The use of economic instruments in environmental policies to mitigate diffuse pollution from agriculture

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Abstract: The study focuses on the environmental problem of diffuse pollution from agriculture (DPA) as a result of the land use and the policy intervention that can be used to mitigate the problem. Attention is paid to the use of economic instruments (EIs) in policies concerning the DPA. Also, policy options, the advantages and disadvantages of the EIs and their assessment are looked at.

Key words: economic optimum, environmental problem, farmers education, fertilizer use, land use policy, pesticide use

Land occupies a special niche, not only in the market place, but also deep in the human soul (Tietenberg and Lewis 2009). Land use is sometimes used as a measure of the state of the environment in its own right; as a surrogate for some wider environmental pressure such as the conversion of land to arable use and the implication this might have on the sediments loss (soil erosion and diffuse pollution), or as a measure of the effectiveness of a particular policy (Potschin 2009). Land use profoundly influences soil functions at multiple levels with agro-ecosystems and in many areas, the human pressure for production has modified land use causing both known and unknown ecological effects (Sharma 2004; cited in Mandal et al. 2010).

The environmental problems: DPA

The DPA is the contamination of soils, air and water environments caused by the releases of pollutants from a range of agricultural activities on land that individually may have a little effect on the water environment, but cumulatively they can have a significant impact across (river) catchments (SE 2005; SEPA 2011). Campbell et al. (2004) listed the sources of the DPA as follows: increased erosion and soil loss, chemical pollution, irrigation and livestock. For the purposes of this study, the pollution of water as a result of the DPA would be focused on.

Agricultural land management and farm holdings contribute significant loads of pollutants to the water environment through the diffuse pollution (DP) and farming contributes approximately 60% of nitrates, 25% of phosphorus and 75% of sediment entering our waters (Defra, undated). The DPA also causes eutrophication of rivers and water bodies (Campbell et al. 2004). It is estimated that around 70% of nitrate pollution emerges from agriculture (Barnes et al. 2004). Also, 82% of rivers, 53% of lakes and 75% of groundwater bodies in the UK are at a risk from diffuse pollutants such as nitrate (NO_3) and phosphorous (P) (EA 2006).

DPA and the justification for intervention

The pollution of water by nitrates (mainly from fertilizers) is a serious problem throughout the EU and agriculture is one of the main contributors to the problem (Lally et al. 2007).

According to Defra (2004), the Environment Agency estimated the water pollution cost from agriculture to be £250m per year. Therefore, there is a need for an intervention – a suitable policy instrument (PI) to address the problem.

MATERIAL AND METHODS

Different policy options as well as policy instruments (PIs) can be employed in policies relating to the DPA. Campbell et al. (2004), based on the root causes of the diffuse pollution and its symptoms, suggested government regulation, economic instruments and education (voluntary agreement, VA).

However, for the purposes of this study, the EIs would be focused on as the policy options for the DPA (i.e. product/input charges: fertilizer (nitrate) taxes and pesticide taxes).

The EIs selected are based on the following criteria stated in Inman (2006), Price (2011) and Weersink et al. (1998): cost effectiveness and economic efficiency, fairness, dynamic efficiency and enforceability. This is because economic instruments such as pollution taxes are now widely regarded by economists as being superior to command-and control (CAC) instruments on the basis of these criteria in most cases of pollution control (OECD 1989a; cited in Weersink et al. 1998).

Also, the selection of economic instrument is based on the two main purposes given by Campbell et al. (2004):

– They shift the economic balance in favour of a desired behaviour change or other sought after the outcome (e.g. improved environmental quality).
– They can also be used for the revenue-raising purposes.

DPSIR framework related to land use – DPA

The strength of the DPSIR framework or model is that it seems to show in a simple way the important connections between people and the state of the natural environment and it also seems to help in communicating ideas between different disciplines, even though it has limitations (Potschin 2009). The DPSIR stands for drivers (D), pressures (P), state (S), impact (I) and response (R) and these are linked to show the pressure and event that trigger the environmental change through to the responses and interventions that might be tried to mitigate the problem (Potschin 2009) – Figure 1.

Property rights, market failure, externalities and the need for environmental policy (economic) instruments

Property rights governing environmental resources will determine the manner in which producers and consumers use these resources and property rights help the understanding of environmental problems which arise from the government and market allocations (Tietenberg and Lewis 2009). In ideal circumstances, these market allocations are efficient; however, the actual market departs from ideal circumstances thereby resulting in market failures. Externalities are a source of market failure (Tietenberg and Lewis 2009; Perman et al. 2011). According to

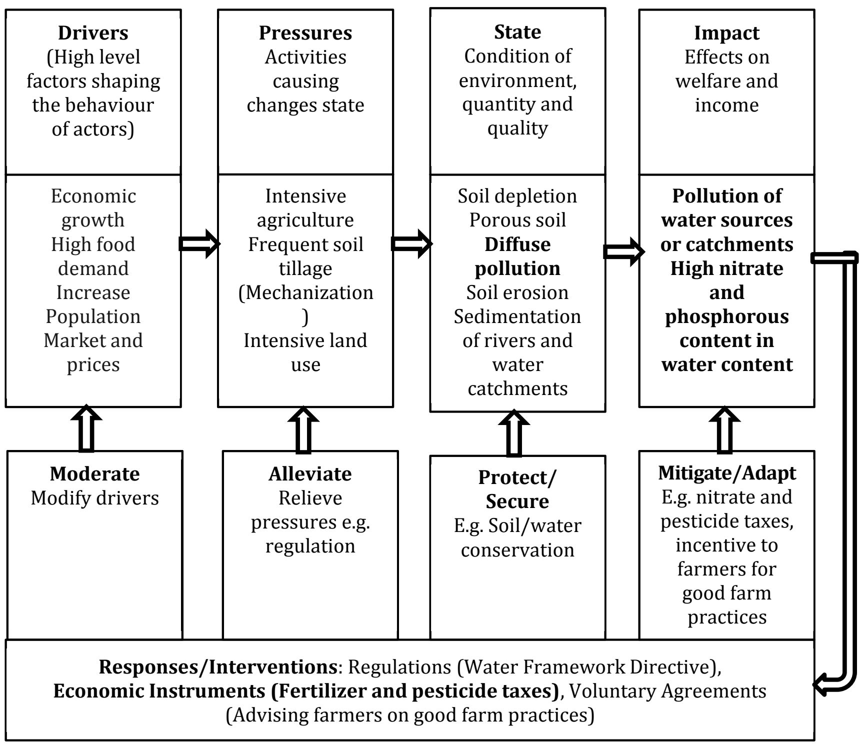

Figure 1. DPSIR framework relating to DPA due to land use for agriculture

Perman et al. (2011), an externality arises when the production or consumption decisions of one agent have an impact on the utility or profit of another agent in an unintended way, and when no compensation or payment is made by the generator of the impact to the affected party.

Let us consider a farmer who is intensively producing wheat to make profit due to an increase in the demand for wheat. This may lead to the intensive pesticide or fertilizer application which will in turn leads to the DPA and hence the pollution of water sources.

Figure 2 can be likened to a supply and demand curve – as the demand increases, the supply will increase, but the MEC, which represents the cost to society from the production of wheat, will also increase. For both the farmer and society to be better off, the farmer needs to produce at QS, where the MPB equals the MEC. At this point, it can be said that the Pareto improvement or efficiency has been achieved. According to the Coase theorem (cited in Perman et al. 2011 and Hanley et al. 2007), suitable property rights between the farmer and the society can correct the externality problem of DP.

The inability or unwillingness to assign property rights to create a complete set of markets provides a rationale for the government intervention (Hanley et al. 2007).

If the farmer decides to produce beyond the QS, the farmer has to compensate the society (polluter pays principle) and this can be done with the introduction of an EI (such as fertilizer taxes), or the society can pay the farmer to reduce pollution if the farmer adopts good farming or agronomic practices (provider gets principle).

From Figure 3, the PMC is derived from the cost of input for wheat production. The MEC represents what society will be willing to pay for the farmer to reduce the diffuse pollution by a small amount. SMC = PMC + MEC. The MEC increases with the increase in production.

The farmer producing at Y_0 is not efficient because at that point P_Y equals PMC and the cost borne by the society is ignored. To be efficient, the farmer needs to produce at Y^*, where SMC equals P_Y. In the absence of any correction of market failure, that is the external cost borne by the society, the market-determined level of Y output will be too high for efficiency. To correct this market failure or externality, the government can intervene with the use of an EI (in this case tax t).

t = SMC* – PMC* = MEC*; thus the tax equals the MEC at the efficient level (Y^* and QS). The taxation at the MEC* is required to bring efficiency.

The environmental policy objective is to secure the provision at the level required for allocative efficiency (Perman et al. 2011). Therefore, it can be said that the EIs can be used to mitigate the problem of market failure by creating a level playing field or by internalising externalities.

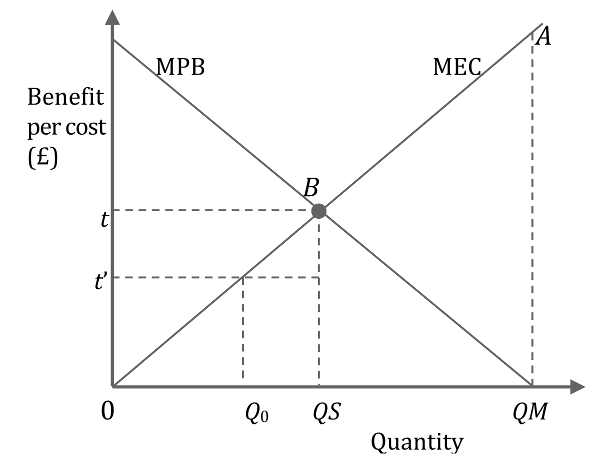

Figure 2. Socially optimal level of output and pollution (or negative environmental externality)

MEC = Marginal External Cost, MPB = Marginal Private Benefit

Source: Adapted from Perman et al. (2011) and Hanley et al. (2007)

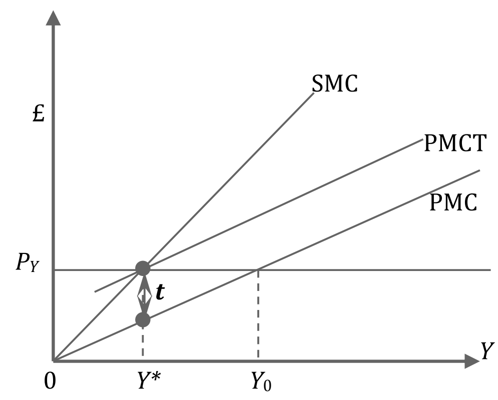

Figure 3. Correction of an externality with economic instrument (taxation)

SMC = Social Marginal Cost, PMC = Private Marginal Cost, PMCT = PMC with tax in place, Y = Wheat output

Source: Adapted from Perman et al (2011)

RESULTS AND DISCUSSION

For the purpose of this study, the EIs considered are pesticide and fertilizer (or nitrogen) taxes. These are the input charges used indirectly to influence the behaviour by putting a charge directly on the input perceived to cause the environmental problem (Hanley et al. 2007). The EIs such as the environmental tax can lead to an improvement in water quality (Rinaudo and Strosser 2007; cited in Graveline and Rinaudo 2007). Graveline and Rinaudo (2007) went on to say that the principle of environmental tax (fertilizer tax) consists in shifting the economic optimum from high to low intensity cultivation practices. The use of taxes is likely to increase the awareness among farmers of the environmental impact of the taxed product (Pearce and Koundouri 2003).

From Figure 4, the maximum yield (agronomic optimum) that can be achieved by farmers with the application of fertilizer is at the point A. In the absence of a tax on fertilizer, farmers will continue to maximise their production in order to increase their gross margin. According to Graveline and Rinaudo (2007), the economic situation corresponding to this situation is at the point E1. However, with the introduction of fertilizer tax, the profit curve will shift downwards with the economic optimum moving towards E2, E3 to E4 on the tax level increases. These will result in the reduction of the fertilizer use as well as the income of farmers. The reduction in the fertilizer use will subsequently reduce the DP of water sources. Graveline and Rinaudo (2007) gave an example of a situation in France, where the increase in fertilizer tax to 1 €/kg forced farmers to reduce the level of corn fertilization and a further increase in the tax forced farmers to cover half of their land with cereal crops.

Advantages of EIs

The advantages and disadvantages or the pros and cons of the EIs are based on the heading used by Smith (1995) and Leicester (2006).

Static cost minimisation

The static efficiency gains from the use of the EIs arise in situations where the polluters face different opportunities for the pollution abatement or different marginal abatement costs (Smith 1995; Leicester 2006). For example, different farmers may apply different levels of fertiliser on their farms, some of which may have a more positive impact on reducing the DP. This is not the case with regulatory policies which require that the regulator gets more information before it can set the abatement levels for each farm.

Weersink et al (1998) also said that the EIs are cost effective than regulatory policies. They went on to

Table 1. Case study Examples of EIs application on pesticide and fertilizer application

Economic instrument	Location	Objective(s)	Effectiveness/Remarks
Fertilizer taxes* (Pearce and Koundouri, 2003)	Austria, Norway, Sweden, Denmark	To control non-point agricultural pollution and also to raise revenues for other environmental projects.	**Austria** – Had significant 'signalling' effect through raising awareness that fertilizers are environmentally damaging **Sweden** – Fertilizer tax reduced demand for fertilizer in 1991–2 by 15–20% and also financial optimal dosage by 10%. **Norway** – Not effective but difficult to disentangle tax effects from other policy effects. **Denmark** – Recycling of revenues back into agriculture reduced the effectiveness of the tax.
Nitrogen tax (Pearce and Koundouri, 2003; Graveline and Rinaudo, 2007)	Netherlands	DPA	Farmers were taxed based on nitrogen surplus under the Minera Accounting System (MINAS). It was said that its effectiveness might be sight specific.
Pesticide taxes (Hanley et al, 2007)	Denmark	To raise revenues for pesticide research and extension advice and also reduce environmental risk of pesticides	The tax was levied as a percentage of the wholesale price at rate of 53% (insecticides), 33% (herbicides) and 3% (wood preservatives and rodenticides)

*Campbell et al. (2007) also have similar examples (pages 207–208)

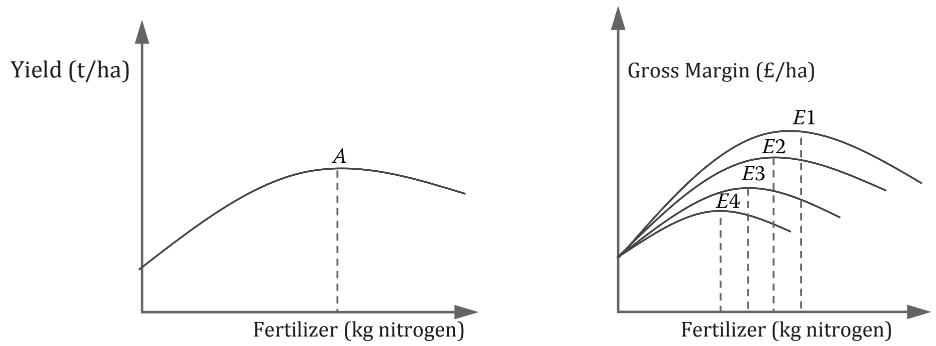

Figure 4. Agronomic and economic optimum for different fertilizer tax levels

Source: Redrawn from Graveline and Rinaudo (2007)

say that the EIs also have the attraction that they may induce polluters to choose the efficient, cost minimising pattern of abatement in response to the price signals they provide.

Dynamic incentives for innovation

According to Smith (1995), the EIs confer a dynamic efficiency providing an incentive for the research and development in pollution abatements. Pearce and Koundouri (2003) cited the Swedish and Danish examples, the revenues from which were recycled back into agriculture, research and development; however, it reduced the effectiveness of the taxes. According to Hanley et al (2007), the specific aim of the Danish pesticide tax was to raise revenues for the pesticide research and extension advice.

The EIs hold out the possibility of a more rapid rate of development of pollution control technologies than regulatory instruments (Smith 1995; Weersink et al. 1998; Hanley et al. 2007).

Vulnerability to regulatory failure

The EIs may be less exposed to the regulatory failure than certain quantitative regulation (Smith 1995). Vickers and Yarrow (1988), cited in Smith (1995), said that one of the sources of the regulatory failure is the asymmetry of information between the regulators and their subjects. Farmers may withhold information on how much fertilizer they use on their farms from the regulators, however, with EIs such as the fertilizer tax, the farmers withholding information may not have any effect on the effectiveness of the policy.

Revenues-raising and the double dividend

The use of EIs such as the fertilizer tax can raise the revenue and in some circumstances, the revenue may constitute a second source of benefits or a double dividend from their use over and above the impact on the environment; even though such circumstances are quite limited (Smith 1995). However, the revenue recycling effect according to Pearce and Koundouri (2003) reduces the effectiveness and they gave the Danish fertilizer tax as an example. The EIs such as the environmental tax will not be suitable for all pollution problems and in some cases; the regulation will be preferable (Smith 1995).

Efficiency

With the CAC regulation, the regulators could require a great deal of information in order to design a uniform system, however, the tax (EI) will lead to the firms self-selecting high or low-cost abaters (Leicester 2006). With the regulation, it is not possible for farmers to reduce the diffuse pollution at the same marginal cost if the technology differs across them.

Disadvantages or limitations of EIs

Uncertainty

The EIs such as the environmental tax may not generate the correct level of abatement if there is an uncertainty over the MEC/MPB schedules or over the extent to which the polluters will respond (Smith 1995; Leicester 2006). A CAC policy may be used to obtain the target set to control pollution and this will provide a certainty over the outcome which a tax will not. The government may prefer the certainty of a CAC system if the penalty for missing the target is severe (Leicester 2006).

Distributional implications

In a situation where taxes are used discourage pollution, the distribution of the burden of the tax payments may be evenly spread across the tax payers (Smith 1995; Leicester 2006).

Non-uniform damage

Due to the diffuse nature of pollution from agriculture, a complex tax or EI is needed where the pollution is concentrated (Smith 1995). The DP and its associated damage may vary according to the locations of the farm and a straightforward EI such as the fertilizer tax may not be effective. According to Smith (1995), a number of papers have considered the use of zoned taxes or other non-linear tax system to reflect the fact that the pollution in particular locations or certain times causes a greater damage. A farmer with a small farm size close to a river may be causing more damage to the river (water) than a farmer with a bigger farm size far away from the river.

Monopoly

The imposition of fertilizer tax with the aim of reducing the fertilizer use and hence the DPA will cause farmers (polluters) to have a monopoly power in the output, because the tax imposition will induce a reduction in the output below the socially optimal level (Smith 1995; Leicester 2006).

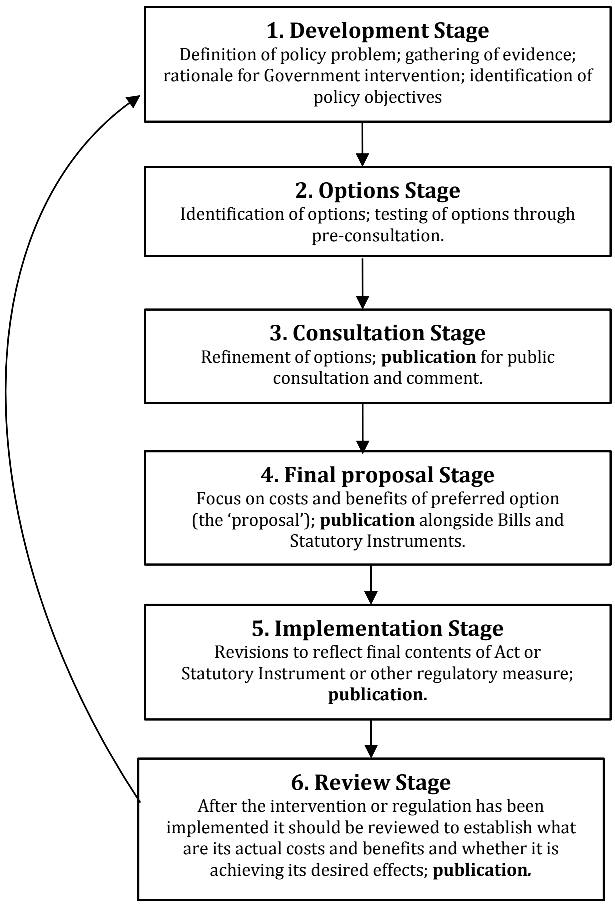

Figure 5. Stages for producing impact assessment

Source: Adapted from BERR (undated); accessed on 27th December 2011)

Assessment of economic instruments

For the purposes of this study, the usefulness and the practicality as well as the impact of the EIs would be assessed based on the following criteria: effectiveness, efficiency equity and flexibility. See the Figure 5 for the impact assessment stages.

Effectiveness

The effectiveness of an EI depends on the success in achieving the regulator's objective in the pollution control (UNEP 2004; Hanley et al. 2007). The effectiveness of input charges on reducing the input use depends on the magnitude of the tax, the breadth of the tax base and the proportion of the total production cost made up by the input, and the price responsiveness of the crop demand and the input use (Weersink et al. 1998). They continued to say that the effectiveness of input charges such as the pesticides and fertilizer taxes will vary because:

– Input use varies among farms.
– They do not encourage any other abatement actions such as the crop choice and so cannot lead to a cost effective attainment of the pollution targets.
– Substitution of inputs induced by the input charge may change the environmental problem instead of controlling it.

In terms of the environmental effectiveness, there is a problem with the pesticide and fertilizer taxes, in terms of their being proportional to the damage done.

Efficiency

According to Hanley et al. (2007), efficiency is desirable because it means that the regulator's objectives are achieved at the lowest possible cost. Pesticide and fertilizer taxes are administratively efficient because they are incorporated into the tax system (Weersink et al. 1998). In terms of the dynamic efficiency, the EI should be able to provide for the development of a more efficient abatement.

Equity

EIs can influence the distribution of costs and benefits among the members of society (Hanley et al. 2007). For example, the introduction of the fertilizer tax can bring the pollution level to a point where both the farmer and the society would be better off. However, setting taxes too high can increase the production cost of farmers to the extent that some farmers can be pushed out of the business or will not be able to compete; the consumers (society) may end up paying for the cost through price increases (Hanley et al. 2007).

Flexibility

A useful EI can adapt to the changes in markets, technology, knowledge, social, political and environmental conditions (Hanley et al. 2007). Pesticide and fertilizer taxes can adapt to some of these conditions – the flexibility can allow the farmer to go for environmentally safe fertilizers or improved crop varieties that depend heavily on nitrogen.

The future of EIs

Based on the number of literature on EIs and its applications (Smith 1995; Weersink et al. 1998; Leicester 2006; Hanley et al. 2007; Tietenberg and Lewis 2009; Perman et al. 2011), it can be said that the EIs have a future and their application will become more common and efficient.

RECOMMENDATIONS AND CONCLUSION

According to Weersink et al. (1998), no single EI emerges as the ideal choice for reducing the DPA. EIs cannot be the panacea to the DPA (due to the diffuse nature of the pollution). Aftab et al. (2010) also suggested a mixed approach of economic incentives and management standards. Therefore, it is recommended that in designing a policy to solve the DPA, all the three major PIs need to be combined. There should be a regulation on the types of fertilisers or pesticide, an EI to induce the reduction in their use and a voluntary initiative to educate farmers on the best farm practices and harmful effects of the pesticide and fertilizer use.

From the above information, the following conclusions have been drawn:

– The EIs have many advantages compared with the CAC and/or VA and therefore their application should be enhanced and encouraged.

– For a policy to mitigate the DPA to be effective, the EIs, CAC and VA need to be combined or incorporated in the same policy.

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