one year) taking account of the market. The latter provides the state with revenue whereas the former method does not. Nevertheless, agency costs, sometimes considerable, have to be met when marketing of pollution rights is adopted as a policy (Tisdell, 1997a, b).

In the case of aquaculture, many environmental spillovers are site-specific or vary in their consequences according to their location. In these circumstances, uniform rates of taxes, subsidies or prices for rights for environmental-use do not promote economic

efficiency (Tietenberg, 1974). Thus, extra administrative costs are involved in adjusting these refer appropriately by regions or locations so reducing their value as regulatory instruments. This is not to say that adjustments are impossible. For example, marketed pollution rights may be designated for use in particular regions. However, in this case, it is possible that the market for such rights will become 'thin'.

As for the view of Coase (1960) that the strengthening of private property rights is likely to eliminate spillovers, this approach is only likely to be a success if the cost of enforcing those rights is low. Unfortunately, in relation to aquaculture, especially if non-point pollution is involved, these (transaction) costs are usually quite high. This limits the scope for private property solutions to environmental problems caused by aquaculture.

The nature of most aquaculture is such that traditional economic pricing and market-making approaches to pollution control and environmental use have limited application or can only be imperfectly applied. This is not to say there is no scope for such regulations. They may be used in controlling use of underground water, for example. Furthermore, if such methods are used, they often have to be modified to suit actual circumstances. For example, taxes or prices on using the environment may have to be varied according to the locality involved. Furthermore, the stage of economic development of a country can limit the practical use of instruments that are employed in more developed countries.

7. Prohibitions and Administrative-type Regulations

Prohibitive and administrative-type regulations are usually not favoured by economists because their allocative and dynamic economic consequences are believed to be less favourable than pricing and market-making approaches to the control of environmental use. However, the comparison is often made while ignoring the transaction costs involved in environmental pricing and market-making approaches to control of environmental use. When all costs are taken into account, prohibition and administrative type regulations will sometimes be the most economic means of controlling use of the environment.

The nature of such regulations can vary greatly as does their cost and overall effectiveness. This may take the form of (1) emission standards (2) controls on inputs used in aquaculture (3) on stocking rates (4) preservation orders, for example, requirements that a certain amount of vegetation such as mangrove cover be retained and (5) zoning affecting the location and nature of operations of aquaculture farms and other enterprises.

These methods need to be assessed by taking into account all the factors listed in Table 2. This means that alternative environmental policies should not be evaluated just in terms of their possible consequential economic effects.

Some prohibitions can be costly to enforce whereas others may be relatively inexpensive. For example, it is likely to be more costly to monitor compliance with emission standards than to enforce zoning regulations or maximum stocking rates of fish. One has to balance the agency costs against their contributions otherwise to improving the overall level of economic welfare. In reality, achieving a utopian or ideal solution to controlling environmental spillovers from aquaculture seems impossible.

8. Further Discussion of Sustainability Implications

Traditional economic approaches to environmental regulation are based on social cost-benefit analysis. Such analysis requires account to be taken of spillovers as well as private net benefits. While it is impossible to go into details here, a major issue raised by social cost-benefit analysis is how empirically to place economic values on the spillovers or externalities that arise. Where there is loss of marketed production or commodities because of such spillovers, measuring the economic loss arising from these can be straightforward, in principle. However, in some cases, aquacultural activities can affect the supply of non-marketed goods and the reduction in their supply will need to be valued. Methods such as contingent valuation methods have been developed for this purpose, but they are not without their limitations (Tisdell, 1991, Ch. 9).

Some authors have suggested that because of the uncertainty involved in evaluation of environmental effects, systems of safe minimum standards should be adopted (Bishop,

1978, 1979). In some instances, such standards can be combined with the use of transferable pollution rights. A further modification to the traditional economic approach to environmental regulation has arisen from debate about sustainable economic development. While most parties to the debate agree that externalities need to be taken into account to achieve sustainability, some parties believe that this is insufficient. These individuals argue that strong conditions need to be enforced to achieve economic sustainability.

This group claims that it is now necessary to hold the world's remaining natural resource and environmental stock at approximately current levels (see Pearce, 1993). This means that any new economic activity should have a zero net effect on the environmental stock. In relation to aquaculture, this approach may require zero net emissions of pollutants by an aquaculture farm, water recirculation and so on. In other cases, offset policies may be allowed. For example, where an aquacultural development destroys a natural wetland, the developers may be required to establish an artificial wetland, at least equivalent environmentally to the one destroyed. Alternatively, artificial or augmented natural wetlands may be required to be established to help process effluents from aquaculture farms.

In the 1990s, in Queensland, Australia, introduced legislation intended to force aquaculture farms to have zero net emissions of nitrogen and phosphorous in their wastewater. But the standard could not be achieved. Furthermore, the question arises of whether such stringent standards are desirable, even if they can be physically and biologically achieved. The *ad hoc* promulgation of such rules can certainly add to economic costs and create economic inefficiencies. Furthermore, there could be *some* circumstances in which the release of nutrient-enriched water adds to the natural environmental resource stock and so creates a positive externality.

Economists have traditionally suggested that when environmental spillovers are optimally regulated, some degree of spillover or pollution is <u>likely</u> to be optimal from an economics viewpoint. Nevertheless, strong sustainability-advocates may call for a zero <u>net</u> environmental effect. Their main argument is that aggregate stocks of natural environmental capital are now at critically low levels. Any further reduction is likely to endanger the welfare of future generations.

9. Concluding Comments

As pointed out, aquaculture is a rapidly expanding 'new frontier' industry, and has the ability to add considerably to material income and wealth But that also raises the question of whether its development is liable to be sustainable. It was shown that lack of sustainability of aquaculture development is sometimes a desired alternative even when market failure does not occur. Nevertheless, some concerns have been expressed about resource choices in such cases that adversely impact on sustainability. There is, however, less controversy about the fact that adverse environmental spillovers can result in income or economic paths being followed that are less sustainable than socially preferred and available alternative paths. This discussion is specifically linked to environmental spillovers arising from aquaculture.

Particularly in the case of environmental spillovers from aquaculture, of what policies can and should be adopted to regulate these spillovers so as to increase economic welfare and contribute to sustainable development. A considerable number of policy instruments for regulating such spillovers were shown to exist. However, it seems that no single policy instrument or class of instruments constitutes the best choice in all circumstances.

Although economists favour pricing and market-making methods of regulation because of their favourable economic consequences, when all costs are taken into account, there can be circumstances where these methods are not the best available. As a rule, one has to select the best amongst imperfect methods of regulation and the appropriate type of regulation or combination of regulations is likely to vary with the cases requiring attention. For this reason, policy-making in aquaculture cannot be a mechanical affair. Furthermore, it has become more complicated with growing interest in conditions required for sustainable development. There is still much to be learnt about appropriate economic ways to satisfy strong conditions for sustainability. Nevertheless, the continuing importance of environmental assessment, planning and management of aquaculture development for sustainable development has been underlined by FAO (1995).

Unfavourable externalities are generated by many social and economic activities. Aquaculture is both a source and a victim of several of these spillovers. Such

externalities threaten sustainable development and often are sources of economic inefficiency and market failure. Their control can help to sustain economic development and improve the ability of economies to satisfy human wants. However, economic regulation is not costless and different policy instruments often have different side effects, some of which may be unwanted. Furthermore, their impact can vary depending on the attribute of production to which they are applied, for example, to inputs, outputs, emissions, etc. Consequently, the assessment of alternative economic instruments for regulating environmental spillovers from aquaculture are much more complicated than some economists and non-economists have led us to believe. In assessing alternative policy instruments for control of spillovers from aquaculture, account must be taken of the comparative agency costs involved in each and limitations on the knowledge available to policy-makers. These, and other factors, influence the practicality of using the available alternative policy instruments as a means to support sustainable development.

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