Environmental lobbying with imperfect monitoring of environmental quality

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Abstract

In this paper we present a two stage game of political lobbying for policies designed to enhance environmental quality. Unlike previous work which has tended to assume perfect monitoring of environmental quality in lobbying games we allow for imperfect monitoring of environmental quality. We characterize perfect public (politico-economic) equilibria in the game for the case of both perfect and imperfect monitoring of environmental quality and compare these with imperfect private monitoring of environmental quality. Results are discussed with respect to farmer behaviour in the context of non-point source pollution and implications for the political consequences of farm extension programmes highlighted.

Keywords: Game theory, public choice, imperfect public monitoring, imperfect private monitoring, non-point source pollution, agricultural extension and public education

1 Introduction

While environmental standards have become the norm to address traditional point source pollution such as smoke stacks and effluent treatment plants in urban settings, the issue of non-point source pollution in rural land use systems remains highly politically charged. Recent debate on the matter has occurred in Australia particularly with regard to potential impacts of agricultural non-point source pollution on the coastal ecosystem in the Great Barrier Reef region. In Europe, the proposals in a variety of countries towards implementation of the European Union water framework directive are the topic of recent policy debates. There is an extensive literature on agricultural non-point source pollution dealing both on the theory and practice, where the debate has recently moved from traditional regulatory control to voluntary approaches for prevention and mitigation. Key contributions have included Braden and Segerson (1991), Lichtenberg, Strand et al. (1993), Horan and Ribaudo (1999) and Ribaudo, Horan et al. (1999). While transaction costs have featured prominently in the discussions on effective policy design to address market failure (Smith and Tomasi 1995) impacting on public good environmental quality, most of the related studies appear to overlook the role of the political process that may potentially determine how and when governments intervene in correcting the externality. Government interest for policy intervention has often been analysed in terms of two explanatory theories of regulation: first, public interest theory, that suggests government action must aim to produce an optimum level of well-being for the entire population of a country; while the second, economic theory of regulation, considers that well-organized groups engages in activities to influence government decision-making in their favour (Olson 1965; Stigler 1971).

A number of papers have analysed the political economy of environmental lobbying from a public choice perspective. Well known contributions to the literature include Lee (1985), Brooks and Heijdra (1987), Migue and Marceau (1993), Damania (1999), Wilson and Damania (2005) and Polk and Schmutzler (2005). This literature has, for the most part ignored the problem of monitoring environmental quality, despite much of the work featuring a tacit assumption of perfect monitoring of environmental quality. Consequently one could term the resultant political (politico-economic) equilibrium a perfect public politico-economic equilibrium to borrow from the literature on perfect public equilibria.

There is also a considerable literature on private versus public monitoring with both perfect and imperfect information, that would appear to have clear relevance to the question of how environmental monitoring impacts on the political process, i.e. environmental politics and the politico-economic equilibrium. This literature has developed in the context of the theory of repeated games (See, for example; Mailath and Samuelson 2005) . In the model presented here we examine monitoring issues in the context of a multi-stage game rather than a repeated game. This literature begins with Abreu, Pearce and Stachetti (1990). The distinction between perfect and imperfect monitoring of environmental quality is of particular relevance to considerations of non-point source pollution problems, because monitoring costs for non-point source pollution are likely to be higher than for point source pollution due to the diffuse nature of the pollution discharge. Because farm pollution is for the most part non-point source in nature, and despite the relative ease of monitoring application rates for fertilisers and pesticides, monitoring nutrient run-off and pesticide run-off into the environment is fraught with numerous difficulties. Therefore, it is important to recognise that agricultural pollution is characterized by imperfect monitoring. If one treats environmental quality as a public good then one is clearly dealing in terms of resource allocation with an imperfect public equilibrium.

2 The Model

In this paper we extend a version of the Tullock rent-seeking model with the outcome of the lobbying game being improved environmental quality as a result of a particular policy, the policy could be a tax or it could be a legislative measure designed to restrict pollution. There are two political groups one in favour of the new measure because they stand to benefit more from improved environmental quality and one opposed because they stand to lose from the economic imposition of the new policy. We assume that one group consumes the public good environmental quality and that the other group discharges pollutant and does not value the environment at all. The set-up is similar to Anderson and Siwan (1997) and Beard (2006).

The model can be conceived of as a multi-stage game. In each stage of the game information about environmental quality becomes available through monitoring. Monitoring of environmental quality will be either a publicly observable signal or privately observed signals. In the first stage of the game politicians propose a policy measure in the form of a penalty. We do not explicitly model this stage in this version of the paper. We simply assume that self-interested politicians have proposed this penalty in their own interest. In a second stage of the game an electoral contest (via political lobbying) occurs between politicians associated with particular interest groups (producers opposed to the penalty and consumers in favour of the penalty). Once the outcome of the election is known producers and consumers make appropriate production and consumption decisions in a third stage of the game. The model is solved via backwards induction. Firms (farmers) make production decisions and households (consumers) make consumption decisions. Farms are assumed to generate a non-point source pollutant which is detrimental to a public good environmental quality and consequently diminishes consumer welfare. In the second stage both farmers and consumers lobby regarding the imposition of a possibly policy measure that will penalize farmers in an effort to reduce the extent of environmental damage that is induced by farming activity.

The farmer's profit maximizing problem is given by:

$$\max_a \Pi(a) = pa^{\gamma} - ca$$

where p is the price received for the crop, a the chosen action of the farmer, e.g. fertilizer application and c a cost associated with that action and γ an elasticity of production parameter.

The optimal rate of fertilizer application is then given by:

$$a^* = \left[\frac{c}{p\gamma} \right]^{\frac{1}{\gamma-1}} \tag{1}$$

Consumers maximize utility by consuming a private good and a desired level of public good so environmentalists' utility is given by

$$U(a_i, z) = a_i^{\alpha} z^{\beta} \tag{2}$$

where α, β represent elasticities of substitution.

Consumers face a budget constraint (alternatively this can be interpreted as a linear production possibility frontier that transforms private goods into public goods where despite appearances the public good z should not be interpreted as possessing a price):

$$B_i = qa_i + z \tag{3}$$

where q is a transformation parameter.

Rearranging and substituting

The following Utility function is obtained

$$U(a_i, z) = \left[\frac{B_i}{q} - \frac{1}{q}z\right]^{\alpha} z^{\beta} \tag{4}$$

The optimal household consumption of the public good environmental quality is then given by

$$z_0 = \frac{\beta}{\alpha + \beta} B \tag{5}$$

Before turning to the lobbying stage-game, we need to discuss environmental monitoring. We draw on the literature on imperfect private monitoring in repeated games to establish a framework for environmental monitoring.

Following Kandori (2002) we introduce a monitoring signal $\omega_i \in \Omega_i$ received by the i-th agent, this may be either a farmer or a consumer at this stage. In the public monitoring case ω is identical for all agents (farmers and consumers). In other words everyone has the same information about environmental quality and there are no disputes regarding information. In previous work reported in Beard (2006) the issue of political conflict regarding possible impacts of agricultural non-point source pollution was analysed as an environmental lobbying game applied to Queensland’s Great Barrier Reef. In that game although interest groups differed it was implicitly assumed that agents had the same information regarding environmental quality. Typically interest groups disagree about information as well. Under perfect monitoring the signal received by each agent $\omega_i = z_0 - \sum_i^n a_i$, where *n* is the number of firms (farmers). If there are observation errors then this signal will be perturbed by an error term. The question is exactly how it will be perturbed and this depends on whether one is monitoring environmental quality or whether one is monitoring individual behaviour. In point source pollution it is relatively easy to monitor individual emission levels. In the case of non-point source pollution, this cannot be done efficiently although inputs could be monitored. In what follows we will examine the case of input monitoring which is the basis of input controls as a policy measure and we will also examine the case in which environmental quality is monitored. The latter, if imperfect, corresponds to the case of imperfect public monitoring and the former to the case of imperfect private monitoring.

In the second-stage farmers choose lobbying effort by maximizing the expected benefits from unrestricted application of fertilizer and restricted application of fertilizer. So that the expected payoff to farmers is represented by:

$$E\Pi = p\left(\Pi^* \mid a^*\right)\left[\Pi^* - e_i\right] + p\left(\Pi' \mid a'\right)\left[\Pi' - e_i\right] \tag{6}$$

where:

$p\left(\Pi^* \mid a^*\right) = \dfrac{\sum_{i=1}^{n} e_i}{\sum_{i=1}^{n} e_i + \sum_{j=1}^{m} l_j}$ is the probability of a pollution mitigation policy not succeeding electorally and $p\left(\Pi' \mid a'\right) = 1 - p\left(\Pi^* \mid a^*\right)$ is the probability of such a policy succeeding .

If environmental quality is given by the preferred level of environmental quality z_0 net of any external impact: $z_0 - \sum_i^n a_i$, then if monitoring is perfect and public all agents receive the signal $\omega = z_0 - \sum_i^n a_i$. If the status-quo is unchanged farmers receive $\Pi^* - e_i$ and don't care about measurement of environmental quality. If however a restrictive policy is imposed then monitoring of environmental quality does matter to them. The profit in the case of a restrictive policy is $\Pi' = \Pi^* - \theta(\omega)$, where $\theta(\omega)$ is a government imposed penalty on profit that depends on the perceived signal. If environmental quality is not measured correctly, then $\omega = \delta\left(z_0 - \sum_i^n a_i\right)$, where δ is the probability of correctly measuring environmental quality and is a random variable with support [0, ∞), mean 1 and constant variance. This corresponds to the case of imperfect public monitoring of environmental quality. The penalty is assumed to take the form $\theta(\omega) = \theta\omega$. Substituting the farmers expected utility from lobbying is given by

$$E\Pi = p\left(\Pi^* \mid a^*\right)\left[\Pi^* - e_i\right] + p\left(\Pi' \mid a'\right)\left[\Pi^* - \theta\omega - e_i\right] \tag{7}$$

We will leave informational distinction to the later discussion and turn now to consumer behaviour. Firstly, it should be remarked that while consumers can send signals about environmental quality the signal does not depend on consumer actions. This is because consumers are assumed to be on the receiving end of the externality in our model. If consumers can also signal then this will only matter in the case of private monitoring, this is because $\omega_i = \omega_j$, for all i,j and $\omega = \delta\left(z_0 - \sum_i a_i\right)$ regardless. In the private monitoring case we need to make some assumptions as to who is monitoring the environment where. Assume farmers monitor the environmental quality at source (input monitoring) so that under imperfect private monitoring $\omega_i = z_0 - \sum_j \delta_{ij} a_j$ where δ_{ij} is the probability of the i-th agent correctly measuring environmental quality at the j-th source and is distributed as previously discussed. Knowledge of environmental quality depends on farmers communicating with each-other we will come back to this point when we discuss mediated and unmediated communication and the role it plays. Consumers on the other hand cannot monitor environmental quality at source (trespass laws apply) instead they monitor environmental quality at the point of consumption after the environment has been affected by pollution, so $\omega_i = \delta_i^c \left(z_0 - \sum_i a_i \right)$, where δ_i^c is the monitoring error of consumers. This differs from the individual monitoring error of farmers. Another interpretation of monitoring error here is that these correspond to consumer and individual producer beliefs about environmental quality.

From this we then obtain the expected utility of the environmentalist:

$$EU_j = p(U^* \mid a^*)[U^* - l_j] + p(U' \mid a')[U' - l_j] \qquad (8)$$

where:

$p(U^* \mid a^*) = \dfrac{\sum_{j=1}^{m} l_j}{\sum_{i=1}^{n} e_i + \sum_{j=1}^{m} l_j}$ and $p(U' \mid a') = 1 - p(U^* \mid a^*)$ Are the probabilities that farmers will be successful in their lobbying effort and unsuccessful in their lobbying effort respectively and U^* is the indirect utility function obtained from the previous optimization but with consumer welfare now affected by the perceive level of the public good, consequently environmental monitoring has an impact on consumer welfare. Whether or not pollution mitigation measures are implemented after lobbying consumers are concerned about environmental monitoring, if no policy measure is implemented they are concerned as it impact on their welfare and if a policy is adopted then they are concerned because they wish to know if it works or not.

Consequently, $U^* = U\left(a_i^*, \omega^*\right) = \left[\frac{B_i}{q} - \frac{1}{q} z_0\right]^\alpha \left(\omega^*\right)^\beta$. How the signal depends on farmer behaviour depends on whether or not farmers have won the political contest, so that optimal fertilizer application rates will be adjusted to account for any penalty imposed on farmers by government. This completes the outline of the model. In the following we derive the politico-economic equilibrium in lobbying effort for each information scenario and compare them.

3 Perfect Public Politico-Economic Equilibrium

In a perfect public politico-economic equilibrium δ=1 because environmental quality is now perfectly observable. We first derive the politico-economic lobbying equilibrium under this assumption. This gives us a theoretical benchmark against which to compare the other equilibria that we will obtain when we assume less than perfect mo9nitoring of environmental quality.

Farmers maximize

$$E\Pi = p\left(\Pi^* \mid a^*\right)\left[\Pi^* - e_i\right] + p\left(\Pi' \mid a'\right)\left[\Pi^* - \theta\omega - e_i\right]$$

by choosing e_i . We will assume symmetry throughout, so that after substituting probabilities we obtain:

$$E\Pi = \frac{ne}{ne+ml}\left[\Pi^* - e\right] + \left(1 - \frac{ne}{ne+ml}\right)\left[\Pi^* - \theta\omega - e\right]$$

where $\omega = \left(z_0 - na^*\right)$ and $a^* = \left[\frac{c}{p\alpha}\right]^{\frac{1}{\alpha-1}}$.

The first-order condition for this are given by (after substitution)

$$\frac{\partial EU}{\partial e} = \frac{n(ne+ml) - n^2 e}{(ne+ml)^2}\left[\Pi^* - e\right] - \frac{n(ne+ml) - n^2 e}{(ne+ml)^2}\left[\Pi^* - \theta\omega' - e\right] - 1 = 0$$

Solving for *e* and assuming *e* to be non-negative one obtains:

$$e(l) = \frac{-ml + \sqrt{nml(\theta\omega^*)}}{n}$$

Which will be non-negative if environmental damage is positive and $(\theta\omega^*) \geq \frac{ml}{n}$ in other words if environmental damage exceeds the ratio of the size of the two lobbying groups time the lobbying effort of environmentalists. Interesting is that the lobbying effort depends solely on the amount of environmental damage and the lobbying effort of the interest group.

Similarly the reaction function of the environmentalists to lobbying by farmers can be derived. Assuming symmetry the objective function of the environmentalists is given by:

$$EU = \frac{ne}{ne+ml}\left[U^* - l\right] + \left[1 - \frac{ne}{ne+ml}\right]\left[U' - l\right]$$

maximizing this one obtains the first-order condition:

$$\frac{\partial EU}{\partial l} = \frac{-nem}{(ne+ml)^2}\left[U^* - l\right] + \frac{nem}{(ne+ml)^2}\left[U' - l\right] - 1 = 0$$

From this one obtains only one positive real valued reaction function for the environmentalists:

$$l(e) = \frac{-ne + \sqrt{nem(U^{'} - U^{*})}}{m}$$

The indirect utility function of consumers is $U^{*} = U(a_{i}^{*}, \omega^{*}) = \left[\frac{\alpha}{\alpha+\beta}\frac{B}{q}\right]^{\alpha}(\omega^{*})^{\beta}$, recall that how the signal depends on farmer behaviour depends on whether or not farmers have won the political contest, so that optimal fertilizer application rates will be adjusted to account for any penalty imposed on farmers by government. Consequently, $U^{'}$ is obtained by first resolving the farmers profit maximizing problem taking into account the impact of a penalty on farmer behaviour. Therefore farmers solve:

$$\max_{a} \Pi(a) = pa^{\gamma} - ca - \theta\left(\frac{\beta}{\alpha+\beta}B - na\right)$$

where p is the price received for the crop, *a* the chosen action of the farmer, e.g. fertilizer application and c a cost associated with that action.

The optimal rate of fertilizer application is then given by:

$$a^{'} = \left[\frac{c - \theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}$$

So that fertilizer application is now reduced. Consequently, the consumers' indirect utility function is given by

$U^{*} = U(a_{i}^{*}, \omega^{*}) = \left[\frac{\alpha}{\alpha+\beta}\frac{B}{q}\right]^{\alpha}(\omega^{*})^{\beta}$ in the unrestricted case and in the restricted case by

$U^{'} = U(a_{i}^{*}, \omega^{'}) = \left[\frac{\alpha}{\alpha+\beta}\frac{B}{q}\right]^{\alpha}(\omega^{'})^{\beta}$.

The politico-economic equilibrium is given by equating the reaction functions and solving for (*e,l*). Clearly, $U^{'} > U^{*}$ and this can be verified by inspection. So that the lobbying effort will be positive for both interest groups.

Proposition 1:

$$l^{*} = \frac{nm(\theta\omega^{'})(U'-U^{*})^{2}}{[n(\theta\omega^{'}) + m(U^{'} - U^{*})]^{2}}$$

$$e^{*} = \frac{nm(U^{'} - U^{*})(\theta\omega^{'})^{2}}{[n(\theta\omega^{'}) + m(U'-U^{*})]^{2}}$$

Proof: See Hillman and Ursprung (1988).

■

Each of the different informational scenarios, consists now of a special case.

Case 1: Perfect public equilibrium:

$$l^{*} = \frac{nm(\theta\omega^{'})(U'-U^{*})^{2}}{[n(\theta\omega^{'}) + m(U^{'} - U^{*})]^{2}}$$

$$e^{*} = \frac{nm(U^{'} - U^{*})(\theta\omega^{'})^{2}}{[n(\theta\omega^{'}) + m(U'-U^{*})]^{2}}$$

The equilibrium will be independent of monitoring error delta because delta =1 and this is also the case for consumer perceptions of environmental quality. In what follows producers will behave the same however consumers will be affected by imperfect monitoring of environmental quality.

Case 2: Imperfect public Equilibrium

In the case of imperfect public monitoring things are more interesting.

farmers solve:

$$\max_a \Pi(a) = pa^{\gamma} - ca - \theta E(\delta)\left(\frac{\beta}{\alpha+\beta}B - na\right)$$

where p is the price received for the crop, a the chosen action of the farmer, e.g. fertilizer application and c a cost associated with that action. However, the principle of legal certainty requires that government not penalize farmers randomly. Consequently, government must penalize farmers by some constant amount. The penalty function cannot therefore depend on δ, however it could depend on a given realization of delta or better still on the mean value of some sample of measures of environmental quality $E(\delta)$. Assuming an unbiased monitoring instrument $E(\delta)=1$.

The optimal rate of fertilizer application is then given by:

$$a^{'} = \left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}$$

$\omega^{'} = \delta\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)$, so substituting one obtains:

$$l^{*} = \frac{nm\left(\theta\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)\right)(U'-U^{*})^{2}}{\left[n\left(\theta\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)\right) + m(U^{'} - U^{*})\right]^{2}}$$

$$e^* = \frac{nm\left(U^{'} - U^*\right)\left(\theta\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)\right)^2}{\left[n\left(\theta\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)\right) + m\left(U' - U^*\right)\right]^2}$$

Recall that the signal ω has variance $\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)^2 \operatorname{var}(\delta)$, so

$\operatorname{var}(\omega) = \left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)^2 \operatorname{var}(\delta)$ therefore

$\left(\frac{\beta}{\alpha+\beta}B - n\left[\frac{c-\theta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}\right)^2 = \frac{\operatorname{var}(\omega)}{\operatorname{var}(\delta)} = \left(\frac{\sigma_\omega}{\sigma_\delta}\right)^2$. The equilibrium can now be simplified to

$$l^* = \frac{nm\left(\theta\frac{\sigma_\omega}{\sigma_\delta}\right)\left(U' - U^*\right)^2}{\left[n\left(\theta\frac{\sigma_\omega}{\sigma_\delta}\right) + m\left(U^{'} - U^*\right)\right]^2}$$

and

$$e^* = \frac{nm\left(U^{'} - U^*\right)\theta^2\left(\frac{\sigma_\omega}{\sigma_\delta}\right)^2}{\left[n\left(\theta\frac{\sigma_\omega}{\sigma_\delta}\right) + m\left(U' - U^*\right)\right]^2}$$

Note that after substituting into the indirect utilities these become:

$$U' - U^* = \left[\frac{\alpha}{\alpha+\beta}\frac{B}{q}\right]^\alpha\left(\delta\frac{\sigma_\omega}{\sigma_\delta}\right)^\beta - \left[\frac{\alpha}{\alpha+\beta}\frac{B}{q}\right]^\alpha\left(\delta\frac{\sigma_\omega^*}{\sigma_\delta^*}\right)^\beta = \delta^\beta\left[\frac{\alpha}{\alpha+\beta}\frac{B}{q}\right]^\alpha\left[\left(\frac{\sigma_\omega}{\sigma_\delta}\right)^\beta - \left(\frac{\sigma_\omega^*}{\sigma_\delta^*}\right)^\beta\right]$$

Delta now appears because monitoring error affects consumer perceptions of environmental quality, although principles of the rule of law such as that of legal certainty prevent monitoring error having a direct impact on imposed penalties.

Note also that the signal and measurement process are different depending on whether the penalty has been imposed on farmers or not. Scientists will measure different levels of environmental damage in each of these cases and consumers will observe different levels of environmental quality.

So how does the equilibrium change as the ratio of the standard deviation of the perceived signal increases with respect to the standard deviation of the monitoring process? This ratio is a measure of lay uncertainty compared to scientific sagacity. Another way of interpreting it is in terms of people's scepticism about science. The larger this ratio, the more uncertain people are about the accuracy of measurements concerning environmental damage. The easiest way to answer this question is to differentiate the equilibrium values with respect to our consumer uncertainty ratio and then establish the sign of the derivative. To obtain a tractable solution we examine the case of a multiplicative utility function, i.e. we set $\alpha = \beta = 1$ and examine how a change in the quality of the signal would have an impact on the trivial equilibrium of zero lobbying effort. We analyse this equilibrium as a limiting case of the more general equilibrium. One way to think about this is that the zero lobbying case is a benchmark, implementation of the proposed policy to penalize farmers' results in a monitoring problem with respect to the effectiveness of the policy. Would an increase in people's trust of scientific information lead to an increase or a decrease in lobbying effort on the part of producers and consumers and therefore shift the equilibrium? What information induces people to become politically active? Does the level of their scepticism about scientific information play a role in this?

First notice that if utility is multiplicative $\alpha = \beta = 1$ so that after substituting

$$U' - U^* = \left[\frac{1}{2}\frac{B}{q}\right]\left(\delta\frac{\sigma_\omega}{\sigma_\delta}\right) - \left[\frac{1}{2}\frac{B}{q}\right]\left(\delta\frac{\sigma_\omega^*}{\sigma_\delta^*}\right) = \delta\left[\frac{1}{2}\frac{B}{q}\right]\left[\left(\frac{\sigma_\omega}{\sigma_\delta}\right) - \left(\frac{\sigma_\omega^*}{\sigma_\delta^*}\right)\right] = \delta\frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_\delta}\right)$$

where $\varepsilon\left(\frac{\sigma_\omega}{\sigma_\delta}\right)$ is the change in peoples scepticism about scientific information that is induced by the proposed policy, this depends linearly on the level of scepticism.

Propostion 2: An increase in exogenous public scepticism of scientific monitoring of environmental quality has no impact on consumer lobbying in the zero lobbying equilibrium.

Proof:

Substituting the expression for the change in consumer utility due to a change in policy into the equilibrium expressions gives:

$$l^* = \frac{nm\left(\theta\frac{\sigma_\omega}{\sigma_\delta}\right)\left(\delta\frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_\delta}\right)\right)^2}{\left[n\left(\theta\frac{\sigma_\omega}{\sigma_\delta}\right) + m\left(\delta\frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_\delta}\right)\right)\right]^2}$$

and

$$e^* = \frac{nm\left(\delta\frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_\delta}\right)\right)\theta^2\left(\frac{\sigma_\omega}{\sigma_\delta}\right)^2}{\left[n\left(\theta\frac{\sigma_\omega}{\sigma_\delta}\right) + m\left(\delta\frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_\delta}\right)\right)\right]^2}$$

Differentiating lobbying effort with respect to the ratio of standard deviations and taking the limit of the derivative as ε approaches zero allows us to evaluate the change in lobbying effort away from no political activity to becoming politically active due to an increase in scepticism about science.

The result is

$$\lim_{\varepsilon \to 0} \frac{\partial l^*}{\partial \left(\frac{\sigma_\omega}{\sigma_\delta} \right)} = 0$$

and

$$\lim_{\varepsilon \to 0} \frac{\partial e^*}{\partial \left(\frac{\sigma_\omega}{\sigma_\delta} \right)} = \delta \frac{m}{n} \frac{B}{2q}$$

■

This last expression is just the indirect utility of consumers due to private consumption scaled by the ratio of consumers to producers and accuracy of environmental monitoring.

Farm lobbies become political active in an environment of increasing scepticism about what science has to say about environmental quality and when farmers are relatively small in number compared with consumers. Consumers on the other hand would appear to remain unmoved by the degree of public scepticism.

A similar approach can be taken to analysing the impact that a change in the degree of scientific scepticism due to a policy shift may have on lobbying effort. Science driven policy changes engender increased scepticism about science due to the economic interests of the affected parties.

Proposition 3: An increase in policy induced public scepticism of scientific monitoring of environmental quality has no impact on consumer lobbying in the zero lobbying equilibrium.

Proof: Differentiating the equilibrium expression with respect to ε and evaluating the derivative at ε=0 gives $\left.\frac{\partial l^*}{\partial \varepsilon}\right|_{\varepsilon=0} = 0$. ■

Consequently the zero lobbying equilibrium is stable with respect to any policy instrument increase in scientific scepticism. This result is somewhat surprising as it implies that consumers will not respond directly to any increase in scepticism arising from the policy itself. Consumer scepticism about scientific evidence appears to be exogenous to the policy process itself.

Proposition 4: $\left.\frac{\partial e^*}{\partial \varepsilon}\right|_{\varepsilon=0} = \delta \frac{m}{n} \frac{B}{2q}$

Proof: Differentiating the equilibrium expression with respect to ε and evaluating the derivative at ε=0 gives the desired result.■

In this case producers will deviate from the zero lobbying equilibrium in response to an increase in public scepticism about monitoring of environmental quality proportional to the private component of consumers indirect utility. Producers' decisions to begin lobbying are therefore affected by increased public scepticism about the quality of environmental monitoring. This is in clear contrast to consumers. The conclusion here is that producers are likely to respond in a far more sensitive manner to public scepticism about the quality of scientific monitoring of environmental quality than consumers. The key driver here is not improved accuracy in the measurement of environmental quality σ_δ becoming smaller although this clearly plays a role but public perception of environmental quality relative to the accuracy of monitoring. Public perception is influenced by both endogenous policy factors as well as exogenous factors that go beyond the immediate policy context. Producers respond to both of these pathways but consumers appear to be solely responsive to exogenous factors. Consequently, consumers care little about the size of policy impacts and whether perceived levels of variation in monitoring environmental quality are impacted by these, producers on the other hand are highly sensitive.

We next turn to case 3 and examine how private monitoring on the part of producers and consumers affects the politico-economic equilibrium.

Case 3: Imperfect Private Monitoring

$$l^* = \frac{nm(\theta\omega^{'})(U'-U^*)^2}{[n(\theta\omega^{'}) + m(U^{'} - U^*)]^2}$$

$$e^* = \frac{nm(U^{'} - U^*)(\theta\omega^{'})^2}{[n(\theta\omega^{'}) + m(U'-U^*)]^2}$$

the signal is then substituted into this assuming a symmetric equilibrium. Consumers and producers receive different signals. The farmer receives the following signal:

$$\omega = z_0 - n\delta a \, .$$

Consumers on the other hand receive:

$$\omega = \delta^c (z_0 - na)$$

Farmers solve:

$$\max_a \Pi(a) = pa^{\gamma} - ca - \theta\left(\frac{\beta}{\alpha+\beta}B - n\delta a\right)$$

where p is the price received for the crop, *a* the chosen action of the farmer, e.g. fertilizer application and c a cost associated with that action. Note that in this formulation the penalty is based on reported demands for the public good net of farmers reported fertilizer application rates, as reported for example by an extension officer familiar with farm practice. Consumer perceptions are not used to determine the level of penalty. If delta is now interpreted as a given realization of monitoring error characteristic of how well farmers are informed but constant, then we can distinguish three cases of interest, farmers have an unbiased estimate of environmental quality. They consistently, underestimate the damage they cause or they consistently overestimate the damage they cause. The argument concerning legal certainty can no longer be used here. A polluting producer facing a possible penalty is likely to underestimate any damage caused. Private monitoring does not imply private compliance. Policy still needs to address the issue of compliance.

The optimal rate of fertilizer application is then given by:

$$a' = \left[\frac{c - \theta\delta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}$$

So that fertilizer application is now reduced and the signal received by farmers becomes

$$\omega = z_0 - n\delta\left[\frac{c - \theta\delta n}{p\gamma}\right]^{\frac{1}{\gamma-1}}$$

Because the signal is now non-linear in delta we can only with difficulty establish a relationship between the variance of the signal and variance of monitoring error. However if we assume farmers know their own beliefs about the damage they cause and that these are essentially constant and not random. Then we can determine the variance of the signal received by consumers similarly to the way in which we did this in the imperfect public monitoring case. Another way to interpret this is that we can derive the variance and standard deviation of the marginal distribution of the signal received by consumers. This is done as follows:

First consider the signal received by consumers $\omega = \delta^c(z_0 - na)$, fertilizer application rate a is now considered constant (we are only analysing the marginal distribution). The variance of the signal is therefore, $Var(\omega) = (z_0 - na)^2 Var(\delta^c)$, so $\frac{\sigma_\omega}{\sigma_{\delta^c}} = z_0 - na = \frac{\beta}{\alpha+\beta}B - na$ which is now interpreted as the degree of scientific scepticism of consumers alone.

Or for a multiplicative utility function

$\frac{\sigma_\omega}{\sigma_{\delta^c}} = \frac{B}{2} - na$, where a may be either the fertilizer application rate after penalty $a^{'}$ or the fertilizer application rate without penalty a^*.

Note that, the consumers' indirect utility function is given by

$U^* = U(a_i^*, \omega^*) = \left[\frac{B}{2q}\right]^\alpha (\omega^*)^\beta$ in the unrestricted case (theta=0) and in the restricted case (theta > 0) by $U^{'} = U(a_i^*, \omega^{'}) = \left[\frac{B}{2q}\right]^\alpha (\omega^{'})^\beta$.

Recall that consumers cannot monitor environmental quality at source (trespass laws apply) instead they monitor environmental quality at the point of consumption after the environment has been affected by pollution, so $\omega = \delta^c(z_0 - na)$ assuming symmetry.

Substituting the signals and indirect utilities into the equilibrium expressions and assuming multiplicative utility we get:

$$l^{*} = \frac{nm\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right)\left(U^{'} - U^{*}\right)^{2}}{\left[n\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right) + m\left(U^{'} - U^{*}\right)\right]^{2}}$$

$$e^{*} = \frac{nm\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right)^{2}\left(U^{'} - U^{*}\right)}{\left[n\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right) + m\left(U^{'} - U^{*}\right)\right]^{2}}$$

Notice also that

$$U^{'} - U^{*} = \left[\frac{B}{2q}\right]\left(\delta^{c}\left(\frac{B}{2} - na^{'}\right)\right) - \left[\frac{B}{2q}\right]\left(\delta^{c}\left(\frac{B}{2} - na^{*}\right)\right) = n\delta^{c}\frac{B}{2q}\left(a^{*} - a^{'}\right)$$

or alternatively

$$U^{'} - U^{*} = \left[\frac{B}{2q}\right]\left(\delta^{c}\left(\frac{\sigma_{\omega}}{\sigma_{\delta^{c}}}\right)\right) - \left[\frac{B}{2q}\right]\left(\delta^{c}\left(\frac{\sigma_{\omega}^{*}}{\sigma_{\delta^{c}}^{*}}\right)\right) = \delta^{c}\frac{B}{2q}\left(\frac{\sigma_{\omega}}{\sigma_{\delta^{c}}} - \frac{\sigma_{\omega}^{*}}{\sigma_{\delta^{c}}^{*}}\right) = \delta^{c}\frac{B}{2q}\varepsilon\left(\frac{\sigma_{\omega}}{\sigma_{\delta^{c}}}\right)$$

Substituting and simplifying in we get:

$$l^{*} = \frac{nm\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right)\left(\delta^{c}\frac{B}{2q}\left(a^{*} - a^{'}\right)\right)^{2}}{\left[\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right) + m\left(\delta^{c}\frac{B}{2q}\left(a^{*} - a^{'}\right)\right)\right]^{2}}$$

$\frac{B}{2} - n\delta a^{'}$ is the difference between the consumer demand for private consumption and the total external cost that producers perceive that they impose upon consumers. When this is premultiplied by the penalty rate this can be interpreted as the opportunity cost of consumption or alternatively as a deadweight loss borne by consumers that is associated with the policy instrument. $\frac{B}{2q}\left(a^{*} - a^{'}\right)$ is the consumer demand for private consumption times the reduction in applied fertilizer. When premultiplied by the consumers' belief regarding environmental quality this can be interpreted as the perceived gain to consumers from the policy in terms of private goods. Consequently lobbying is a ratio of private losses times the square of private gains to the square of a weighted sum of private losses to private gains from the policy. The weights are given by the penalty parameter and the size of the consumer interest group.

Farmers optimal lobbying effort is given by

$$e^{*} = \frac{m\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right)^{2}\left(\delta^{c}\,\frac{B}{2q}\left(a^{*} - a^{'}\right)\right)}{\left[\left(\theta\left(\frac{B}{2} - n\delta a^{'}\right)\right) + m\left(\delta^{c}\,\frac{B}{2q}\left(a^{*} - a^{'}\right)\right)\right]^{2}}$$

This says lobbying effort of farmers is the ratio of private benefits due to introducing the penalty time the square of private opportunity costs divided by a weighted sum of private opportunity costs net of externalities and private benefits of changed fertilizer use due to the imposition of the penalty. The weights imposed are in both cases the size of the penalty parameter and the size of the consumer interest group. Alternatively, expressing the equilibrium in terms of consumer scepticism we get:

$$l^* = \frac{nm\left(\theta\left(\frac{B}{2} - n\delta a'\right)\right)\left(\delta^c \frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_{\delta^c}}\right)\right)^2}{\left[\left(\theta\left(\frac{B}{2} - n\delta a'\right)\right) + m\left(\delta^c \frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_{\delta^c}}\right)\right)\right]^2}$$

$$e^* = \frac{m\left(\theta\left(\frac{B}{2} - n\delta a'\right)\right)^2\left(\delta^c \frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_{\delta^c}}\right)\right)}{\left[\left(\theta\left(\frac{B}{2} - n\delta a'\right)\right) + m\left(\delta^c \frac{B}{2q}\varepsilon\left(\frac{\sigma_\omega}{\sigma_{\delta^c}}\right)\right)\right]^2}$$

What impact does consumer scepticism about the quality of environmental monitoring now have on the politico-economic equilibrium?

Proposition 5: An increase in exogenous consumer scepticism of scientific monitoring of environmental quality has no impact on consumer lobbying in the zero lobbying equilibrium.

Proof: Differentiating lobbying effort with respect to the ratio of standard deviations and taking the limit of the derivative as ε approaches zero allows us to evaluate the change in lobbying effort away from no political activity to becoming politically active due to an increase in scepticism about science.

The result is

$$\lim_{\varepsilon \to 0} \frac{\partial l^*}{\partial\left(\frac{\sigma_\omega}{\sigma_\delta}\right)} = 0$$

■

This result does not differ from the imperfect public equilibrium case. The same cannot be said for the impact of consumer scepticism on farmers propensity to become politically active.

Proposition 6 Under private monitoring farmers propensity to become politically active in response to consumer scepticism about scientific evidence is greater than their propensity to become politically active under public monitoring if the number of farmers is greater than the ratio of farmer beliefs about environmental quality to consumer beliefs about environmental quality.

Proof: Differentiating lobbying effort with respect to the ratio of standard deviations and taking the limit of the derivative as ε approaches zero allows us to evaluate the change in lobbying effort away from no political activity to becoming politically active due to an increase in scepticism about science. The result is

$\lim_{\varepsilon \to 0} \frac{\partial e^*}{\partial \left(\frac{\sigma_\omega}{\sigma_\delta} \right)} = m\delta^c \frac{B}{2q}$ comparing this with the imperfect public monitoring result $\delta \frac{m}{n} \frac{B}{2q}$ and simplifying we obtain for response of farmers to consumer uncertainty to be greater than the response of farmers to public uncertainty, that $n > \frac{\delta}{\delta^c}$ or the number of farmers must be greater than the ratio of farmer beliefs about environmental quality to consumer beliefs about environmental quality.

Farmers are likely to underestimate fertilizer application rates and consumers overestimate damage, i.e. underestimate the available environmental quality. So both delta's are likely to be less than 1. If farmers are relatively well informed about each others actions but consumers relatively ill-informed and if the number of farmers is sufficiently small then farmers are likely to have a low propensity for political activity under private monitoring compared with public monitoring (the inequality will be reversed). Consequently, we can conclude that public monitoring is more likely to encourage farm activism than private monitoring in the real world (real world here means a world in which there are a small number of relatively well-informed farmers and a large number of relatively ill-informed consumers). The opposite would hold for a world in which consumers were better informed than farmers.

What role does extension play in this? Extension influences the standard deviation of the signal perceived by farmers. In a world of public monitoring extension can influence farmer's propensity to political activism but not that of consumers. In a world of private monitoring extension has no impact when it targets farmers. Targeting consumers through extension programmes could however have an impact on the political activism of farmers by allaying their fears about anti-scientific green consumer groups. A more effective form of extension under private monitoring would be to promote the use of soil monitoring technology amongst farmers and thereby increase the accuracy of scientific monitoring. To some extent this is where things have been heading.

6 Conclusion

In this paper we have extended a Tullock game of environmental lobbying to the case of imperfect monitoring of environmental quality. We have considered three cases: perfect monitoring of environmental quality, imperfect public monitoring of environmental quality and imperfect private monitoring of environmental quality. In the first case the equilibrium will be independent of monitoring error delta because delta =1 and this is also the case for consumer perceptions of environmental quality. In the second case we were able to prove that consumers would not respond to increased scepticism about scientific evidence by increasing lobbying effort, however farmers are sensitive to the degree of scepticism about scientific information and are likely to become politically active in response to scepticism about scientific evidence, whether this is induced by a proposed policy or is exogenous to the policy process. In the third case, we have provided an interpretation of the politico-economic equilibrium in terms of opportunity costs to consumers and gains to consumers due to the imposition of a penalty on farmers. Perceived opportunity costs under imperfect monitoring relative to true opportunity costs to consumers play a role in this. Interesting is that opportunity costs here are in terms of private consumption net of the external effect and gains to consumers are in terms of a wealth effect on consumers that can be attributed to a reduced externality effect.

The results have implications for extension programmes and the choice of public versus private monitoring of non-point source pollution. In a world of public monitoring extension can influence farmers' propensity to political activism but not that of consumers'. In a world of private monitoring extension has no impact when it targets farmers. Targeting consumers through extension programmes could however have an impact on the political activism of farmers by allaying their fears about anti-scientific green consumer groups. A more effective form of extension under private monitoring would be to promote the use of soil erosion monitoring technology amongst farmers and thereby increase the accuracy of scientific monitoring. To some extent this is where much of the on-farm monitoring efforts have been heading. More work is needed to explore these results further.

References

Abreu,D., Pearce, D and Stachetti, E. (1986) Optimal cartel equilibrium with imperfect monitoring, *Journal of Economic Theory* Vol. 39 pp. 251-269.

Aidt, T. (1998) Political internalization of economic externalities and environmental policy, *Journal of Public Economics*, Vol. 69, pp. 1–16.

Braden, J. B. and K. Segerson (1991). *Information Problems in the Design of Nonpoint Source Pollution Policy*.

Brooks, M.A. and Heijdra, B.J. (1987) Rent-seeking and Pollution Taxation: An extension, *Southern Economic Journal* Vol 54 No. 2 pp. 335-342.

Damania, R. (1999) Political competition, Rent Seeking and the Choice of Environmental Policy Instruments, *Environment and Resource Economics* Vol. 13 pp. 415-433.

Frederikson, P.G. (1997) The political economy of pollution taxes in a small open economy, *Journal of Environmental Economics and Management*, Vol. 33 pp. 44–58.

Frederikson, P.G. (2003) Political instability, corruption and policy formation, the case of environmental policy, *Journal of Public Econom*ics Vol. 87, pp. 1383-1405.

Hillman, A.L. and Ursprung, H. (1988) Domestic politics, foreign interests, and international trade policy, *American Economic Review* Vol. 78 No. 4, pp. 729-745.

Horan, R. D. and M. O. Ribaudo (1999). "Policy objectives and economic incentives for controlling agricultural sources of nonpoint pollution." *Journal of the American Water Resources Association* Vol. 35 No. 5, pp. 1023-1035.

Lee, D. R. (1985) Rent-seeking and its implications for pollution taxation, *Southern Economic Journal* , pp. 731-744.

Lichtenberg, E., I. Strand, et al. (1993). Subsidizing agricultural non-point source pollution control: targeting cost sharing and technical assistance. *Theory, Modeling, and Experience in the Management of Nonpoint-Source Pollution*. C. Russell and J. Shogren. Boston, MA, Kluwer Academic Publishers**:** 305-328.

Lockard, A. and Tullock, G. (Eds.) (2001) *Efficient Rent Seeking: Chronicle of an Intellectual Quagmire*, Kluwer Boston.

Mailath, G. J. and L. Samuelson (2005). *Repeated Games and Reputations: Long-Run Relationships* Oxford University Press.

Migue J-L. and Marceau R. (1993) Pollution Taxes, Subsidies and Rent Seeking, *Canadian Journal of Economics* Vol. 26 No. 2, pp. 355-365.

Neary, H.M. (1997) A Comparison of Rent-Seeking Models and Economic Models of Conflict, *Public Choice* 93: 373-388.

Olson, M. (1965). *The logic of collective action: Public goods and the theory of groups*. Cambridge, Massachusetts, Harvard University Press.

Polk, A. and Schmutzler, A. (2005) Lobbying against environmental regulation vs. lobbying for loopholes, *European Journal of Political Economy* Vol. 21: 915-931.

Ribaudo, M. O., R. D. Horan, et al. (1999). Economics of Water Quality Protection From Nonpoint Sources: Theory and Practice. *Agricultural Economics Report No 782*. Washington DC, USDA.

Smith, R. B. W. and T. D. Tomasi (1995). "Transaction costs and agricultural nonpoint-source water pollution control policies." *Journal of Agricultural and Resource Economics* Vol. 20: 277-290.

Stigler, G. J. (1971). "The Theory of Economic Regulation." *Bell Journal of Economics and Management Science* Vol. 2: 1-21.

Tullock G. (1980) Efficient Rent Seeking, in: Buchanan, J. Tollison, R.D. and Tullock, G., *Toward a Theory of the Rent-Seeking Society,* Texas A&M University Press, College Station.

Ursprung, H.W. (1990) Public Goods, Rent Dissipation and Candidate Competition, *Economics and Politics* Vol.2 No.2, pp. 115-132.

Wilson, J.K. and Damania, R. (2005) Corruption, political competition and environmental policy, *Journal of Environmental Economics and Management* Vol. 49, pp. 516-535.