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Institutional analysis for nitrogen pollution abatement in a Waikato river sub-catchment in New Zealand

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Key words: Environmental policy, Transaction cost, Compliance, Contract design and Heterogeneity

Nitrogen levels in water resources in the Waikato region are increasing, mainly as a result of non-point source pollution from agricultural activities. Non-point pollution management is a complex issue requiring sufficient information and appropriate institutions. This paper considers the environmental policy literature and analyse how institutions, contract design, and monitoring and transaction costs in the presence of farm heterogeneity encourage optimal abatement. The analysis identifies the key institutional issues to be addressed in the design of appropriate policy measures to address water quality in Waikato river sub-catchment.

1. Introduction

Agricultural land use has contributed to increased levels of nitrogen in Waikato water bodies. Pastoral agriculture's contribution to the degraded water quality has been well recognized (Parliamentary Commissioner for the Environment, 2004). Agricultural non-point sources have largely been free from regulation to-date. There is a development of community pressure for better water quality in recent times (Broadnax, 2006). Besides supporting healthy living, water bodies contribute to aesthetic beauty, tourism and sporting opportunities. Lake Karapiro and Arapuni are identified as waters of national importance for tourism by the Ministry of Tourism. Lack of monitoring and enforcement are said to be of deteriorating water quality (Cullen, Hughey, & Kerr, 2006). The challenge is how to reduce the non-point source pollution from agriculture. Agri-environmental policy in New Zealand has increasingly focussed on how to manage water quality. Bio-economic modelling focussing on abatement cost of policies plays an important role in the analysis of environmental policy (Ramilan & Scrimgeour, 2006). However appropriate institutions are important for effective policy implementation. Institutional factors in this text mainly refers to establishment and enforcement of property rights, transaction costs and instrument issues related to property rights, monitoring and enforcement of agri-environmental policies. High enforcement costs and imperfect compliance make policies less effective than desired.

In the presence of well-defined property rights the majority of issues are resolved by markets. It is often difficult to adequately define property rights across multiple dimensions, however the greater economic value on resources at stake yields greater incentives. Adequately defined property rights are important to address the water quality issue.

Scientific research has played a key role in providing basic data for environmental management and developing innovative best management practices. There is a need for new tools for facilitating implementation of environmental management by analysing the issues in designing and implementation of institutions. Therefore this article considers the economics, environmental and law literature on property rights, monitoring and enforcement of environmental policy in order to develops a conceptual framework for a catchment based institutional approach to address the water quality problems. Attention focuses on the nitrogen discharges into water, which currently receive intense attention in general in New Zealand and particularly in Waikato.

We begin with fundamental issues associated with property rights and their present status in New Zealand. The reminder of the paper is structured as follows. Section 2 analyses the need for an institutional change. Section 3 discusses the transaction cost. Section 4 analyisis the importance of proxies in measuring discharges. Section 5 addresses monitoring and information. Section 6 outlines the way in which the conceptual framework is adapted to encompass non compliance and monitoring in agri-environmental policy enforcement. Section 7 discusses the implications for policy and research and section 8 concludes the paper.

1.1 Property rights, present status and prospective needs

In economic literature property rights are defined as a bundle of entitlements defining owners rights privileges and limitations for use of resources (Tietenberg, 2006). (Allen & Lueck, 2002) defined property rights as the ability to freely exercise choices over the asset in question. Property rights include the law, customs and regulations governing the rights and obligations of individuals and firms to have access to and use the environment. Rights are relationship among individuals with respect to resource use. Efficient property rights must be exclusive that all benefits and costs accrued as a result of an activity should accrue to owner, transferable among individuals in a voluntary exchange; and enforceable.

Farms often enjoy an initial allocation of property rights because it is easier for them to discharge nutrients rather than who wants improved water quality to control the discharge. Under the present property rights regime farms are not required to pay the full social cost of the nitrogen pollution they generate. In the absence of environmental and human health costs, farms have an incentive to ignore them in the decision making process. Ignorance of external damage cost leads farms to select management practices that result in greater than the socially optimal levels of nitrogen discharge. This violation of exclusiveness is referred to as externality. Since there is a divergence between private cost and social cost of the pollution created, the nitrogen discharge problem can be considered as a negative externality (Figure 1). MSC and MPC refer marginal social and private costs respectively.

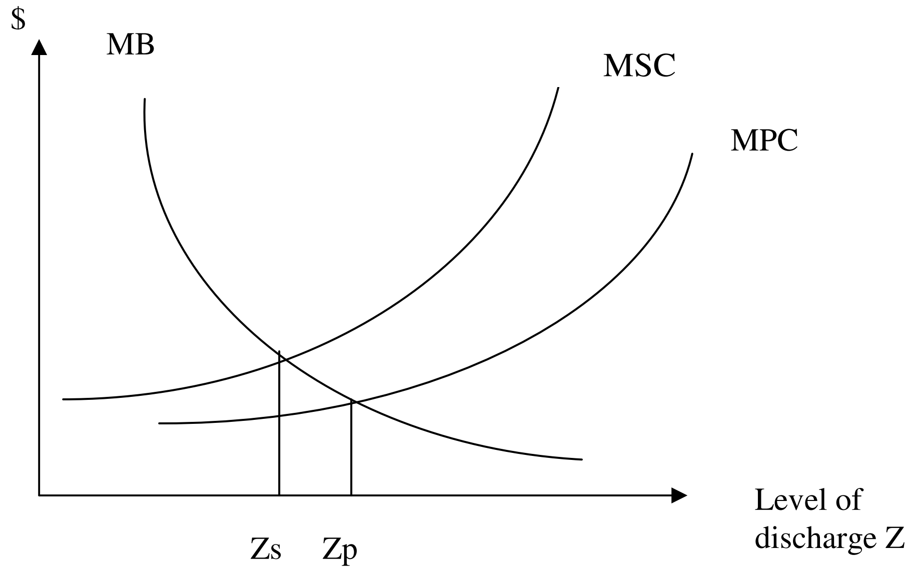

Figure 1: Privately and socially optimal levels of output

To date, discharging nitrogen into water bodies has not been constrained, so landowners have effectively been exercising a perceived privilege to discharge. In the past this was not seen to infringe on the rights of others. The right of society to high water quality is now found to be in conflict with the privilege to discharge nitrogen. Non-point pollution control in the Waikato region largely depends on moral suasion and on voluntary measures such as establishment of riparian margins. Lack of implementation of other regulatory measures can be attributed to the perception of agriculture as a key regional economic activity, absence of scientific evidence on the impact of farm nitrogen discharges until recently and difficulties in developing efficient means of regulation. Existing structure of rights and obligations are unacceptable to some members of society. To enhance environmental outcomes, rights and obligations need to be structured such that they increase the net benefits. The structure chosen will impact on how wealth is redistributed, and therefore, the extent of social disruption. Environmental policies proposed seriously curtail pre existing property rights of farms to an extent that may threaten the viability of their operation (Hardaker, Humie, Anderson, & Lien, 2004)

Environmental problems basically arise when property rights are ill defined, when rights are exchanged under non competitive conditions and when social and private discount rates diverge (Titenberg, 2006). Efficient solutions to the environmental problem can involve such as private negotiation, judicial remedies and regulation by the legislative and executive branches of government. Knowledge of property rights and their impacts on incentives are imperative to orchestrate a coordinated approach to resolve pollution problem in Waikato water bodies.

Property rights institutions are especially important to enhance water quality through all kinds of policy instruments. Therefore there is need to define property rights adequately and establish clear lines of authority to implement and enforce policies**.** Property rights evolve through common law courts, legislatures, voluntary associations and other governmental institutions (Anderson, 2004).

If we consider a region, we may need generic and specific types of institutions to address the issues. Since catchments vary across many dimensions throughout the landscape and respond primarily local land use and water use actions, comprehensive uniform regional or national rules may be inappropriate (Ruhl et al., 2003). For instance in Waikato, the Waikato river catchment from the Lake Karapiro to Taupo control gates has been identified as one of the water bodies in the region with its highest priorities for nutrient management (Brodnax, 2006). Environment Waikato has identified the establishment of nutrient targets for the Waikato river and tributaries between Lake Taupo control gates and Lake Karapiro Dam and the as a key component of future environmental policy development (Environment Waikato, 2005 d). Implementation of policy instruments like tradable permits requires a clear definable unit and trading must occur within clearly defined catchment boundaries. This will help to ensure that water quality improvements will appear. In controlling non-point source pollution in a catchment geo-physical factors influence the direction of nutrient flow. Part of the clear definable unit is the property right necessary to make use of the credit (Ruppert., 2004). Best management practices convey the property rights in a specific manner. Non-point source best management practices are thought to be a particularly cost-effective means to achieve water quality improvements (Stephenson, Norris, & Shabman, 1998).

In Waikato many farmers have adopted land base effluent management system despite high capital cost but in the presence of slightest economic incentives in the form of fertilizer cost and consent application fee savings (Parminter, 1999). Rules are being proposed to control nitrogen discharges in terms of stocking standards and best management practice and the regional council is exploring the feasibility of controlling nutrient problem through tradable emission permits (Environment Waikato, 2005). This approach privatises the right to access the resource to a pre-specified degree. This necessitates establishment of limits on nitrogen discharge to achieve water quality targets. Establishing a market for nitrogen emissions requires the establishment and allocation of rights to discharge. This requires all current privileges to be surrendered, and the rights to nitrogen emissions to be allocated Undefined property rights and transaction costs are reported to be a major barriers for the smooth functioning of tradable permit markets among non-point sources (Collentine, 2006).

1.2 Industry led initiatives

Dairying is the predominant pastoral farming activity in the region reportedly contributing considerably to the problem of nitrogen discharges to water bodies. In order to be self responsible the dairy industry has undertaken some initiatives in the recent past. Under the dairying and clean streams accord measures are taken to exclude livestock from water ways and proper effluent disposal on voluntary basis.(Fonterra, MFE, & MFA, 2003). To date, non-point pollution control initiatives have heavily relied on voluntary measures such as establishment of riparian margins.

There are couple of industry led initiatives to improve the environmental performance of dairy farming in New Zealand. The industry has recognised the need to ensure the environmental sustainability and mapped out a strategy for sustainable environmental management (Dairy Environment Review Group, 2006). Environment Waikato along with Fonterra, Tatua and Dexcel, have been undertaking an education campaign about dairy effluent rules. Effective policy implementation requires robust mechanisms to estimate the performance of farms with respect to environment.

1.3 Legislative structure for the environment

The core of the legislation in New Zealand intended to help sustainable management of agricultural lands and water bodies, is the Resource Management Act (RMA) of 1991. It promotes the voluntary, economic and regulatory approaches to control non-point source pollution. The section 32 of the Resource Management Act states that the local authorities must consider alternatives, assess the benefits and costs of objectives, policies, rules and other methods. The other methods mean the provision of information, services or incentives levying charges including rates. The act by itself has reportedly not empowered the councils to use them (Denne, 2006). Clear tools for managing the environment have not been explicitly mentioned. Similarly under section 24, the role of the Minister for the Environment has been mentioned to consider and investigate the use of economic instruments including charges levies, other fiscal measures and incentives to achieve the purposes of the resource management act. No specific power has been provided to administer economic instruments. The amended version of section 32 removes the explicit reference to charges and incentives, stating only that local government should consider the extent to which each objective is the most appropriate way to achieve the purpose of this act. Regional councils are given statutory responsibility under the RMA (sections 9 and 15) to avoid, remedy or mitigate adverse effects on water quality in the region. In some countries best management practices are directly enforceable. For instance Oregon law requires the development and use of best management practices to protect water quality (Boyd, 2000).

If we look into the experiences elsewhere on the issue of property rights and pollution, (Cole & Grossman, 2002) cited some interesting court rulings in which the defendant claimed a “right to pollute” groundwater partly by virtue of the fact that it had been doing so for a long time without penalty. The court ruled that regardless of when the polluting acts occurred, and regardless of society's changing views on the propriety of polluting the environment over the years, the defendants have never had a right to pollute the groundwater. We view it that overall benefits and cost of rules will be considered in Waikato context as dairy farming is a major economic activity and linked many other industries. However facilitating favourable land use changes to reduce discharges using public fund is viewed as victim pays regime has been criticized (Environmental Defence Society, 2007). This society stresses that the regulator should take the view that land owners are not authorized to damage the lake and do not have the presumptive rights.

2. Is there a need for a change?

Since the current property rights structure allows discharges of nutrients into water bodies, producers are not required to pay the full cost of environmental pollution caused by nutrient discharges. According to (Stiglitz, 2000) internalising the cost of pollution is confronted with following challenges. Firstly the dispersed nature of non point pollution and difficulties in measurement increases the transaction costs of internalizing externality through voluntary negotiations among individuals. Secondly achieving a solution through judicial system is difficult as individual contribution of farms to the pollution is small to justify costly judicial process. Further uncertainties associated with the impact of non point pollution results in unwarranted results through litigation process.

Arguably there is a space to redesign present structure of property rights to implement environmental policy(Weersink, Livernois, Shogren, & Shortle, 1998). Economic and legal institutions are important when transaction costs are not zero and property rights are not well defined (Allen & Lueck, 1999). In the absence of well defined property rights, the regulator can play a vital role for assignment of initial entitlements (Richards, 2000). In the event of high transaction costs, apart from assigning values, regulator can set environmental quality targets, choose instruments to accomplish those goals, monitors compliance, and initiate actions to enforce the rules. (Gangadharan, 2000) proposed regulator designed programmes could facilitate the evolution of markets that encourage participation. In the case of externalities the state can play a significant role of defining and assigning property rights to enable bargaining solutions. The degree of subdivision of rights can improve the efficiency of transactions, because agents could contract on the necessary rights only (Depres & Grolleau, 2005).

Given current challenges there has been increasing reliance on public remedies to redefine property rights. Arguably government intervention is required to regulate the nutrient discharge into water, either in the form of redesigning the current property rights structure to allow for a private market solution or in implementing policy instruments that will convey the desired property rights structure. Solution to the pollution problem through public initiative are broadly categorised into direct regulation and market based solutions.

In New Zealand local authorities are empowered through the Resource Management Act to monitor resource consents, compliance and complaints. (Ruhl et al., 2003) stated the features of a model institutional structure for a catchment management act. This act must empower local agency with authority and responsibility to manage surface and ground water quality and quantity issues and the relavant authority must be capable of establishing democratically based legitimacy at regional and local levels. Further institutional structure must have the capacity to carry out scientific, economic and social analysis functions, as well as the responsibility to make policy and regulatory decisions through public, transparent procedures based on the record of best available evidence it generates through its capacity. They further stressed the need for local authorities to play a stronger local partnership with a shift from regulator/ advisor to facilitator/partner

3. Transaction costs

Transaction costs are defined as the cost of information gathering, contracting and enforcing property rights (Allen, 1991; Allen & Lueck, 1999). In case of non-point pollution transaction cost is mainly incurred by the regulator in order to carryout the pollution control policy. Transaction costs include information, contracting and enforcement costs. Information costs include the cost of targeting farms, finding the linkages between the discharges and farming practices. Contracting costs are the administrative and staffing cost involved in contracting targeted farms. Enforcement costs are costs of monitoring to audit adoption of nitrogen discharge measures, estimating discharge levels and administering incentives The way the property rights are defined is going to have an impact on the transaction costs. In the presence of transaction costs assignment of property rights plays a crucial role to determine efficient solution. (Cole & Grossman, 2002) described the normative inference of Coase's theory that that the property rights need to be assigned in a way to reduce transaction costs. i. e rights need to be awarded to the party who has the higher cost of abating them

Inclusion of transaction costs is very important for policy analysis as it lead to the design of policies and institutional arrangements with lower transaction costs. (McCann & Easter, 1999)listed the importance of transaction costs in environmental policy analysis as it may affect which policy alternative attains an environmental goal at least cost; reduce the amount of abatement that is optimal from the point of view of society and they may lead to the design of policies and institutional arrangements which lower transaction costs.

3.1 Components of transaction cost

We synthesised the components of the transaction cost following (McCann & Easter, 1999; Moxey, White, & Ozanne, 1999) and (Thompson, 1999). The magnitude of transaction costs involved with an environmental policy is thus represented by the sum of these costs.

$$T_i = \sum_{t=0}^{T} \beta (R_{it} + E_{it} + D_{it} + S_{it} + M_{it} + P_{it})$$

T- Transaction cost
R- Cost of research information gathering and analysis
E- Enactment of enabling legislation including lobbying cost
D- Cost of design and implementation of policy
S- Support and administration of ongoing programme
M- Monitoring and detection
P-Prosecution and inducement costs
B- Discount factor
i- Policy
t- Time period

Monitoring costs can vary depending on entailed negotiation effort and intensity of monitoring effort. Intensity of monitoring can be measured as monitoring frequency. The primary input used is labor as represented by staff and farmer time. Fixed and variable costs are related to set up and continuing cost in each category. It is visible that the transaction costs have fixed and variable cost components for instance the monitoring costs are a variable cost. This is in line with the cost specification for empirical analysis by Falconer & Whiteby (1999). In policy selection abatement costs and transaction costs need to be considered together. (McCann, Colby, Easter, Kasterine, & Kuperan, 2005) stated that policies must not be rejected due to high transaction costs alone since there may be trade off between transaction costs and other types of costs. Some policies with low abatement costs have high transaction costs.

4. Estimates of outcomes and associated transfer costs

Measuring, monitoring and enforcement of diffuse discharges in a physical sense are relatively impractical and expensive. Therefore deriving technically perfect property rules based on real measurement could be informationally demanding in practice, thereby incurring high transaction costs. Further there is a presence of time lag, for the discharged nitrogen from farm to reach the water. Given the non-point source information is imperfect and costly to obtain, there is a need to develop water quality protection proxies as an interdependent surrogates for property rule formulation. This necessitates the use of a simulation models. This approach has been adopted in many circumstances. Simulated discharges are used to establish relationship between farm management activities and nitrogen discharges. Proxy values make environmental policies operational in a transparent way.

The legal validity of simulated discharges is questioned (Weersink et al., 1998) based on the level accuracy of the estimates due to stochastic influences outside the farmers' control. For instances nitrogen discharges can increase with precipitation intensity. Since the model results are generally not acceptable evidence, they can be challenged through the legal system. This leads to costly litigation. This problem can be solved by formulating the model based discharges in a contract framework, where one of the contract items is that signatories decline the right to challenge model results through the court system (Romstad, 2002). Legal action would adversely affect the use of these models for emission based policy enforcement purposes. Despite the difficulties growing capability of environmental process models enable designing policies based on the model estimates of environmental impact (Romstad, 2002). In Waikato the Overseer nutrient budget model developed by Agresearch has been used to simulate nitrogen discharges(Ledgard & Power, 2006).

The use of calibrated and validated catchment specific simulation model enhances the transparency of the implemented environmental institutions. In order to enhance the legal validation, it is important to carry out monitoring and measurements in stream water quality as well to complement and verify the closeness of estimates to the reality. Models not only reduce the information problem but also help to decompose environmental impacts into natural and man made impacts.

The challenge is even we could achieve precise model based estimates of nitrogen discharge, the periodic use of these complex models on a farm may be demanding particularly in terms of data collection and specification.

5. Monitoring and Information

Successful adaptation of property rights in the form of catchment based policies depends on information acquisition. Catchment based approach for water quality improvement requires much more information about pollution sources, water quality conditions, spatial relationship between land use activities and pollution.

Compliance monitoring is important for the effective operation of agri- environmental policy. Monitoring is also an important component of transaction cost and proxies are used to reduce the cost. Here we focus on what to monitor. The diffuse nature of nitrogen discharges from agricultural sources posses serious challenges in monitoring and enforcement of environmental policies. It is difficult to isolate individual farm contribution. This makes development effective monitoring strategies for individual farms difficult. Regulators have little information about the contribution of individual farms to pollution problems. Economists hypothesize that farmers have more information about their pollution discharges than regulators, and this creates a hidden action problem for non-point source pollution abatement. To some extent monitoring can be carried out by implementing visible best management practices.

Since the measurement of water quality is costly in spatial and temporal domains, researchers have employed remote sensing techniques for water quality information retrieval. (Boyd, 2000) stated monitoring strategies include proposals for remote-sensing via satellite to determine compliance with land management and construction requirements, such as buffers and cover crops. In 2006, remote sensing techniques for lake water quality information retrieval is used (Sudheer, Chaubey, & Garg, 2006). This shows the phase at which technology revolves. Cost of measuring water quality in spatial and temporal domains will dwindle with evolving precise technologies.

According to (Johansson, 2002) abatement is a function of two parameters: observable abatement effort and unobservable abatement effort. In our situation observable abatement efforts are best management practices like riparian margin, feed pad, stand off/winter pads, grazing off and effluent disposal systems and number of animals. Unobservable abatement efforts include the rate of fertilizer application and feeding practices. Unobservable abatement efforts lead to strategic non-compliance because of information asymmetry. Non point source can mislead the regulator by reporting and adopting different levels of unobservable abatement efforts. The problem of hidden information arises because monitoring does not detect all those who fail to comply with contractual obligations. This provides polluter with an incentive by escaping policy regulations or penalties.

As a monitoring indicator for environmental policy animal density is increasingly being used as a standard for nutrient management policies (Ribaudo et al., 2003). The strength of using animal density as a regulatory standard lies in its ability to provide a straightforward, relatively easy to calculate indicator of farm's nutrient balancing potential. The concept of using animal density as an indicator of nutrient balancing potential is fairly transparent, it needs certain assumptions about feeding practices and fertilizer applied need to be considered. For instance feeding practices can have dramatic effect on the nitrogen discharges. But in case of nitrogen discharges potential animal characters can have a variability and tracking the number of animals can be a problem problematic.

5. 1 Contract design

Contracts between the regulator and polluter are an enforcement vehicle for environmental policies. The contract is signed between the regulator and the polluter. The contract may specify the input levels and best management practices to manage the discharge levels. In non- point discharges based on proxies information asymmetry exists because an environment agency does not possess perfect information regarding the technological profile and conduct of polluters who are subject to agri-environmental policy. The informational advantage that farmers enjoy in their relationship with the regulator can be two forms: one is ex -ante and other is expost. When signing a contract to reduce the use of input levels, the polluter always has an incentive to declare inflated input use levels. This enables the farmer to enjoy the same input use after signing the contract. After signing the contract there is an incentive to renege on their contracts, for if they can be successful in avoiding detection by the regulator. The challenge is to devise policies that function effectively in the presence of information asymmetry.

We propose the above the first problem can be tackled by assigning discharge reduction levels based on appropriate composite index of input levels and output-input ratios. Here it is assumed that the regulator can observe the output levels. The polluter with lower ratios can be allocated larger percent of discharge reductions. Higher ratios can be allocated with lower percent of discharge reductions. This method is some how closer to the concept of greater abatement where the marginal abatement cost is lower. The following section on conceptual model for monitoring describes the model for information asymmetry.

6. Conceptual model

This section develops a conceptual model for monitoring of a farm subject to agri-environmental policy that requires an income forgoing action on the farm. In addition the regulator used a monitoring and penalty scheme to discourage information asymmetry. We assume the regulatory authority wants polluters to reduce the nitrogen discharges. Consequently they receive reduced levels of returns.

The pollution problem can be framed in the context of pastoral farm and regulator, who represents the society. Farm production can be denoted as a function of input use. Consider a catchment where nitrogen discharge is generated from farming activity. Farms in the catchment are heterogeneous in terms of production structure and pollution potential. Causes for the heterogeneity are soil type, land slope, distance from the main stem of the river etc. Heterogeneity of farm is denoted by i, $i \in \Theta$ General specification of the production function for Yield per ha for a farm is

$$y^i = y^i(x_n) \qquad (1)$$

This function is assumed to be a twice differentiable and concave in inputs use, x_n.

Pollution discharge from the farm depends on the farm heterogeneity and input use.

$$z^i = z^i(x_n) \qquad (2)$$

This function is assumed to be twice differentiable and convex in inputs use, x_n.

The regulator has limited knowledge about the polluters' production and pollution function. In the absence of contractual arrangements between farms and regulator, farms always tend to choose the input levels to maximise the profit
Suppose input is used by price –taking, profit maximizing farms and output price is p_y
The maximum profit achievable without contract is

$$\pi_0^{*i} = p_y y^i(x_n^{*i}) - p_x x_n^{*i} \qquad (3)$$

Where the optimal input use x_0^{*i} is determined solving the first order condition
$p_y \frac{\partial y^i}{\partial x}(x_n^{*i}) = p_x$ this optimal input use vary according to the farm heterogeneity.

We assume the regulator wants farmers to reduce their nitrogen discharge through a combination of adoption of best management practices and input use restriction. Regulatory contract is assumed to be mandatory. As a result of restricted levels of input and adoption best management practices x_n^{Ri} they receive restricted profit π_R^{*i}. The abatement cost, C, is defined as the difference between the unrestricted maximum level of profit π_0^{*i} and the restricted level of profit π_R^{*i}.

$$C = \pi_0^{*i} - \pi_R^{*i} \qquad (4)$$

We assume the environmental agency wants to maximize the following function.

$$Max = \pi_R^{*i} - m(p) \qquad (5)$$

m (p) stands for monitoring cost of the regulator. The regulators monitoring costs depend on the degree of monitoring effort undertaken i.e. to a large extent on the frequency of visits and effort put into scrutinizing farmers' activities. It is assumed that monitoring costs, m are function of p i.e. *m(p)*, where
$m^{'}(p) \geq 0$ and $m^{''}(p) \geq 0$

Therefore in designing contracts regulator must ensure that farmer compliance is secured despite there being imperfect monitoring.

Under the agri-environmental policy farmers income for truthful behaviour

$$I_t = \pi_R^{*i} \qquad (6)$$

Alternatively if the agent wants to renege the agreement, the income is assumed to be

$I_v = \pi_v$ If not caught (7)

$I_v = \pi_v(1-\delta)$ caught (8)

π_v can be equal or less than the unregulated profit π_0^{*i} but definitely greater than the restricted profit π_R^{*i}. δ is a penalty parameter.

Specifying the probability of detection is p, the expected income from violating the agreement is

$$E(I_v) = (1-p)\pi_v + p(\pi_v(1-\delta)) \quad (9)$$

The degree of violation depends on the relative merits of I_t and $E(I_v)$

Targeting the farms based on the heterogeneity reportedly increases the information efficiency while lessen the data collection effort (Farzin & Kaplan, 2004). On this premise we seek to explore the implications of different types of monitoring on the cost of monitoring and non compliances by adapting the scheme proposed by (Fraser, 2004) to reduce moral hazard in agri-environmental schemes. In selective monitoring sub group of farms with a higher potential of nitrogen discharges are targeted, implying their probability of being monitored is higher than participants outside the group.

What the regulator wants is minimization of the discharge violation at a lower cost of monitoring across the catchment. To achieve the targeted aggregate discharge level Z

$$Z = \sum_{q=1}^{Q} z^i(x_n) \quad \text{Q –number of farms in the catchment} \quad (10)$$

$$Min = \sum_{n}^{N} V + m(p) \quad (11)$$

$$V = \pi_v - \pi_R^{*i} \quad (12)$$

Resource neutral targeting

Overall monitoring resources are unchanged with the introduction of targeting, and so an increase in the probability of detection in one zone and reduction in other zone. Higher probability p_H of detection is achieved in the target zone by shifting monitoring resources away from those in the non target group, where the probability of detection is p_L. Under this scheme expected income from violating in the target group. $p_L < p < p_H$

$$E(I_v)_{Target} = (1 - p_h)\pi_v + p_h(\pi_v(1 - \delta)) \qquad (13)$$

Under non target group expected income from violation is

$$E(I_v)_{Non} = (1 - p_l)\pi_v + p_l(\pi_v(1 - \delta)) \qquad (14)$$

Even though it minimizes the violation in the target group. It may encourage those previously not violating in the non target group to violate as the relative merits of violating is on the rise. The proportion of agents violate depends on degree of difference in the income out of true behaviour and violation

Non-resource neutral targeting

In this case regulator devote additional resources for monitoring to target activities in order to maintain the probability of detection in the non target group at the level prevailing prior to the introduction of targeting

$p_L = p$. In this case the proportion of farms violating, in the catchment will come down but will not be eliminated totally, because the farms in the non target group still has incentive to violate. Further regulator has to dedicate more resources in monitoring. This will increase the *m (p)*, Therefore the choice of degree of targeting depends on the trade off between the minimisation of violations and cost of monitoring. To what level nitrogen is to be abated depends on a trade-off emerges between the social benefits nitrogen abatement and the cost of nitrogen abatement and the costs incurred from the need to undertake higher levels of monitoring to secure it

Resource neutral targeting with weighted penalties

Under this scheme adjustments are done in the monitoring and penalty parameters of the non target group. Purpose of this approach is eliminating violation completely without either using more resources on monitoring and increasing the perception among non-target group farmers of the expected penalty δ associated with violation. Increased probability of detection in the target group is resourced by a decreased probability of detection in the non target group. Anyhow the expected cost of violation in the non target group is kept constant by applying new penalty parameter δ_T for non targeted group. That is for non targeted group.

$$(1 - p)\pi_v + p(\pi_v(1 - \delta)) = (1 - p_l)\pi_v + p_l(\pi_v(1 - \delta_T)) \qquad (15)$$

However monitoring schemes themselves can never be perfect, information asymmetry remains a potential source of weakness. We may think of minimising the degree of violation by increasing the penalty to a higher level. In fact by raising the penalty, the regulator can lower the probability and thus the cost of monitoring close to zero. However, in the case of agri-environmental policy, this usually does not reflect judicial reality (Ozanne, 2001). Therefore penalties need to be fixed at a relatively low level.

Geographic delineation of target farms in the catchment is technically possible according to their pollution potential based on soil physical parameters, but the political feasibility of differentiated penalties is a contentious issue. On the other hand it may be feasible to enforce geographically differentiated compensation plus penalty schemes for the forgone production losses. This issue needs to be considered in assigning property rights. Reduction in cost of monitoring could be achieved through technical enhancement of monitoring (Choe & Fraser, 1999). Compliance monitoring can be complemented through technological subsidies in terms of extended extension services. This minimises non compliance due to lack of information and skills.

7. Implications for policy and research

The major causes of nitrogen discharge from farms are stocking rate, nitrogen fertilizer application and supplementary feeding. The degree of the nitrogen discharges can be reduced to a certain extent by adopting best management practices. The rest of the reduction is needed to come from management of nitrogen fertilizer, stocking rate and supplementary feeding. We can reasonably assume that the farmers have no incentive to violate the best management guidelines on timing of input applications. However polluting agricultural inputs like fertilizer and supplementary feeding are difficult to monitor. The problem of this violation can be tackled by setting incentives associated with milksolids. This approach shifts the monitoring burden to outputs that in many instances are readily observerable. Assessing producers' response to input changes requires empirical knowledge of the production function. (Peterson & Boisvert, 2004) showed that monitoring corn yields could be substituted for the potentially costly and intrusive monitoring of fertilizer use. In the Netherlands nutrient discharges from crop farming are estimated using nutrient accounting system. Nutrient budgets derived from self reporting. Apart from self reporting, information is sourced from off farm sources. Feed and fertilizer suppliers are required to supply farm wise sales details to the regulator. This approach is feasible in New Zealand

(Bontems, Rotillon, & Turpin, 2005) used the relationship between the pollution and production of a particular farm type to design incentive based environmental policy. The programme requires farmers to report the estimated pollution as well as the production. In our case there is an involvement of two difficult to observe inputs and the input- output relationship is complex as inputs are transformed into final product through multiple transformations within the farming system. Therefore devising methods which enable output based monitoring in the catchment with minimum information needs an empirical exploration. Output based monitoring the production can be minimised if regulator cooperates with the industry passing on the benefits to the industry.

Environmental impact of the nitrogen discharge depends on the location of the production activities because of spatial variation in soil type, land slope and hydrological flows. The variability in potential emissions and contamination risks can vary within relatively small geographic regions (Schou & Birr-Pedersen, 2001). Good environmental policy need to be based on the insights of robust science. Geographic information system is used in provide the information needed to design spatial policy environmental policy interventions(Cook & Norman, 1996; Horst, 2005). Informational requirements on farm boundaries, stocking rate, pattern of production and pollution feature can be established using geographic information system. Geographic information based spatial tools can be used to define the most suitable or relavant geographical target areas for the policy intervention. All farms in the catchment need to be represented in Geographical Information System on internet, including data on land use, number of dairy cows, fertilizer application and adoption of best management practices. milksolids production. Since most farmers have internet access this approach enhances the transparency and reduces the transaction cost of overall regulatory procedure.

Choosing effective and efficient environmental policy involves consideration of ability to achieve the goal, cost effectiveness, lower transaction costs, enforceability and information demand, dynamic incentives for further research and development of technologies, equitable distribution of cost and benefits and political feasibility. Further unawareness of the cause and effect relationship between the farming activities and the resultant nitrogen discharges also can contribute to the problem (Weersink et al., 1998).

In a trade off in the presence of budgetary constraints, a greater intensity of data collection and thus dedicating fewer resources for sediment load abatement, results in greater reductions in uncertainty and sediment loading (Kaplan, Howitt, & Farzin, 2003) This suggests that diverting some resources from abatement effort to information acquisition or monitoring may improves the overall abatement effectiveness

Nitrogen discharge impacts have two aspects: difficulties in observing individual emissions and stochastic damage. This paper assumes discharges are deterministic. In most circumstances, the discharge levels and consequent damages caused by discharges depend on stochastic environmental factors. Particularly variability in rainfall over time can have profound effect on discharges as well as consequent pollution transport. Farm specific technical parameters are not fully known to the regulator, but a reasonable amount of information can be elicited from available farm survey data and geographic information systems.

8. Conclusions

Innovative institutions can both improve outcomes and reduce the transaction cost. Development of scientifically and legally defensible data collection procedures and catchment modelling are key steps. Institutional structure must rely on more than voluntary governance and voluntary compliance. There is a need to empower full range of market based and regulatory compliance mechanisms.

Despite the policy consideration of institutional change, it is important to know politicians will place considerable emphasis on distributional issues and any analysis should carefully consider distributional issues. There is need to extend sufficient extension services to maintain the nutrient budgets. The evolution of property rights is driven by an ongoing search for ways to internalise externalities. Institutional arrangements need to evolve to empower people to take abatement measures for nitrogen discharges. The diversity of risk preferences should not be ignored in designing environmental policy.

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