Economic Instruments and Environmental Policy in Agriculture

Alfons Weersink
Department of Agricultural Economics and Business
University of Guelph, Guelph, Ontario

John Livernois
Department of Economics
University of Guelph, Guelph, Ontario

Jason F. Shogren
Department of Economics and Finance
University of Wyoming, Laramie, Wyoming

James S. Shortle
Department of Agricultural Economics and Rural Sociology
Pennsylvania State University, University Park, Pennsylvania

Les instruments économiques peuvent atteindre des objectifs environnementaux à moindres coûts et fournir des incitatifs à de plus amples améliorations. Les opportunités d'utiliser de tels instruments dans le secteur agricole où l'origine des problèmes de pollution peut être identifiée, comme dans le cas des opérations intensives d'élevage de bétail, sont limitées. Cependant, la plupart des problèmes environnementaux touchant l'agriculture impliquent plusieurs sources de pollution diffuses pour lesquelles les pratiques de réduction ne sont pas observables, ce qui rend difficile un contrôle efficace de la pollution en utilisant n'importe quel instrument. Plutôt que de compter sur l'atteinte des meilleures solutions en utilisant les instruments économiques, les façons les plus efficaces de s'occuper des problèmes de sources de pollution diffuses dans l'agriculture sont peut-être les développements technologiques et les initiatives des entreprises.

Economic instruments can achieve environmental goals at least cost and provide incentives for further improvements. There are limited opportunities for the use of such instruments in agriculture where the pollution problems can be traced as in the case of intensive livestock operations. However, most environmental problems in agriculture involve a large number of diffuse pollution sources whose abatement practices are unobservable rendering it difficult to achieve cost-effective pollution control with any single instrument. Rather than relying on first-best solutions through economic instruments, the most effective way of dealing with diffuse-source pollution problems in agriculture may be technological developments and business-led initiatives.

Background

Integrating environmental and economic objectives is a necessary requirement to develop policies promoting sustainable development. Environmental sustainability was made one of the four pillars in the 1989 reform of Canadian agriculture policy. More recently, Ralph Goodale, the former Canadian minister of agriculture, announced that "future [federal agricultural] programming must foster sound management of the resource base and target any negative impacts of the agri-food industry on surrounding ecosystems, such as soil and water quality and wildlife." Explicit recognition of environmental health as a criterion in the evaluation of agricultural support programs is an acknowledgment that agricultural practices can detrimentally affect resources. The concerns over soil and water quality, the consequences of climate change, and the loss of wildlife habitat are likely to grow with increasing resource scarcity (Miranowski and Carlson 1993). Strategies to ensure an agricultural system that is both economically and environmentally healthy will require the integration of these two dimensions of policy.

Moral suasion has been used more extensively than other options in the agro-environmental policies of Canada and other countries of the Organisation for Economic and Cultural Development (OECD) as the means of promoting environmental quality objectives deemed to be associated with a sustainable agricultural system. The objective of such programs is to increase the farm sector's awareness of the contribution of their current practices to environmental problems and of best management practices to reduce those problems. Despite being supplemented with technical and financial assistance, this voluntary approach has had limited success and led to the interest in alternative environmental policy instruments (Harrington, Krupnick and Peskin 1985; Phipps 1991), in particular, the use of economic instruments. The Joint Working Group of Agricultural and Environment Experts of the OECD reached a consensus in its inaugural September 1993 meeting that economic instruments should be assessed in terms of their effectiveness to encourage sound environmental practices. Interest has been increased further as a result of the fiscal constraints faced by many countries and the new international trading rules under the GATT. Both developments are leading to a restructuring of safety net programs including the incorporation of incentives to achieve environmental objectives. In Canada, economic instruments have not only been promoted as a means to promote sustainable development within agriculture but also for other sectors as explicitly noted in *A Guide to Green Government* (1995).

In this paper we examine the potential for applying economic instruments to address environmental problems in Canadian agriculture. We begin by discussing how agricultural production can affect the environment. Environmental policy options to mitigate these effects are presented along with criteria to assess their effectiveness. The general inability to determine cause and effect from pollution damage due to farming and the uncertainty and complexity of that process complicates the design of any environmental policy in agriculture. The major part of the paper examines how effective individual economic instruments would be to achieve environmental health objectives in agriculture given the pervasive nature of the problem. We then propose a mixture of instrument schemes and give suggestions for environmental policy design.

Agriculture and the Environment

Producing agricultural goods unavoidably generates residuals and by-products categorized into soil sediments, nutrients, pesticides, mineral salts, heavy metals, and disease organisms (Libby and Boggess 1990). Residual levels depend not only on physical characteristics, such as soil type and weather, but also on the farm management practices employed. For example, vegetative cover and tillage practice chosen as part of a cropping system can modify soil erosion levels while the amount, timing, form and placement of organic (livestock manure) or inorganic fertilizer can influence nutrient deposition. Unfortunately, there is not a direct correlation between farm management practices and the levels of all residuals together. Reducing tillage creates a rougher soil surface that inhibits water flow and thus soil erosion but it also slows the nitrification process and enhances water infiltration which combine to increase the amount of nitrate leaching into the groundwater (Bedient and Huber 1992). Even for a given pollutant, production practices affect technology trade-offs such as that between application rate and persistency of alternative pesticides (Archer and Shogren 1994).

Detrimental impacts on species diversity, habitat, landscape, and the quality of air and water from agricultural pollutants can occur either on or off the farm site. On-farm effects are usually associated with a reduction in farm productivity and a subsequent increase in production costs. Off-farm damages tend to be much larger and are borne by other users of the affected resources (Braden and Lovejoy 1990). Examples of off-farm impacts include sedimentation from soil erosion that damages aquatic organisms, reduces water-based recreational activities, limits navigation, and increases cost of water treatment; eutrophication of a water body from excessive nutrient levels that decreases biodiversity, reduces productivity of fisheries, increases cost of water supply, and decreases aesthetic values; contamination can be associated with any of the pollutants and may result in acute or chronic health damages to both the environment and humans.

The impacts associated with agricultural production and the change in practices required to mitigate those damage impacts varies by location. In Ontario, agriculture is the major contributor of nutrients to the waters of the Great Lake Basin (Great Lakes Water Quality Board 1989). The eutrophication of Lake Erie in the 1970s was due largely to phosphorus attached to eroded soil particles (Environment Canada 1987). However, the adoption of less erosive farming practices encouraged in part by a variety of government programs (Stonehouse and Bohl 1990) has reduced phosphorus runoff into surface waters and now the major environmental problem associated with agriculture is nitrate contamination of groundwater in rural areas. Over 14 percent of domestic farm wells tested had nitrate concentrations above the Ontario drinking water quality objective (Rudolph *et al*. 1992). In the Prairies, the major environmental issue during the 1970s was also soil erosion but the damages tended to be on-farm and the result of wind in contrast to the off-farm effects of soil loss from water runoff in Eastern Canada. Now the environmental concerns from Prairie agriculture arise from the loss of wildlife habitat as evidenced by the initiation of programs and policies such as the federal National Wildlife Strategy.

Determining whether the residuals generated by agricultural production are excessive requires comparing the benefits and costs of reduced levels. However, the concern over issues such as deteriorating water and air quality related to agricultural production suggests that the levels of pollutants generated are greater than the socially optimal level. The reason for the excessive levels is that farms are not required to pay the full social costs of the pollution they generate. Since there are no prices for the environmental and human health costs, farmers have an incentive to ignore them when making their decisions on management practices. Ignoring external damage costs leads farmers to select management practices that produce greater than socially optimal levels of residual pollutants. Residuals from agricultural production can thus be considered a negative externality since there is a divergence between private cost and social cost of the pollution created and as a result, the residual pollutants are greater than the optimal level. In addition to the externalities, the levels of pollutants could also be the result of farmers being unaware of the adverse environmental impacts of their practices or the result of input use designed to reduce the variability of returns.

Environmental Instrument Design Issues

Policy Options

Implementing an economically optimal level of pollution is often not a policy option due to the difficulty of assessing the benefits from reductions in pollution residuals. Instead, it is common for policymakers to set environmental objectives and standards. (For example, the drinking water quality standard for nitrates is currently set at 10 parts per million.) Attention then shifts to assessing alternative methods or instruments to achieve the objective.

Instruments for achieving environmental goals can be classified into command and control or incentive-based mechanisms. Command and control has dominated environmental policy in most countries — regulators direct polluters to adhere to restrictions on either the level of pollution, the type of activities that may be practised, or the type of technologies that may be used. In contrast, incentive mechanisms indirectly influence firms' actions by providing financial incentives for pollution reduction. Incentive-based approaches, also called economic instruments, are categorized in this paper as charges or subsidies, tradable permits, and decentralized policies.

Assessment and Design Criteria

A number of criteria can be used to assess and compare alternative policy instruments for pollution control. For example, ecological effectiveness, cost-effectiveness, incentives created for innovation, administrative costs, monitoring and enforcement costs, and consistency with other government policies. Economic instruments such as pollution taxes or tradable permits are now widely regarded by economists as being superior to command-and-control instruments on the basis of these criteria in most cases of pollution control (OECD 1989*a*).[1] In particular, simple economic reasoning suggests that economic instruments are a more cost-effective method of control than command-and-control instruments because they encourage firms with the lowest costs of pollution control to do the greatest amount of control. As a result, economic instruments can achieve a given environmental objective at the lowest possible aggregate cost. At the same time, they encourage innovation in control technologies by financially rewarding the most innovative firms. One can also argue that administrative costs may be lower with the use of economic instruments because setting command-and-control standards often requires policymakers to make choices about appropriate and cost-effective abatement technology options for individual firms. Economic instruments let the individual firms decide upon their least-cost method of abatement. Since individual firms likely have better information about what technology options are appropriate and cost effective in their own cases, information costs to the regulator in implementation may be lower with economic instruments. Finally, the costs of monitoring and enforcing economic instruments are not likely to be higher than for command-and-control policies in the case of point sources of pollution. As we explain below, however, these costs are likely to be prohibitively high in the case of non-point sources of pollution such as agriculture.

Complications in Policy Design with Agriculture

The difficulty in designing effective environmental policy for the agricultural sector, either with economic instruments or other options, is that pollution emissions tend to be from diffuse sources. Rather than coming from specific *point sources* which makes measurement of emissions relatively easy, at least in principle, agricultural pollution primarily is associated with water runoff, seepage, and soil erosion. With *non-point* or *diffuse* source pollution, it is difficult to trace the exact origins of pollutants which thereby rules out the feasibility of using certain policy options on the level of emissions. In addition, any environmental problems must be addressed by preventing the generation of the residuals at their source rather than attempting to control the delivery of the pollutant between its source and final delivery as can be considered with point-source pollution problems.

Diffuse pollution sources could be traced with an increase in monitoring costs. However, two factors compound the informational requirements necessary to do so in agriculture. First, many farms contribute to the pollution levels making it difficult to separate damages across firms and subsequently assign liability. Costs of obtaining information about each farm's potential contribution to damages increase with the number of farms. The large number of farms contributing to the problem also decreases the possibility of farms cooperating to reduce pollution levels and the likelihood that an individual firm, whose contributions are small relative to the total, will ignore the impacts of its practices on resource quality (Tomasi, Segerson and Braden 1994).

Second, the costs of monitoring agriculture are high because of the complexity of the production and environmental fate process, which make it difficult to directly infer emissions from observable inputs (Braden and Segerson 1993). While technology is developing which will reduce the costs of monitoring certain practices on individual farms, such as conservation tillage, emission levels not only depend on potentially observable inputs such as type of tillage but also on unobservable ones such as the timing of tillage and the care with which it is practiced. Observing such inputs would require continual monitoring that is impractical for agriculture given the large number of farms.

Another complication in the development of environmental policies for agriculture is spatial, temporal, and technological heterogeneity. The impacts of a farm's actions on the environment depend on its location. For example, a farm with a low level of sediment loss but located next to a water body may be imposing greater environmental damages than a farm with a high erosion level located further from the water body. When this occurs, cost-effectiveness requires policy instruments to be targeted to individual farms. There is also a time separation between activities and damages. For example, it may take years before excessive nutrient applications result in a deterioration in groundwater quality. In addition, technological differences among farms alters the level of all outputs produced including pollutants and the marginal abatement costs of attempting to reduce residuals.

Not only is the relationship between agricultural production activities and environmental quality generally complex and multi-faceted, exact relationships are not known with certainty. Thus, the use of simulation models that represent such relationships cannot likely be used as a legal means to proxy damages from individual farms. In addition, these relationships are subject to a number of stochastic influences outside the farmer's control. For example, pesticide, nutrient, and sediment loadings generally increase with the intensity of a rain storm at inopportune times.[2]

The type of environmental policy action required in any sector is influenced by the marginal costs and benefits of reducing pollutant levels. In agriculture, abatement costs tend to increase rapidly as there are few pollution control technologies that can be easily identified, purchased, and installed on farms (Braden and Lovejoy 1990). With no simple devices to collect emissions, environmental damages are reduced through systematic changes in farming practices such as tillage and crop choice.[3] Some of the changes, however, may be identified through nutrient management plans at relatively low cost. The benefits to altering production practices include reducing water treatment costs, promoting wildlife habitat, enhancing ecosystem diversity, and increasing the quality of recreational sites. These benefits do not prompt the call for action as would a dramatic, health-threatening problem, such as a toxic spill (Ibid.). In addition, there is a great deal of uncertainty as to their value. The inability to assess the costs of the environmental damages stemming from agriculture makes it difficult to determine the level of abatement effort necessary and the potential acceptability of the instruments attempting to achieve that effort.

Political acceptability of any environmental policy in agriculture is also influenced by the composition of the polluters. Environmental problems arising from agricultural production are caused by a large number of farms, the majority of which are family-owned operations that have traditionally been supported by government. Given the general perceived need to continue to support these farms and the influence of the farm sector to garner such support, any potential policy instrument will need to consider such political realities.

Economic Instruments to Achieve Environmental Objectives in Agriculture

Whether economic instruments can be used to alter farm management practices and, consequently, pollutants in a cost-effective manner depends largely on the ability of the regulator to monitor and enforce the choices made by producers. This ability is limited but the degree to which it can be done, and consequently the effectiveness of economic instruments, depends upon the type of residual and a number of site-specific characteristics. In this section, the ability of alternative economic instruments to achieve environmental objectives will be evaluated in terms of the criteria and design complications presented earlier. We examine three categories of instruments: (i) charges and subsidies on emissions, ambient concentration, and farm management choices; (ii) tradable permits; and (iii) decentralized policies such as liability rules, performance bonds, and property rights definition. Conditions under which each economic instrument is likely to be successful in effectively achieving environmental objectives are summarized in Table 1.

Table 1
Conditions for Economic Instruments to be Effective

Type of Instrument	*Base or Form of Application*	*Conditions*
Charges and Subsidies	Emissions	- accurate relationship between estimated emissions and readily observable inputs and site characteristics - data
	Ambient Concentration	- readily monitored resource quality affected by a relatively homogeneous group of producers within a small area - short time lag between emissions and environmental effects
	Design-Based	- ability to discriminate charge/subsidy for polluting farms in affected region on inputs outputs that have a direct relationship with pollution levels
Tradable Permits	Inputs	- clearly-defined, homogeneous input related to environmental problem - sufficient polluters to establish market
Decentralized Policies	Liability Rules	- infrequent polluting events with clear cause and effect link involving a few parties
	Non-Compliance Fees	- homogenous group of polluters with understood links between behaviour and environmental damages - fees related to damage and communicated to polluters *ex ante*
	Performance Bond	- actions of the few polluters are observable and have clearly understood damage effects and values - relatively small bond value
	Property Rights Definition	- privately-owned resource where institutional restrictions have prevented markets for environmental amenities from developing

Charges and Subsidies

Emission Charges

Emission charges are fees levied on the discharge of pollutants into air or water or onto the soil, or fees levied on the generation of noise. Such charges reduce the level of residuals by making the polluter pay for at least some of the damages caused by their pollution. Emission charges can minimize the social costs of achieving environmental protection goals by inducing firms to reduce their emissions to the point that their marginal cost of control equals the tax. Marginal abatement costs differ between firms and thus so will the least-cost control strategy that each firm adopts in response to the emission tax.

Measurement of individual emissions at reasonable costs is a precondition for the use of emission-based policies which is not met for most agricultural residuals that travel by diffuse and indirect pathways over a potentially long period to the receiving resource. Since the non-point nature of most agricultural residuals means that economic incentives cannot be applied to actual emission levels, an alternative is to apply them to estimates of the residual flows (Shortle and Dunn 1986; Dosi and Moretto 1993; Shortle and Abler 1994). Emission estimates can be generated through physical simulation models that express changes in resource quality as a function of management practices and location-specific environmental attributes. However, current models cannot provide accurate estimates of the complex fate and transport of most agricultural pollutants and accurate proxies are necessary if this indirect approach is to withstand legal challenge and gain political legitimacy. Even if the estimates were accurate, the costs of regularly applying these complex models, particularly in terms of data collection, might be so large as to outweigh any gains.

Another issue with indirect emission measures is their political acceptability. Soil properties and tillage practices can be identified for a number of locations using Geographic Information Systems (GIS), but political pressures would likely prevent the government from using such information on individual resource settings to establish tax levels (Chambers 1992). As a result, charges on either actual or estimated emissions are unlikely to be a useful tool of environmental policy in agriculture. An exception is in the Netherlands where a levy will be assessed on surplus phosphate from manure in conjunction with other policies such as individual farm quotas on livestock population. The indirect estimates are based on a nutrient accounting system as described in Breembroek *et al.* (1996). Implementation of the approach is possible because of the direct relationship between livestock numbers and manure levels that counters some of the accuracy concerns. In addition, the extent of the manure surplus allows such a measure to overcome the cost and political resistance of measures to deal with the problem.

Ambient Charges and Subsidies

Given the problems with obtaining information on fate and transport of agricultural residuals that prevent the use of incentives based on emission levels, an alternative is to base the tax or subsidy on the environmental quality of the resource receiving the pollutant, such as a water body.[4] Following Holmstrom's (1982) work on incentive structures for labour, Segerson (1988) proposed a system for non-point source pollution that rewards farmers for environmental quality above a given standard and penalizes them for substandard levels of the ambient residual concentration. Since individual emissions are unobservable, the compensation or liability for each polluter depends upon the aggregate emissions from the entire group of polluters affecting the water body. When faced with such a program, farmers have the incentive to reduce residual levels to lower their tax liability if the ambient concentration of the pollutant exceeds the standard or increase their subsidy payment if the concentration is less than the standard.

The major advantage of the incentive scheme on ambient concentration is that it is directly correlated with the environmental health of the resource concerned and it does not require continual monitoring of emissions. Cabe and Herriges (1992), however, point out several drawbacks. The most significant problem is the need to determine both the correlation between an individual farmer's management practices and the ambient concentrations on which the farmer is taxed or subsidized and the farmer's beliefs about that transport system. With many agricultural residuals, the correlation between practices and ambient concentrations is low because of the large number of contributors to the pollution problem and the long lag time between the polluting activity and the delivery of pollutants to the monitoring station. Consequently, if abatement activities are costly, then they are unlikely to be adopted by producers until the charge is raised high enough that it may ultimately force them to shut down. However, the ambient charge may be the appropriate stick to force the adoption of less costly measures such as nutrient management plans. The limitations suggest the ambient charge/subsidy is best suited to environmental problems in small watersheds with relatively homogeneous farms solely contributing to the problem, readily monitored water quality, and relatively short lags between polluting activities and pollutant delivery. This instrument is not used in any location at the present time.

Design Charges and Subsidies

Environmental policies in agriculture have tended to use design-based instruments to influence production decisions and thus environmental quality due to the information problems associated with theoretically first-best schemes such as emission and ambient charges. Griffin and Bromley (1982) and Shortle and Dunn (1986) have demonstrated theoretically that complex systems of design-based incentives can be used to achieve efficient control of non-point pollution.[5] The ideal incentive structure would have an incentive attached to each choice a farmer can make, involve a mix of subsidies and taxes, and be farm specific. While information, administration and enforcement costs limit the practicality of such a complex system, less sophisticated design-based instruments assigned to a few easily observed choices have been applied extensively.

Inputs

Taxes have been levied in a number of European countries and in several American states on farm inputs, particularly fertilizer and pesticides. Such taxes can have a number of desirable effects on the associated pollutants and are administratively efficient because they can be incorporated into existing tax systems. For example, in the case of nitrogen fertilizer, a tax will encourage more conservative application and cause a shift in cropping patterns away from relatively nitrogen-intensive crops and toward nitrogen-fixing crops such as soybeans and alfalfa. However, the charges actually levied on farm inputs appear designed primarily to generate revenue for other environmental programs rather than to alter producer behaviour.

The effectiveness of input charges on reducing input use depends on the magnitude of the tax, the breadth of the tax base (national vs. local), the proportion of total production costs made up by the input, and the price responsiveness of crop demands and input use. The inelasticity of farm input demand implies the tax rates must be high to cause the desired reduction in input use, so high that they are not likely politically feasible (Burrell 1989; Helfand and House 1995). Even if input use were responsive to taxes, three additional problems remain. First, because the environmental impact of input use can be very different for different farms depending on factors such as location, soil type and rainfall, the input tax should in principle vary with location and application method (Zilberman, Khanna and Lipper 1997). Yet, discriminatory taxation is unconstitutional in many countries and is easily avoided even if it were introduced. Second, although an input tax may reduce input use, it does not encourage any other (possibly lower-cost) abatement actions such as crop choice and tillage practice; therefore, it cannot lead to the cost-effective attainment of pollution targets. Third, the substitution of inputs induced by the input charge may change the environmental problem instead of correcting it.

Rather than levy a charge on an input associated with the polluting residual, an alternative often used in conjunction with tax programs is to offer financial incentives encouraging the adoption of inputs or a set of practices that have a more benign effect on the environment. Financial assistance normally takes the form of grants, loans, and tax allowances. These subsidies are advocated as a means of easing the financial burden to individual producers and thus increasing the probability of adopting measures for which the social benefits are greater than private abatement costs (OECD 1989*b*). Canadian applications of such assistance are generally focused on reducing soil erosion. Examples include the two Land Stewardship Programs in Ontario that reduced the cost of conservation tillage practices and the Permanent Cover Program that provided Prairie farmers grants to take marginal land out of intensive crop production (Stonehouse and Bohl 1990). Grants are also available, however, for the construction of storage facilities for both pesticides and manure.

Input subsidies have many of the same shortcomings as do input charges. While taxes are often politically infeasible due to the generally high rates required to induce changes in behaviour, subsidies are popular with the benefiting farm community but incompatible with debt reduction which is a major goal of most governments. Thus, the financial assistance programs that are available tend to be lump-sum in nature and funded by environmental charges rather than from general tax revenue. The major limitation of these programs is their universal availability and the resulting cost ineffectiveness. Farmers with the greatest contribution to the pollution problem may not apply to a cost-sharing program if they cannot manage the practice or if the financial incentive is insufficient. On the other hand, funding may be granted to polluting firms even though they would have adopted the abatement regardless or to non-polluting firms because the subsidy makes the practice profitable for them. The cost effectiveness of financial assistance programs can be improved significantly if the funds are targeted to areas, such as a watershed, where expected social benefits are greatest. While discriminatory input taxes are infeasible, targeting input subsidies are possible and could be based on a region's effective demand for environmental quality. However, questions such as who pays for the subsidies and the long-term resource allocation effects from distorted prices still remain even with targeted input charges.

Outputs

Rather than tax or subsidize the use of a particular input, an alternative is to assess the financial instrument against the output produced. For example, "green payments" could be given to producers of environmentally benign crops such as alfalfa. However, such incentives are uncommon and suffer from the same limitations as input-based charges or subsidies. Output subsidies that are presently provided as a means of farm income support tend to exacerbate the problems. For example, Canadian agricultural stabilization programs such as GRIP have been geared largely to non-forage, and thus more erosive, crops. The recently removed rail transport subsidy (under the Western Grain Transportation Act) was estimated to have created the incentives to cultivate 1 to 2 million hectares of land in Western Canada that otherwise would have provided wildlife habitat (Gray, Burden and Conacher 1994).[6] Thus, reducing the level of support, rather than altering price levels further, would provide incentives for more environmentally benign output choices.

Cross compliance is a term that refers to a program that ties eligibility for agricultural support to meeting a specific environmental criterion. It has not been used in Canada but has generated interest here since the enactment of the 1985 US Farm Bill and its sodbuster, conservation compliance, and swampbuster provisions. Environmental and economic effectiveness of cross compliance again depends upon whether it is the farmers contributing to the environmental problem that are eligible and participate in the program. An additional problem is the tendency for farmers to opt out of the program and reduce abatement efforts during periods of high commodity prices when program benefits become less attractive.[7]

Tradable Permits

Tradable permits involve establishing marketable property rights for discharging pollutants into the environment. Individual pollution permits define the allowable amount that a firm is able to discharge and the sum of all permits is equal to the total level of emissions permissible within an area. The permits are tradable. Firms that exceed their permit limits are subject to non-compliance fines and so may wish to acquire permits from another firm. Conversely, a firm that finds emission control cheap might find selling its permits and reducing its emissions more profitable than keeping its permits and polluting. Provided the total emission levels are set low enough, permits become valuable and incentives are created for trading them among firms (Dales 1968; Hahn 1989). Competitive trading will lead to a cost-effective allocation of pollution control among firms, but aggregate emissions would not be affected by the trades.

The use of tradable permits to control pollution is limited to the United States (OECD, 1989*a*). The most recent program is one designed to reduce sulphur dioxide emissions from thermal power plants. Earlier programs were introduced to facilitate the phasing out of lead from gasoline, to control water pollution in the Fox River in Wisconsin, and to control a variety of air pollutants nationally.

The main feature of a tradable permit policy is that its shifts decisions about design and location of pollution control equipment from the regulator to the firm. Choosing a tax rate on emissions or inputs requires full information on how polluters will respond to the charges which is not likely even known by the polluters themselves in the short run. Moreover, the rate structures will have to be continually revised with changes in economic conditions. With tradable permits, the government sets the environmental goal directly when it determines total permissible pollution and lets the permit market determine the price to acquire them. Another appeal of permits is the opportunity they provide to adjust the initial allocation and subsequent control of supply to satisfy equity and political concerns. Unit costs of abatement in emission levels have been reduced through tradable emission permits in the American experience but the system has proved cumbersome. Frequent quarrels over baseline emission levels, the need for government approval at all stages of policy formulation, and the lengthy process of exchanging proposals between firms have contributed to high administrative costs of the emission trading system for both firms and regulators (Cropper and Oates 1992).

The diffuse nature of agricultural pollution makes the use of conventional tradable permits infeasible. However, two modified systems have been proposed. The first is a tradable permit system on polluting inputs. Such a system would reduce aggregate input use and would enable inputs to move to farms on which their use is most highly valued. A second marketable permit system potentially applicable to agriculture is a point/non-point source trading scheme in which the regulator establishes an aggregate level of environmental quality for a region and allows both discharge sources to determine the cost-effective combination of abatement strategies to meet the standard (Letson, 1992). Point sources could acquire permits to pollute from non-point sources who are assumed to have lower abatement costs. A major weakness with this proposal is the difficulty in defining the units of trade between point and non-point sources of pollution because of the problems in measuring emissions from non-point sources. However, there are successful cases of point-non-point trading including the several informal trading arrangements between water treatment facilities and farmers affecting the water quality. An example of such an arrangement are the payments being made by the Regional Municipality of Waterloo to farmers in the Grand River Watershed who change practices to reduce phosphate loadings. The cost to the municipality for treating the water is subsequently reduced.

Decentralized Policies

Decentralized policies are ones that allow individuals to resolve environmental problems through negotiation or through the legal system. Included in this category are liability rules, non-compliance fees, performance bonds, and property rights definition.

Liability Rules

Liability laws make polluters liable for the damages they cause. Under strict liability, a farm would be held liable for any damages resulting from its production behaviour regardless of the care taken to avoid that harm. Under negligence rules, farms are only liable if appropriate actions were not taken to prevent the damage. The advantages of either liability rule are that the affected individuals are compensated and that the expectation of paying damages motivates a modification in producer behaviour. Provided firms have accurate expectations of the costs and that the costs correspond to actual damage costs, liability rules are efficient means to obtain the socially desired farm management practices.

Liability rules, however, are only suited for certain situations where polluting events are infrequent, there are only a few parties involved, and the cause and effect links are well understood. Under such conditions, the polluter can be identified and the generated pollution shown to be the cause of the damage. Costs of reaching and enforcing agreements are also minimized. These conditions are only met for a limited number of localized situations in agriculture such as accidental spillage, overflows or leakages of animal manures, pesticides or petroleum products. Since most environmental problems in agriculture are more pervasive, liability rules can be used only as a complimentary mechanism with other instruments.

Non-compliance Fees

A random fine mechanism has been proposed by Xepapadeas (1991) to deal with the difficulty of assigning individual liability in environmental problems. The approach involves randomly selecting and fining at least one polluter if the ambient concentration of the pollutant at the concerned resource is above a targeted standard. Only information about the pollutant at the receptor site is required rather than emission levels of each polluter. In addition to the reduced data needs, the mechanism is also budget balancing. This approach is unlikely to be politically acceptable, however, given the separation between behaviour and penalty.

A variation of the random fine approach is a nonpoint tournament suggested by Govindasamy, Herriges and Shogren (1994). Producers are ordinally ranked based on their pollution abatement effort. Depending on the ambient concentration of the pollutant, penalties or rewards are assessed based on a relative abatement effort ranking. Although information needs are less than if a cardinal ranking were established, the tournament system may punish or reward the wrong producers because of the uncertain link between management practices and environmental quality. In addition, the administrative efficiency of non-compliance fee schemes is low because of the high proportion of cases that must be settled in court (Perrings 1989).

Performance Bonds

Rather than pay a fee after environmental damages have incurred, an alternative mechanism is to require potential polluters to post a bond prior to production which would be forfeited if pollution control is inadequate. The bond increases the cost of environmental shirking and thereby reduces the incentive for malfeasance. Perrings (1989) identifies several benefits of environmental performance bonds. Cost of potential environmental damages by the pollutant are explicitly registered when the bond is posted. Thus, firms become aware of the effects of their actions and will increase their abatement effort provided the value of the bond is set high enough. The value becomes open to public scrutiny and serves as a benchmark for guiding the environmental costs of future innovative activities. In contrast to liability rules and non-compliance fees where the regulator must show the producer's action resulted in damage, this mechanism requires the producer to prove that no environmental effects occurred. The interest earned on the bonds could also be used to fund other environmental programs.

Performance bonds have not been used for environmental management with the exception of clearcut environmental damage cases such as surface mining. Shogren, Herriges, and Govindasamy (1993) identify seven conditions under which bonds may work for environmental problems: (i) well-understood costs of environmental damages, (ii) observable producer actions, (iii) few agents to administer, (iv) fixed time horizon for remittance issues, (v) well-defined states of nature and their likelihood of occurrence, (vi) no irreversible effects, and (vii) a relatively small bond value. Agricultural non-point source pollution does not satisfy most of these conditions. The long-term health costs are still being debated; the actions of the producers are not observable; there are numerous agents to monitor; the time horizon associated with impacts on the ecosystem are ambiguous; many states of nature can affect damages, the question of irreversibility is still open; and severe liquidity constraints would be imposed given the financial situation of many farmers. Consequently, while performance bonds could be used in the transportation of manure or pesticides, they are an unlikely policy instrument for achieving most environmental health objectives in agriculture.

Property Rights

The instruments discussed thus far all attempt to internalize negative externalities caused by poorly defined property rights over the use of a resource. Coase (1960) argued that provided property rights are well-defined and transaction costs are low, the efficient level of pollutant can be arrived at through bargaining between the owner of an environmental asset and prospective users irrespective of who has the initial property rights. Such efficiency cannot be attained for most environmental problems related to agriculture due to the public-good nature of the affected resources. However, inadequate property rights on agricultural land use in some situations has prevented markets from developing for environmental amenities associated with natural ecosystems such as the provision of wildlife habitat.

In the case of wildlife habitat on private land, property rights on the privately owned land and publicly owned wildlife are interrelated. Wildlife on private land are Crown property and so the land owner is strictly prohibited from selling hunting access to game on the land under current law. Without the ability to capture the benefits associated with providing wildlife habitat, private landowners cultivate more wooded areas and wetlands than socially desired. For example, changes in hunting regulations inadvertently destroyed private markets in Wisconsin for recreational access that in turn had provided landowners with incentives to tolerate high levels of damage to croplands by Canada geese (Rollins and Briggs 1996).

Changing institutional parameters that more precisely define property rights can allow markets to emerge for environmental amenities from private agricultural land. An example is the United Kingdom's *Wildlife and Countryside Act* of 1981 that compensates farmers for lost income opportunities incurred by preserving their land for wildlife habitat (Bromley 1991). A variation would allow landowners to sell conservation easements against the title of the land in return for restricting land use to practices that would preserve habitat. Property rights could also be partially established for wildlife attributes by allowing farmers to lease hunting access on their land, thereby capturing some of the benefits from consumptive users of wildlife resources. Presently farmers bear the costs of wildlife damage with no access to the benefits of avoiding damage. Those costs to Prairie farmers are larger than the annual compensation payments of approximately $9 million, and farmers are reluctant to participate in programs to increase the amount of wildlife habitat without institutional changes (Canadian Federation of Agriculture 1994).

Mixed System of Instruments

No single economic instrument from among the three major categories of options emerges as the ideal choice for reducing pollutants from agricultural production. Each are appropriate under certain circumstances as summarized in Table 1 but none by itself adequately addresses the informational and uncertainty problems associated with diffuse-source pollution prevalent in agriculture. For such problems, the costs of monitoring and enforcing a given policy are generally inversely related to its effectiveness in meeting the environmental target at minimum total abatement costs. Performance-based instruments such as emission and ambient charges are targeted directly at environmental quality but suffer from measurement problems, while design-based instruments such as input taxes can be implemented more easily but suffer from the indirect relationship between the chosen design base and environmental damage.

Since an economic instrument is unlikely to be strictly preferred over all policy options over all conditions, the optimal strategy for any given situation will likely involve a mix of instruments. Economic instruments could be used in conjunction with the two other major environmental policy choices, moral suasion and direct regulation, or with other economic instruments. An actual example of each mixture is presented below.[8] Finally, technological developments are examined which may increase the feasibility of some instruments by lowering monitoring costs and which may also reduce the need for policy by reducing the level of inputs applied and thus the residuals generated.

Moral Suasion with an Economic Instrument

The most common instrument used by Canadian governments to address environmental problems in agriculture is the provision of information on environmentally benign farm management practices. For example, a series of eight booklets on best management practices for Ontario has been developed by federal and provincial ministries of agriculture under the Sustainable Agriculture Green Plan Initiatives. The intent is to encourage the use of such practices by making farmers aware of the environmental consequences of their actions and promoting the benefits of these alternatives. Compliance is voluntary.

An increasingly popular mechanism that combines moral suasion with financial incentives is Ontario's Environmental Farm Plan (EFP) initiated in the early 1990s through the efforts of a coalition of farm organizations. EFP is a series of self-assessment modules focusing on the farmstead, farming practices, and the environment farmers can use to evaluate the environmental risk management needs of their own operation. Technical support is provided to develop site-specific, voluntary action plans if risks are identified and a financial incentive of $1,500 provided for completion of the EFP. To date over 10,000 Ontario farmers have participated in the EFP program and invested more than $2.5 million and 12,000 hours of labour implementing improvements to reduce environmental risks.[9] The program has now spread nationally and similar environmental farm planning efforts are being initiated in other countries such as Farm*A*Syst which is now in place in 27 states in the US.

Despite the increasing popularity of these voluntary compliance programs, their effectiveness is uncertain. Environmental farm plans must recognize that the impact of a given practice on the ecosystem will vary depending upon farm location despite the tendency to assume a homogeneous cause and effect. Even if the appropriate site-specific practices are prescribed, there is no guarantee that the efforts will be implemented to the appropriate level. Adoption is voluntary and unlikely if the practices are costly unless there is cost sharing. Thus, the burden of the program falls on those who feel a greater sense of moral responsibility and not necessarily on those contributing to the environmental problems.

Direct Regulation with an Economic Instrument

Economic instruments could also be used in conjunction with standards on practices or performance. An example of a direct regulation in agriculture is the prohibition of certain toxic pesticides such as DDT which has been combined with subsidies for the construction of pesticide storage facilities and for the offering of pesticide application courses to producers. Regulations are particularly appropriate for residuals where the acceptable level of tolerance is very low, as it is with toxic chemicals. Although not as cost-effective as economic instruments when uniformly applied and although they lack the incentives for additional pollution control, standards may be the most practical way to deal with certain pollution problems in environmentally sensitive regions. Practices such as cultivation distance from watercourses or prevention of livestock access to watercourses could be readily monitored for farms in regions with sediment or bacterial loading problems. The acceptability of the regulations imposed on the selected farms could be improved through financial assistance programs such as grants or low-cost loans.

Actual regulations or the threat of regulations on pollutant levels are the stick often necessary before firms consider the carrots provided from new technologies directly or from government incentives to encourage the adoption of those technologies (Batie 1997). Not only may direct regulations be required to enhance the uptake of economic instruments, the policy combination can spur innovation and make firms more competitive. "Green competitiveness" can occur through cost savings from recapturing and re-using inputs and through the development of new products from wastes (Porter and van der Linde 1995). An example of technological innovations induced by environmental regulatory pressures within the agricultural sector are Dutch flower producers. Forced to reduce fertilizer and pesticide contamination of groundwater, these producers developed a closed loop system for growing flowers in water and rock wool which reduced input levels, lowered the risk of disease, and narrowed the variation in growing conditions (Ibid.). Both environmental health and the competitive position of the firm improved.

Regulations could also be used as a means to establish markets that send appropriate signals to producers about society's desired management practices. An example is the development of markets for pesticide-free produce. Consumer preferences for such products will be reflected in a price differential between organic produce and conventionally grown products. If the price premium is high enough, farmers will adjust their production techniques to reduce the levels of pesticides and consequently the associated health risks. The process of internalizing some of the non-market benefits from lower pesticide use involves regulations necessary for the establishment of any market, the ability to define the good and its property rights, and to ensure exchanges of those rights are enforced. However, the certification process of organic produce in Canada is hindered by the existence of 43 certifying bodies, each with different standards, which fractures the industry's resources and confuses consumers. Establishing the institutional framework necessary for markets to function for environmental amenities such as organic produce is one role for direct regulations in conjunction with economic incentives.

Direct regulations could also be used to establish standard codes of practice. Firms may have the incentive either through consumer demand and/or existing or anticipated legislation to become signatories to these codes. An example of a voluntary private code is ISO 14000 which is a series of guidelines and standards for quality management directed at the environmental impacts an organization has in the course of doing business. The ISO 14000 series of standards is not based on specific performance standards but instead requires an organization to establish its own environmental management system. Adherence to the practices established by a firm under its management system is verified by an external audit. Compliance with environmental farm plans mentioned in the previous section could serve to establish certification and thereby provide farmers with the appropriate incentives to adjust their practices. However, the conditions are unknown under which agricultural producers would be able to obtain market premiums or reduce input costs sufficient to offset compliance and auditing costs of a voluntary private code such as ISO 14000.

Mixture of Economic Instruments

Sweden's proposed 50 percent pesticide reduction plan involves a mixture of economic instruments: input charges, marketable permits on pesticide use, and subsidies for cost sharing.[10] The first step in the mixed scheme is the establishment of a critical health risk threshold for each pesticide based on its application rate, persistence, mobility, and toxicity to non-target species. For pesticides falling under the threshold (A-risk), a tax indexed by risk and inflation are imposed to curtail its use. The tax provides predictability in pollution-control costs to the producer while permitting some flexibility in use level. The regulator is willing to accept some variability in the ambient concentration level since health risks of A-risk pesticides are relatively low.

For pesticides exceeding the threshold (B-risk), a marketable permit system is proposed to ration their use. The acceptable level of fixed risk within a region establishes the permit total. The marketable permit system allows control over the use of B-risk pesticides and lets the market determine permit prices which will adjust to economic and technological conditions. It also prevents the shift from higher-dose pesticides to lower-dose but more persistent ones that can be part of a producer's pest control substitution opportunities between self-protection and self-insurance. Thus, in contrast to the charges for A-risk pesticides, the permit system for the higher risk pesticides is less flexible in use but more flexible in price (see Weitzman 1974).

The final economic instruments in the Swedish scheme are subsidies to aid producers in the transition to pest control strategies that use pesticides with lower application rates, persistence, mobility, and non-target toxicity. Given the increasingly competitive world markets for agriculture, regulators cannot ignore the equity issues concerning the tradeoff between reduced health risks to society and the higher costs to producers from the proposed A-risk pesticide tax and B-risk permit market. Funding for any subsides can be earmarked from the pesticide tax, auctioned permits, or from the general budget.

Technology and Economic Instruments

Technological developments on several fronts may serve to change the feasibility of and the need for any instrument. Geographic information systems and surveying by satellite can reduce monitoring costs by identifying problem areas and ensuring abatement compliance. Such systems could also further improve the accuracy of physical simulation models which could then possibly be used legally to predict emission levels for any given farm from observable practices. In addition, the new technology can increase the awareness of producers of any negative environmental impact their practices may be having and thereby enhance the individual and political will to reduce those impacts. Improvements in data management techniques along with GIS technology will make detailed recording systems for input use by crop, location, and application technology feasible (Zilberman and Millock 1997). Such improvements increase the potential for using differential design-based economic instruments.

While the ability to monitor residuals will be enhanced with new information technologies, developments in these areas have led to the concepts of precision agriculture which could significantly reduce the level of pollutants generated from agricultural production. For example, site-specific management or variable-rate technology allow producers to modify the rates and form of application of inputs such as fertilizer and pesticides on an individual field rather than the common practice of applying a single rate. The efficiency of those inputs are improved as they are substituted by human capital in the form of knowledge of the physical system. Total levels of the inputs and residuals are reduced as a result. However, improper incentives associated with input prices higher than the socially optimal have led to the under-investment and under-adoption of precision technologies along with the over-use of variable inputs with current application technologies (Zilberman, Khanna and Lipper 1997).

CONCLUSIONS

Economic instruments, although currently used on a limited basis as an environmental policy option, have been identified as an efficient means to achieve environmental objectives. The case for such incentive schemes has been developed primarily with reference to situations in which emissions can be readily monitored by source and are deterministic. In this setting, economic instruments can achieve environmental goals at least cost and provide incentives for further improvements. It is more difficult to use such instruments in agriculture where the pollution problems can be traced as in the case of intensive livestock operations. However, most environmental problems in agriculture typically involve a large number of diffuse pollution sources whose abatement practices are unobservable rendering it difficult to achieve cost-effective pollution control with any single instrument.

The appropriate environmental policy is one that minimizes the environmental costs of the residuals, the abatement costs to producers in reducing those levels, and the administrative costs to the regulator of monitoring and enforcing compliance. Given the spatial and temporal heterogeneity of farms and their environmental impact along with the greater knowledge held by farmers than regulators about their farm operations, that policy choice will be a system of locally specified management incentives. Incentives for relatively low cost nutrient management plans may be sufficient in some locations to reach environmental thresholds while in other locations, such as those with heavy concentrations of livestock, a combination of policy tools may be required. Costs to producers for abatement and to regulators for implementation can be offset by gains in environmental improvement under many situations that exist in Europe and certain intensive livestock producing regions. However, political support to address most environmental problems in Canadian agriculture is lacking because the benefits of ecosystem health are considered by some to be uncompelling while the administrative costs for enforcing any effective policy and producer opportunity costs in meeting those policies are likely to be high.

Rather than relying on first-best solutions through economic instruments such as ambient taxes or tradable permits, the most effective way of dealing with diffuse-source pollution problems in agriculture may be technological developments and business-led initiatives. Information technologies are enhancing the ability to monitor application levels and techniques and thus the feasibility of certain economic instruments. Taxing input use, particularly if differential based on application method or environmental susceptibility, will encourage the adoption of precision technologies that vary input levels depending on site location. The substitution of human knowledge for variable inputs reduces ambient concentrations. Precision technologies could be part of an environmental management system that firms voluntarily agree to abide. The standardization of voluntary private codes related to environmental practices are the next generation of environmental policies. The use of codes such as ISO 14000 and eco-labeling are market-based, business-led, proactive actions that provide farmers with the incentives to adopt environmentally less damaging practices that are more feasible than traditional first-best economic instruments.

NOTES

[1]Since the typical efficiency rule of maximizing the present value of utility over time may lead to resource levels less than required for sustainability, economic instruments and other means of correcting for market failures are necessary but not sufficient for sustainability (Toman *et al*. 1995).

[2]Such natural variability will affect the *ex post* but not *ex ante* efficiency of alternative policy instruments (Weitzman 1974).

[3]The lack of information that producers are likely to have on the effect of these alternative practices on environmental quality must also be considered in the choice of alternative instruments.

[4]The appropriate zone for measuring concentrations in the affected resource must be identified.

[5]Smith and Tomasi (1995) show that only second-best allocations are feasible when the transaction costs of implementing a policy are considered and that these costs will influence the optimal incentive scheme.

[6]The *Farm Income Protection Act* of 1991 enables the government to cancel a support program if it is deemed to have detrimental environmental impacts, but such alterations have not occurred for this reason.

[7]Ziegler (1995) reviews the feasibility of using cross compliance as an environmental policy instrument and how it could be introduced within the current Canadian agricultural policy context.

[8]Little attention has been given to the effectiveness of a multiple-instrument approach, although Braden and Segerson (1993) note that the ability of any proposed scheme depends upon the nature of the single instruments and the interactions between pollution-related inputs.

[9]Participation has been reduced by the reluctance of farmers to provide private information on their operations which may subsequently be used for other purposes.

[10]Ontario also has a goal for a 50 percent reduction in agricultural pesticide use. Announced in 1988 under the Food Systems 2002 program, the aim is to reach the desired reduction by 2002. Most of the funds within the program have been for research and technical assistance into alternative pest control strategies.

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