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SOCIAL REWARDS AND THE DESIGN OF VOLUNTARY INCENTIVE MECHANISM FOR BIODIVERSITY PROTECTION ON FARMLAND

Rupayan Pal, Ada Wossink, and Prasenjit Banerjee

Indira Gandhi Institute of Development Research, Mumbai
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Email(corresponding author): rupayan@igidr.ac.in

Abstract

We examine how endogenous social preferences could affect economic incentive design to encourage biodiversity protection on private land. A 'green' farmer may enjoy esteem from leading by example if there are few farmers who do the right thing. In contrast a farmer without social preferences ('brown' farmer) might merely tick the boxes and is expected to shirk from the desired environmental actions whenever possible unless this affects their reputation. We analyze the design of an incentive scheme that takes into account both types of farmers ('green' or 'brown') under asymmetric information about their true motivation. It follows that under perfect Bayesian equilibrium, the regulator can separate out the farmer types in a two-period setting by monitoring their voluntary conservation actions in response to payment in the first period. The optimal mechanism would be a mixture of a facilitation contract with small monetary incentive but high visibility to keep 'green' farmers interested and a higher monetary-incentive contract to attract the brown farmers.

Keywords: Mechanism Design, Social Norm, Esteem, Motivation Crowding, Signalling, Public goods, Agriculture.

JEL Code: D03 (Behavioural micro-economics - underlying principles); Q57 (Environmental Economics - ecosystem services); Q58 (Environmental Economics - governmental policy); D82 (Asymmetric and Private Information - Mechanism Design)

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Abstract

We examine how endogenous social preferences could affect economic incentive design to encourage biodiversity protection on private land. A 'green' farmer may enjoy esteem from leading by example if there are few farmers who do *the right thing*. In contrast a farmer without social preferences ('brown' farmer) might merely *tick the boxes* and is expected to shirk from the desired environmental actions whenever possible unless this affects their reputation. We analyze the design of an incentive scheme that takes into account both types of farmers ('green' or 'brown') under asymmetric information about their true motivation. It follows that under perfect Bayesian equilibrium, the regulator can separate out the farmer types in a two-period setting by monitoring their voluntary conservation actions in response to payment in the first period. The optimal mechanism would be a mixture of a facilitation contract with small monetary incentive but high visibility to keep 'green' farmers interested and a higher monetary-incentive contract to attract the brown farmers.

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[1]Indira Gandhi Institute of Development Research, Mumbai, India; [2, 3] Economics, University of Manchester, UK;

Email: [1]rupayan@igidr.ac.in ; [2]ada.wossink@manchester.ac.uk; [3] prasenjit.banerjee@manchester.ac.uk

***Corresponding author**: Department of Economics, School of Scocial Sciences, University of Manchester, Oxford Road, Manchester, M13 9PL, UK. Phone: +441613066916.

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1. **Introduction**

Voluntary green payment policies are receiving increasing attention as a means for enhancing the supply of environmental public goods from land that remains in agricultural production (OECD, 2015). In the European Union, in particular, there has been a movement towards this type of policy. The implementation progressed rapidly and agri-environmental schemes now constitute a central element of the Common Agricultural Policy[1]. However, despite the high percentage of agricultural area enrolled[2] there is ample evidence that the ecological results are largely underwhelming which puts into question the cost-effectiveness of these schemes (e.g., Batáry et al., 2015). For this situation to improve, the regulator may want to design an incentive structure that would induce the appropriate environmental management behaviour instead of merely encouraging the enrolment of acreage as such in voluntary schemes. Engagement with farmers' underlying motives might enable more cost effective approaches and move farmers from 'tick box compliance' (with regulatory requirements of voluntary agri-environmental schemes) to a committed environmental stewardship where ecological outcomes are of higher quality and sustained (Pike, 2013; Lokhorst et al., 2011).

A rich literature now supports the importance of personal and social norms to understanding the underlying reasons for farmers' environmental management behaviour (e.g., Howley, 2013; Burton and Paragahawewa, 2011; Mills et al., 2017; Lokhorst et al., 2014). In parallel there is increasing empirical evidence that farmers may engage in voluntary in environmental management activities without any payment which shows that intrinsic and social goals play a

[1] Agri-environmental schemes became a mandatory part of the policy toolkit in EU Member States as part of Pillar II (Rural Development) of the Common Agricultural Policy in 2005. These schemes involve individual contracts signed with farmers who volunteer to implement pro-environmental practices in return for an annual payment. The payment is based on income foregone plus addition costs both determined at the national level. Over 2007-2013, the annual average spending from EU's Fund for Rural Development was €3.3 billion. It is the highest conservation expenditure in the EU.

[2] For example, in the UK 45 % of the utilised agricultural area or 7.8 million ha was enrolled in 2009. See http://ec.europa.eu/eurostat/statistics-explained/pdfscache/16830.pdf

role[3]. In line with these findings, farmers' conservation activities can be attributed to extrinsic, intrinsic, and social motivation but so far the heterogeneity in farmers' commitment to environmental management and the role of their social motivation has been underused in environmental policy design (Defra, 2013; Mills et al., 2017).

Individuals who care about their social image or reputation behave differently when their actions and choices can be observed by others—with more pro-social or intrinsic behaviour in public than private settings (i.e., 'audience effect') (e.g., Bénabou and Tirole, 2006; Dana et al., 2007; Ariely et al., 2009; Andreoni and Bernheim, 2009). Such reputation effects are of particular interest when studying farmers who are open to the direct, uninvited and unavoidable scrutiny of the peer group. A farmer selecting conservation activities on farmland signals, by construction, his social preferences to other farmers or significant others who are able to observe the implemented conservation practices, such as friends and family, or to the retrospective future self to bolster self-perception[4]. Those farmers that value reputation will derive utility from the social esteem[5] associated with their visible conservation activities, conditional on these activities yielding a positive image (see Ellingsen and Johannesson, 2008).

In this paper, we propose a novel mechanism design that takes into account the heterogeneity in farmers' environmental performance as well as in their motives. To ensure improved ecological effects from conservation activities on farmland we propose the use of a facilitative incentive (Grabosky, 1995). The facilitation incentive means the regulator invites farmers with exemplary environmental performance to join an expert opinion/information

[3] A well-documented example of this is farmers' participation in the Campaign for the Farmed Environment. See www.gov.uk/government/statistics/campaign-for-the-farmed-environment

[4] Kuhfuss et al. (2016) for example shows that almost half of the French farmers in their study were willing to maintain contracted conservation practices after the end of the contract and that information about what other farmers intended to do (the social norm) influenced their own decision. This suggests that for farmers that value reputation, the increase in the signalling value counteracted the effect of the lost payment, in effect crowding-in reputational motives. Chen et al. (2009), in a study conducted in China on panda conservation, found that in addition to conservation payment amounts and program duration, social norms at the neighbourhood level had significant impacts on program re-enrolment, suggesting that social norms can be used to leverage participation for efficient conservation investments.

[5] We use 'esteem' (and 'disesteem') as this is defined in economic terms by Brennan and Pettit (2004). Words like social approval, prestige and respect would have almost the same meaning (see Ellingson and Johannesson, 2011).

program on environmental practices and their implementation. The facilitation signals how specific ('green') farmers successfully deliver environmental public goods while cost-effectively managing farmland and that the regulator is interested in working with them to enhance this further. This would serve to convey the *injunctive norm* (the behaviour approved by the regulator). At the same time such an initiative could also help to move greenways the *descriptive norm* (i.e., what most farmers do). Most farmers are uncertain about the 'appropriate' environmental management behaviour and therefore take their cue from the social norm. In this manner strategic 'niche' management can be used as a policy tool to strengthen environmental change 'from below'[6].

The facilitation above provides the green farmers with the opportunity for social esteem. This could be further ensured through the introduction of a symbolic reward, e.g., a medal or plaque, to formally recognise good behaviour at a small monetary cost to the regulator, as an alternative to money[7]. If a regulator were to use only monetary incentives, this can crowd out the incentives of reputation-concerned farmers[8]. Was the regulator to refrain from using monetary rewards, (or using a small monetary reward only) this would mean no incentives to the brown farmers. Therefore an "optimal mechanism" could be a combination of the two — a menu of contracts that supports a separating equilibrium. The regulator offers a contract, with a small monetary incentive and high reputation for the green farmers' behaviour and a high monetary-incentive contract to attract the brown farmers.

[6] For example, CapeNature's Biodiversity Stewardship programme facilitates biodiversity conservation on privately owned land in Western Cape, South Africa, by providing advice, management plans and assistance, clearing and fire management schedules, and supports to benefit more from biodiversity through ecologically sensitive income-generating avenues (CapeNature, 2016). Participation in this program is purely voluntary. Similar biodiversity protection programs are in place in other South African provinces (Selinske et al, 2015).

[7] Structured programs could include regular events such as an 'environmental champions of the year' luncheon.

[8] Monetary rewards may weaken intrinsic motivation, i.e., the crowding out effect due to e.g., *the hidden cost of rewards*, the *overjustification effect*, or the *corruption effect* (see Deci and Ryan, 1985; Frey and Jegen, 2001 ; Frey and Oberholzer-Gee, 1997; Bowles, 2008). Monetary rewards may help reduce the ability to indulge altruistic feelings, or may adversely affect reputation as taking money for a noble work may be seen as 'money hungry' behaviour (Bénabou and Tirole, 2006; Ariely et al., 2009; Banerjee and Shogren, 2012).

One potential problem with farmland-biodiversity protection is that it is not a one-shot enrolment of acres of land. It requires continuous costly efforts from a farmer to generate the intended ecological result. Under asymmetric information, if a brown farmer successfully signals being green by mimicking a green farmer, this may generate a welfare loss; a brown farmer would merely *tick the boxes* and is expected to shirk from the desired environmental actions whenever possible. We address here how to distinguish and induce green farmers in protecting farmland biodiversity by developing a two-period signal extracting problem. In period one, both types of farmer choose their optimal environmental actions in response to the monetary incentive only. Their environmental actions become common knowledge at the end of the period and lead to monetary compensation from the regulator. Having observed farmers' actions, in period two the regulator selects the green type farmers for the facilitation contract whereas the brown type farmers are offered the high-monetary-incentive contract. Results show that, under perfect Bayesian equilibrium conditions, the regulator can separate out the types and that the mechanism reduces overall cost for the regulator. Moreover, the contract design is welfare maximizing — the facilitation contract that includes the social reward (a plaque, medal, certificate or other symbolic reward), has a value which is decreasing in the total number of contracts awarded.

To illustrate how our design is closely based on what is observed in practice we discuss recent developments in voluntary conservation management in U.K. agriculture. Our focus is on the Campaign for the Farmed Environment (CFE), launched by the farming organisations in 2009. During the 2013/14 crop year, 44% of farms in England participated in the CFE totalling 450 thousand hectares. The farmers involved could have received compensation payment for the very same conservation practices through the main government-led agri-environmental scheme. But they opted not to. Given that conservation management on farm land involves economic sacrifices, the CFE data strongly suggest social preferences and social norms are important in this specific context.

2. Mechanism design with social reward

A farmer considers environmental management practices on his private land with homogeneous quality. Let ϑ denote the farmer's intrinsic valuation of money and ϑ follow a distribution function $F(\boldsymbol{v})$ and density $f(\boldsymbol{v})$ with mean $\bar{\vartheta}$. We consider a two period game between a regulator and a farmer, who can be one of two types – green (G) or brown (B). These two types of farmers differ from each other in three respects. First, a green farmer's intrinsic valuation for money (ϑ^{G}) is less than that of a brown farmer (ϑ^{B}): $\vartheta^{\mathrm{G}} < \vartheta^{\mathrm{B}}$. Second, initially a farmer possesses the same know-how to protect biodiversity regardless of his type. However, if the regulator facilitates farmers' biodiversity protection action (x), a green farmer can protect the biodiversity in a more effective manner compared to that by a brown farmer. Third, the green farmer's reservation utility ($\underline{U}^G$) is less than the reservation utility of the brown farmer ($\underline{U}^B$): $\underline{U}^G < \underline{U}^B$. For expositional simplicity we make the following assumption.

Assumption 1: *Green and brown farmers' intrinsic valuations for money and their reservation utilities satisfy the relation* $\frac{\underline{U}^G}{\vartheta^G} > \frac{\underline{U}^B}{\vartheta^B}$.

The farmer's type is his private information. The regulator and other people in the society have identical prior beliefs regarding the type of the farmer. In absence of any additional information, it is believed that the farmer is of green-type with probability ρ $(0 \leq \rho \leq 1)$ and brown-type with probability $1 - \rho$.

In each period the regulator offers an incentive scheme for the farmer and the farmer undertakes some biodiversity protection action, which are common knowledge. Stages of the game involved are as follows.

Period 1:

Stage1. Nature decided the type of the farmer – green (G) or brown (B), which becomes the farmer's private information.

Stage 2. The regulator offers a lump-sum monetary compensation t_1 (≥ 0) for biodiversity protection.

Stage 3. The farmer of type i $(= G, B)$ chooses his biodiversity protection action (x_1^i) and produces $g(x_1^i)$ amount of public good, which are observable and verifiable by the regulator.

Period 2:

Stage 1. The regulator decides whether to facilitate the farmer's biodiversity protection action or not and offers incentives accordingly, given the action undertaken by the farmer in the first period.

Stage 2. The farmer of type i $(= G, B)$ chooses his biodiversity protection action (x_2^i) and produces $f^i(x_2^i)$ amount of public good, which are publicly observable and verifiable.

Stage 3. The farmer gains social reputation, if any.

If the farmer's biodiversity protection action is facilitated by the regulator, the regulator offers him some non-monetary incentives, such as felicitation by presenting a 'medal' and invitation to join an expert opinion/information program as well as a lump-sum monetary compensation t_2^s (≥ 0) in period two. Otherwise, the regulator offers the farmer only a lump-sum monetary compensation t_2^n (≥ 0), as in period one. Non-monetary incentives offered by the regulator play a crucial role in determining the farmer's social reputation. If a farmer receives a non-monetary incentive from the regulator, he gains social reputation and the gain in social reputation increases with the action undertaken to protect biodiversity in the second period (see, e.g., Besley and Ghatak, 2008)[9]. Further, if a brown farmer receives non-monetary incentives from the regulator, his gain in social reputation, if any, is less than that of a green farmer, since (a) his intrinsic valuation for money is higher than that of a green farmer and satisfaction from monetary compensation for doing the right thing adversely affects reputation, and (b) an award loses it social value at least to some extent, if not fully, when there are many recipients. Following Bénabou and Tirole (2006) and the discussion above, we consider that the type i farmer's social reputation function, which is given by equation (1), satisfies Assumption 1;

$$R^i = R\big(E\big(\vartheta \big| x_1^i, t_1^i\big),\ x_2^i\big), i = G, B, \tag{1}$$

where $E\big(\vartheta \big| x_1^i,\ t_1^i\big)$ is the expected value of type i farmer's intrinsic valuation for money given the biodiversity protection action undertaken by him in the first period and monetary compensation received by him for this action. For simplicity, the farmer's social reputation in absence of any non-monetary incentive is normalized to be zero.

Assumption 2: $R\big(E\big(\vartheta \big| x_1^i, t_1^i\big),\ x_2^i\big)$ is twice continuously differentiable function in $E\big(\vartheta \big| x_1^i, t_1^i\big) \in [\vartheta^G, \vartheta^B]$ and $x_2^i \geq 0$, such that (i) $\frac{\partial R(E(\vartheta | x_1^i,\ t_1^i),\ x_2^i)}{\partial E(\vartheta | x_1^i,\ t_1^i)} < 0$, (ii) $\frac{\partial R(E(\vartheta | x_1^i,\ t_1^i), x_2^i)}{\partial x_2^i} \geq 0$, (iii) $\frac{\partial}{\partial x_2^i}\left[\frac{\partial R(E(\vartheta | x_1^i,\ t_1^i), x_2^i)}{\partial x_2^i}\right] \leq 0$, (iv) $\frac{\partial}{\partial E(\vartheta | x_1^i,\ t_1^i)}\left[\frac{\partial R(E(\vartheta | x_1^i,\ t_1^i), x_2^i)}{\partial x_2^i}\right] \leq 0$, and (iv) $R(\vartheta^B,\ 0) \geq 0$ $i = G, B$.

Assumption 2 implies that, under complete information or when the farmer's true type can be correctly inferred by observing his first period's behaviour (i.e., when $E\big(\vartheta \big| x_1^i,\ t_1^i\big) = v^i$, $i = G, B$), (i) $R(\vartheta^G,\ x_2^G) > R(\vartheta^B,\ x_2^B) > 0, \forall\, x_2^G \geq x_2^B > 0$ and (ii) for any x_2, $\frac{\partial R(\vartheta^G,\ x_2)}{\partial x_2} \geq$

[9] Besley and Ghatak (2008) argue that status incentives, such as tokens, medals, can increase effort, even when effort is not observable. Fehr and Schmidt (1999) also emphasize the role of relative rewards.

$\frac{\partial R(\vartheta^B,\ x_2)}{\partial x_2} \geq 0$. That is, when the farmer's true type is known to all and the regulator offers him non-monetary incentives, (i) a green farmer enjoys strictly higher social reputation than a brown farmer, unless the former undertakes less biodiversity protection action than the latter in the second period, (ii) due to an increase in his second period's action from any given level, the increment in social reputation of the green farmer is at least as large as that of the brown farmer.[10]

In period one, the utility of a farmer of type i is assumed to be given by

$$U_1^i(x_1^i,\ t_1^i) = \pi(x_1^i) + g(x_1^i) + \vartheta^i t_1^i - C(x_1^i),\ i = G,\ B; \qquad (2)$$

where $\pi(x_1^i)$, $g(x_1^i)$ and $C(x_1^i)$ denote the farmer of type i's private benefit from undertaking biodiversity protection action, utility of the public good produced by him (which is equal to the amount of public good produced by him) and cost of undertaking biodiversity protection action, respectively. For simplicity, we consider that the farmer's intrinsic valuation for public good is type independent, which is normalized to be equal to one as before, and the regulator offers a lump-sum monetary compensation to the farmer.[11]

Assumption 3: (i) For all $x_1^i \geq 0$, (a) $\pi \geq 0,\ \pi' \geq 0$ and $\pi'' \leq 0$; (b) $g' > 0$ and $g'' < 0$ and (c) $C' > 0$ and $C'' \geq 0$. (ii) $U_1^i(0,\ 0) = 0$ and $\left.\frac{\partial U_1^i(x_1^i,\ t_1^i)}{\partial x_1^i}\right|_{x_1^i=0} > 0$.

Assumptions 3 is a standard regulatory assumption, which ensures that the farmer's utility function in period 1 is strictly concave in $x_1^i \geq 0$.

[10] Note that, unlike Bénabou and Tirole (2006), the above formulation of the reputation function allows for farmers reputation to be directly dependent, not only on conditional expectation of his intrinsic valuation of monetary compensation based on his action and monetary transfer in the first period, but also on his behaviour towards the environment in the subsequent period. We mention here that results of this analysis go through, if we consider $R^i = R\big(E(\vartheta | x_1^i, t_1^i),\ f^i(x_2^i)\big)$, i.e., if we consider that social reputation depends on public good produced by the farmer, instead of his action, in period 2 as long as $f^i(x_2^i)$ is an increasing function.

[11] Main results of this analysis hold true, if we allow for action dependent monetary compensation: $t_1^i = t_1^i(x_1^i)$, where $\frac{\partial t_1^i(x_1^i)}{\partial x_1^i} > 0$.

In period two, given the farmer’s type, his productivity in creating public good as well as reputation depend on whether the regulator facilitates his biodiversity protection action or not. We consider that the type i $(= G, B)$ farmer’s second period utility is as follows.

$$U_2^i = \begin{cases} U_2^{si}(x_2^i, t_2^s) = \Pi(x_2^i) + f^i(x_2^i) + \vartheta^i t_2^s - C(x_2^i) + R\big(E(\vartheta^i \big| x_1^i, t), x_2^i\big) \\ U_2^{ni}(x_2^i, t_2^n) = \pi(x_2^i) + g(x_2^i) + \vartheta^i t_2^n - C(x_2^i); \;\; i = G, B; \end{cases} \tag{3}$$

where $U_2^{si}(x_2^i, t_2^s)$ is the second period utility of the type i farmer when the regulator facilitates his action, $U_2^{ni}(x_2^i,\ t_2^n)$ is the second period utility of the type i farmer when the regulator does not facilitate his action. $\Pi(x_2^i)$ denotes the farmer's private benefit from undertaking biodiversity protection activity and $f^i(x_2^i)$ is his utility of the public good (which is equal to the amount of public good) produced by him, when the regulator facilitates his action in period two, which satisfy Assumption 4.

Assumption 4: (i) $\Pi \geq \pi \geq 0$, $\Pi' \geq \pi' \geq 0$ and $\Pi'' \leq 0$; (ii) $f^G(x_2) > f^B(x_2) > g(x_2)$, $\forall\, x_2 > 0$; (iii) $f^{G'}(x_2) > f^{B'}(x_2) \geq g'(x_2) > 0$, $f^{G''}(x_2) < 0$ and $f^{B''}(x_2) < 0$, $\forall\, x_2 \geq 0$; and (iv) $U_2^{si}(0,\ 0) = U_2^{ni}(0,\ 0) = 0$, $\left.\frac{\partial U_2^{si}(x_2^i, t_2^s)}{\partial x_2^i}\right|_{x_2^i=0} > 0$ and $\left.\frac{\partial U_2^{ni}(x_2^i, t_2^n)}{\partial x_2^i}\right|_{x_2^i=0} > 0$.

Assumption 4(i) implies that, when a farmer receives facilitation services from the regulator to protect biodiversity, his private benefit from undertaking biodiversity protection action is at least as large as in the absence of facilitation services. Further, both average and marginal productivity of a green farmer’s action to protect the environment are higher than those of a brown farmer, if the regulator facilitates the biodiversity protection action (Assumptions 4(ii) – 4(iii)). That is, a green farmer utilizes the facilitation services more effectively than a brown farmer, which may be due to superior capability of the green farmer to process knowledge and adopt modern methods of biodiversity protection and/or due to his higher intrinsic motivation to protect the environment. Clearly, facilitation of the green farmer’s biodiversity protection action better serves the environment, unless the green farmer chooses a sufficiently lower level of action than the brown farmer. Note that, if the regulator does not facilitate the farmer's biodiversity protection action, the utility of the farmer remains same as that in the first period: $U_2^{ni}(x_2^i, t) = U_1^i(x_1^i,\ t), i = G, B.$ Also, Assumptions 2 – 4 imply that both $U_2^{si}(x_2^i, t_s)$ and $U_2^{ni}(x_2^i, t)$ are strictly concave in x_2^i.

We define the social benefit from biodiversity protection in farmland in period j as follows.

$$W_j = W(y_j,\ \tau_j,\ I_j),\ \ j = 1, 2; \tag{4}$$

where $y_j\ (\geq 0)$ denotes the amount of public good produced by the farmer in period j, τ_j denotes the monetary compensation offered to the farmer in period j and $I_j\ (\geq 0)$ denotes the amount of public resources utilized to provide facilitation services to the farmer in period j. Since facilitation services is provided only in the second period, $I_1 = 0$, and we consider that it is necessary to spend the same amount of public resources $I_2 = I\ (> 0)$ to facilitate a farmer's biodiversity protection action regardless of the farmer's type, green or brown.

Assumption 5: (i) $W(y_j,\ \tau_j,\ I_j)$ is continuously differentiable in its arguments, strictly increasing in $y_j \geq 0$, and strictly decreasing in both $\tau_j \geq 0$ and $I_j \geq 0$, $j = 1, 2$. (ii) $W(0, 0, 0) = 0$.

Assumption 5 states that higher level of public good creation through biodiversity protection results in higher social benefit, while higher monetary payments to the farmer and higher amount of public resources used to facilitate the farmer's biodiversity protection action reduce social benefit.

The regulator is concerned about the social benefit of the farmer's biodiversity protection action and decides to facilitate the farmer's action in period 2 only if the social benefit of doing so exceeds the threshold level $\underline{W}$, where $\underline{W}$ is the social benefit from alternative utilization of public resources (I) required to facilitate the farmer's biodiversity protection action, i.e., the opportunity cost of public resources I.

Complete Information

Let us first analyse the farmer's optimum choice under complete information, i.e., when his type is known to all. In this case the stages of the game involved remain the same as before, except that in Stage 1 of Period 1 the farmer's type is now common knowledge. We solve the game by the backward induction method.

Ignoring farmers' participation constraints, the problem of type i farmer in period 2 in case the regulator facilitates his biodiversity protection action can be written as follows.

$$\text{Max}_{x_2^i}\, U_2^{si}\big(x_2^i, t_2^s\big) = \Pi\big(x_2^i\big) + f^i\big(x_2^i\big) + \vartheta^i t_2^s - C\big(x_2^i\big) + R\big(\vartheta^i, x_2^i\big);\; i\; = G,\; B. \quad (5)$$

Note that, since information is complete, we have $E(\vartheta \big|\, x_1^i, t_1^i\big) = \vartheta^i$. The first order condition of problem (5) is

$$\frac{\partial U_2^{si}}{\partial x_2^i} = \Pi' + f^{i'} - C' + \frac{\partial R\big(\vartheta^i, x_2^i\big)}{\partial\, x_2^i} = 0;\; i\; = G,\; B. \quad (6)$$

The second order condition for maximization ($\frac{\partial^2 U_2^{si}}{\partial {x_2^i}^2} < 0$) is satisfied since $U_2^{si}(.)$ is strictly concave in x_2^i. Solving equation (6) we get the optimum choice of type i farmer in period 2 when his biodiversity protection action is facilitated by the regulator.

Definition 1*: Let* $x_2^{si*} = \underset{x_2^i}{argmax}\, U_2^{si}\big(x_2^i, t_2^s\big),\; i = G, B.$

Lemma 1*: Suppose that Assumptions* 2 – 4 *hold true. Then,* $x_2^{sG*} > x_2^{sB*} > 0$ *and* $f^G(x_2^{sG*}) > f^B(x_2^{sB*})$.

Proof: See Appendix.

Lemma 1 states that under complete information, if the regulator facilitates the biodiversity protection action and the farmer's participation constraint is satisfied regardless of his type, in the equilibrium in Period 2 the green farmer chooses a higher level of biodiversity protection action and produces more public good than the brown farmer. This follows because when the regulator provides facilitation services to protect biodiversity in farmland, (a) the green farmer's marginal productivity of biodiversity protection action is higher than that of the brown farmer and (b) the marginal effect of a farmer's biodiversity protection action on his social reputation is non-increasing in expectation regarding his intrinsic valuation of money.

Definition 2*: Let* $x_0 = \underset{x}{argmax}\ \left[\pi(x) + g(x) + \vartheta^i t - C(x)\right]$, $x_1^{i*} = \underset{x_i^i}{argmax}\ U_1^i\left(x_1^i, t_1^i\right)$ *and* $x_2^{ni^*} = \underset{x_2^i}{argmax}\ U_2^{ni}\left(x_2^i,\ t_2^n\right),\ i = G, B.$

Lemma 2: *Suppose that Assumptions 3 – 4 holds true. Then,* $x_1^{G^*} = x_1^{B^*} = x_2^{nG^*} = x_2^{nB^*} = x_0 > 0$ *and* $g(x_1^{G*}) = g(x_2^{G*}) = g(x_1^{nG*}) = g(x_2^{nG*}) = g(x_0)$.

Proof: See Appendix.

Lemma 2 states that, under complete information, if the regulator does not facilitate a farmer's biodiversity protection action and the farmer's participation constraint is satisfied regardless of his type, the equilibrium choice of biodiversity protection action of a farmer and the amount of public goods produced are both time invariant and type independent. This is because (a) under complete information the first period's choice of biodiversity protection action does not affect social reputation and (b) unless the regulator provides facilitation services, productivity of a farmer's action remains unchanged over periods and across types. Further, since $f^B(x_2) \geq g(x_2)$ and $\frac{\partial R(\vartheta^B,\ x_2)}{\partial x_2} \geq 0, \forall\, x_2 \geq 0$, by Assumption 3(ii) and Assumption 1, respectively, we will have $x_2^{sB*} \geq x_0$ and $f^B(x_2^{sB*}) > g(x_0)$. This together with Lemma 1 implies that $x_2^{sG*} > x_2^{sB*} \geq x_0$ and $f^G(x_2^{sG*}) > f^B(x_2^{sB*}) > g(x_0)$.

Definition 3: *Let* $\underline{t}^i$ *be the monetary transfer to the type i farmer such that his participation constraint in absence of facilitation services is binding, when the farmer chooses his biodiversity protection action optimally:* $\pi(x_0) + g(x_0) + \vartheta^i \underline{t}^i - C(x_0) = \underline{U}^i, i = G, B.$

Assumption 6: (i) $[\ \pi(x_0) + g(x_0) - C(x_0)] = \frac{\vartheta^{\mathrm{B}}\, \underline{U}^G - \vartheta^{\mathrm{G}}\, \underline{U}^B}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}}$

(ii) $\underline{U}^B < [\ \Pi(x_2^{sB*}) + f^B(x_2^{sB*}) - C(x_2^{sB*}) + R(\vartheta^B, x_2^{sB*})]$

Note that $\frac{\vartheta^{\mathrm{B}}\, \underline{U}^G - \vartheta^{\mathrm{G}}\, \underline{U}^B}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} > 0$ since $\vartheta^{\mathrm{B}} > \vartheta^{\mathrm{G}}$ (by construction) and $\vartheta^{\mathrm{B}}\, \underline{U}^G - \vartheta^{\mathrm{G}}\, \underline{U}^B > 0$ by Assumption 1.

Lemma 3: *Suppose that Assumptions 1 – 6 hold true. Then under complete information, if the regulator does not provide facilitation services to the farmer, it is optimal for the regulator to offer a fixed monetary transfer* $t^0 = \frac{\underline{U}^B - \underline{U}^G}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} > 0$ *to the farmer regardless of (a) the farmer's type – green or brown and (b) the time period.*

Proof: See Appendix.

Since in the present scenario the sum of monetary transfer from the regulator to the farmer is lump sum, which does not vary with the biodiversity protection action undertaken by the farmer, the amount of monetary transfer affects the farmer's participation decision as such, not the level of biodiversity protection action of the farmer who has decided to participate. In the absence of facilitation services and, thus, in absence of non-monetary incentives, under complete information (a) any monetary transfer less than t^0 does not offer sufficient incentive to the farmer to undertake biodiversity protection action regardless of his type and (b) any monetary transfer greater than t^0 is equally attractive to both green and brown farmers, but neither the green nor the brown farmer's choice of biodiversity protection action differs from x_0. It implies that, when the farmer's type is his private information, the regulator cannot induce the farmer to reveal his true type by offering two different amounts of monetary transfers for two different types of farmers. Since, in that case the farmer will select the offer with higher monetary transfer and undertake the same action in period 1, regardless of his type.

Corollary 1: *Under asymmetric information, in period 1 the regulator cannot induce the farmer to reveal his true type by designing appropriate incentive schemes involving lump sum monetary transfers.*

Assumption 6(ii) implies that, if the regulator facilitates biodiversity protection action, the farmer's participation constraint is satisfied for any monetary transfer $t_2 \geq 0$, regardless of his type. This is because, $\underline{U}^G < \underline{U}^B$ and $[\Pi(x_2^{sB*}) + f^B(x_2^{sB*}) - C(x_2^{sB*}) + R(\vartheta^B, x_2^{sB*})] < [\Pi(x_2^{sG*}) + f^G(x_2^{sG*}) - C(x_2^{sG*}) + R(\vartheta^G, x_2^{sG*})]$ (by Assumption 4 and Lemma 1). Also note that, whenever participation constraint is satisfied, optimal choices x_2^{sG*} and x_2^{sB*} do not depend on monetary transfer. Thus, in this case, it is optimal for the regulator to offer no monetary transfer to the farmer.

Lemma 4: *Suppose that Assumptions 1 – 6 hold true. Then under complete information, if the regulator facilities biodiversity protection action in farmland, it is optimal for the regulator to offer no monetary incentive to the farmer (*$t_2^s = 0$*) regardless of the farmer's type. Facilitation service, which is coupled with non-monetary incentive, suffices to induce both types of farmer to participate and undertake their respective optimal biodiversity protection actions.*

Now, let O^{sG*} and O^{sB*} denote the equilibrium discounted net social benefit (a) when the green farmer's biodiversity protection action is facilitated and (b) when the brown farmer's biodiversity protection action is facilitated, respectively. Then, from Lemmas 1 – 4, we can write $O^{sG*} = W\big(g(x_0),\ t^0, 0\big) + \delta_0 W(f^G(x_2^{sG*}),\ 0,\ I)$ and $O^{sB*} = W\big(g(x_0),\ t^0, 0\big) +$

$\delta_0 W(f^B(x_2^{sB*}),\ 0,\ I)$, where $\delta_0 \in (0,1]$ is the social planner's discount factor. Comparing O^{sG*} and O^{sB*} we get the following.

Corollary 2: *In the equilibrium under complete information the discounted net social benefit from facilitating biodiversity protection in farmland is higher when the farmer is of green-type than when the farmer is of brown-type:* $O^{sG*} > O^{sB*}$.

Proof: See Appendix.

Assumption 7: $W(f^B(x_2^{sB*}),\ 0,\ I) < \underline{W} < W(f^G(x_2^{sG*}),\ 0,\ I)$

Assumption 5 implies that, under complete information, the regulator facilitates the biodiversity protection action of a *green*-farmer, but *not* that of a *brown*-farmer, in period 2.

Asymmetric Information

Let us now consider the asymmetric information scenario in which the farmer's type is his private information. The regulator knows that the farmer is one of two types – green or brown, but cannot identify the true type of the farmer. According to the regulator's prior beliefs, the farmer is *green*-type with probability ρ and *brown*-type with probability $1 - \rho$. These beliefs are common knowledge.

From Corollary 3, facilitation of the farmer's biodiversity protection action is beneficial to the society only if the farmer is of the *green*-type. However, both the green-type farmer and the brown-type farmer are interested in the facilitation offered by the regulator (i.e., to be invited to join the expert opinion/information program on environmental practices and their implementation).

Given the prior beliefs regarding the farmer's true type, there are two possibilities. First, the prior beliefs are such that the expected net social benefit in period 2 is less than the reservation level of net social benefit, i.e. $E(W_2) = \rho\, W\big(f^G(x_2^{sG*}),\ t_2^s,\ I\big) + (1-\rho)W\big(f^B(x_2^{sB*}),\ t_2^s,\ I\big) < \underline{W}$. In such a scenario the regulator will not facilitate the farmer's environmental conservation action, unless she can update her prior beliefs. In this case, the *green*-type farmer would try to signal his true type credibly to the regulator by choosing his biodiversity protection action in period 1 appropriately. Because, by doing so he can obtain not only higher benefits from greater public good creation due to facilitation services in period 2, but also higher social reputation ($R(\vartheta^G,\ x_2^G)$). Clearly, this is a case of the *separating equilibrium*, which induces period 2's outcome to be identical to the symmetric information case by revealing all private information through the signal – the farmer's biodiversity protection action in period 1.

Second, the prior beliefs regarding the farmer's true type are such that the expected net social benefit in period 2 is greater than or equal to the reservation level of net social benefit: $E(W_2) = \rho\, W\big(f^G(x_2^{sG*}),\ t_2^s,\ I\big) + (1-\rho)W\big(f^B(x_2^{sB*}),\ t_2^s,\ I\big) \geq \underline{W}$. In this case the regulator will always facilitate biodiversity protection in farmland in absence of any additional information available. In such a scenario, the *brown*-type farmer would try to masquerade his true identity by mimicking the *green*-type farmer's behaviour in period 1. However, if the brown-type farmer is successful in mimicking the green-type farmer's behaviour in period 1, the green-type farmer will also receive facilitation services and non-monetary incentives but the green-type farmer will incur loss in terms of social reputation compared to the situation in which the green-type farmer can reveal his true type. The reason is as follows. In the case of successful mimicking of the green-type's behaviour by the brown-type there is no room to update prior beliefs regarding the type of the farmer and, thus, the green type's social reputation will be given by $R(\rho\vartheta^G + (1-\rho)\vartheta^B,\ x_2^G)$. On the contrary, in the case of credible signalling by the green type, truth is revealed and, thus, the green type's social reputation will be given by $R(\vartheta^G,\ x_2^G)$. Now, since $\vartheta^G < \rho\vartheta^G + (1-\rho)\vartheta^B\ \forall\, \rho \in (0,1)$ and $R(E(\vartheta | x_1^G, t_1^G),\ x_2^G)$ is strictly decreasing in $E(\vartheta | x_1^G, t_1^G)$ (by Assumption 2), $R(\vartheta^G,\ x_2^G) > R(\rho\vartheta^G + (1-\rho)\vartheta^B,\ x_2^G)\ \forall\, x_2^G >$

0. Therefore, even in the case of $E(W_2) \geq \underline{W}$, the green-type farmer has an incentive to signal its true type credibly.

Separating Equilibrium*:* The pair of biodiversity protection actions $(x_1^{\mathrm{G}}, x_1^{\mathrm{B}})$ forms a separating equilibrium, if by observing x_1^{G} (alternatively x_1^{B}) the regulator concludes with certainty that the farmer is of *green*-type (alternatively *brown*-type). It is well known that if such $(x_1^{\mathrm{G}}, x_1^{\mathrm{B}})$ are to be perfect Bayesian equilibrium (PBE) these must depend on the belief structure of the regulator. For the regulator to update his beliefs, the biodiversity protection actions of period 1 must satisfy the following incentive compatibility constraints.

$$\mathrm{IC}^{\mathrm{G}}: \quad U_1^{\mathrm{G}}(x_1^{\mathrm{G}}) + \delta U_2^{s\mathrm{G}^*} \geq U_1^{\mathrm{G}^*} + \delta U_2^{n\mathrm{G}^*}, \tag{7}$$

$$\mathrm{IC}^{\mathrm{B}}: \quad U_1^{\mathrm{B}}(x_1^{\mathrm{G}}) + \delta U_2^{s\mathrm{B}^0} \leq U_1^{\mathrm{B}^*} + \delta U_2^{n\mathrm{B}^*}, \tag{8}$$

where $\delta \in (0,1]$ is the discount factor of the farmer regardless of his type, $U_1^{\mathrm{i}}(x_1^{\mathrm{G}})$ is the utility of type $i\ (= G, B)$ farmer in period 1 when he chooses the biodiversity protection action x_1^{G}, $U_2^{sG^*} = U_2^{sG}\ (x_2^{sG*}, t_2^s)$ is the complete information equilibrium utility of the green farmer in period 2 when the regulator facilitates his biodiversity protection action and offers non-monetary incentives and monetary transfer $t_2^s \geq 0$, $U_2^{s\mathrm{B}^*} = \underset{x_2^B}{Max}\ [\Pi(x_2^B) + f^B(x_2^B) + \vartheta^B t_2^s - C(x_2^B) + R(\vartheta^G,\ x_2^B)]$ is the brown farmer's utility in the equilibrium in period 2 when his type is perceived to be *green* and his action is facilitated by the regulator and, thus, receives the same incentives as that of green farmer, $U_1^{i^*} = U_1^i(x_1^{i*}, t)$ is the symmetric information equilibrium utility of the type $i\ (= G, B)$ farmer in period 1 when he receives monetary transfer $t \geq 0$, and $U_2^{ni^*} = U_2^{ni}(x_2^{ni*}, t)$ is the symmetric information equilibrium utility of type $i\ (= G, B)$ farmer in period 2 when his biodiversity protection action is not facilitated by the regulator and he receives monetary transfer $t \geq 0$. Note that $U_2^{ni^*} = U_1^{i^*} = U_1^i(x_0, t) \equiv \widetilde{U}^i$ (say), $i = G, B$, by Lemma 2. Note that the regulator must choose $t \geq t^0 > 0$ when the farmer's action is not facilitated, while she can choose any $t_2^s \geq 0$ when the farmer's action is facilitated, to ensure participation of the farmer regardless of his type (by Lemmas 3 – 4 and Definition 1).

Inequalities (7) and (8) are the incentive compatibility conditions for the *green*-type farmer and the *brown*-type farmer, respectively. Condition (7) states that by setting x_1^G in period 1 the *green*-type farmer will induce facilitation in period 2 by the regulator and have a higher two-period discounted payoff than by setting x_1^{G*}, which is the symmetric information level of biodiversity protection action, in period 1 and discouraging facilitation by the regulator. By rearranging the terms of condition (7) we get $U_1^{G^*} - U_1^G(x_1^G) \leq \delta\,(U_2^{sG^*} - U_2^{nG^*})$, that is, for the *green*-type farmer the loss in period 1 due to deviation from the symmetric information level of biodiversity protection action must be less than the corresponding (discounted) gain in period 2.

Condition (8) says that the *brown*-type farmer attains a higher two-period discounted payoff by choosing his symmetric information level of biodiversity protection action x_1^{B*} in period 1, which discourages the regulator to facilitate his action in period 2, than by setting x_1^G in period 1 and inducing the regulator to facilitate his action in period 2. Rearranging the terms of condition (8), we get $U_1^{B^*} - U_1^B(x_1^G) \geq \delta(U_2^{sB^*} - U_2^{nB^*})$. It implies that, due to deviation from the symmetric information level of biodiversity protection action in period 1, the *brown*-type farmer's loss in period 1 must be greater than the discounted value of his gain in period 2.

Rearranging terms we can write conditions (7) and (8), respectively, as follows.

$$U_1^G(x_1^G) \geq (1+\delta)\,\widetilde{U}^G - \delta\,U_2^{sG^*} \;\Rightarrow\; \Psi(x_1^G) \geq \Delta^{\mathrm{G}} \tag{7a}$$

and $$U_1^B(x_1^G) \leq (1+\delta)\,\widetilde{U}^B - \delta\,U_2^{s\mathrm{B}^0} \;\Rightarrow\; \Psi(x_1^G) \leq \Delta^{\mathrm{B}}, \tag{8a}$$

where $\Psi(x_1^G) = \pi\,(x_1^G) + g(x_1^G) - C(x_1^G)$, $\Delta^{\mathrm{G}} = (1+\delta)\,\widetilde{U}^G - \delta\,U_2^{sG^*} - \vartheta^G\,t$ and $\Delta^{\mathrm{B}} = (1+\delta)\,\widetilde{U}^B - \delta\,U_2^{sB^0} - \vartheta^B\,t$. Note that (i) $\Psi(x_1^G)$ is strictly concave in x_1^G (by Assumption 2 and Assumption 3) and (ii) both Δ^{G} and Δ^{B} are independent of x_1^G. Also, note that we have the following.

$$\widetilde{U}^B < \ U_2^{sB^0} \Longrightarrow \ t_2^s > t - t^0 - \ \frac{\Lambda^{\mathrm{SB}^0}}{\vartheta^B}, \quad (9a)$$

$$\widetilde{U}^G < \ U_2^{sG^*} \Longrightarrow \ t_2^s > t - t^0 - \ \frac{\Lambda^{\mathrm{SG}^*}}{\vartheta^G}, \quad (9b)$$

$$\Delta^G < \Delta^B \Leftrightarrow t_2^s < t + \frac{\Omega}{\vartheta^B - \vartheta^G}, \quad (9c)$$

where (a) $\Lambda^{\mathrm{SB}^0} = \left[\Pi\left(x_2^{sB^0}\right) + f^B\left(x_2^{sB^0}\right) - C\left(x_2^{sB^0}\right) + R\left(\vartheta^G, x_2^{sB^0}\right)\right] - \underline{U}^B > 0$ (by Assumptions 2, 4 and 6(ii)) and $x_2^{sB^0} = \underset{x_2^B}{argmax}\left[\Pi(x_2^B) + f^B(x_2^B) + \vartheta^B t_2^s - C(x_2^B) + R\left(\vartheta^G, x_2^B\right)\right]$, (b) $\Lambda^{\mathrm{SG}^*} = \left[\Pi\left(x_2^{sG^*}\right) + f^G\left(x_2^{sG^*}\right) - C\left(x_2^{sG^*}\right) + R\left(\vartheta^G, x_2^{sG^*}\right)\right] - \underline{U}^G > 0$ (by Assumptions 2, 4 and 6(ii)) and (c) $\Omega = \underset{x_2^G}{Max}\left\{\Pi(x_2^G) + f^G(x_2^G) - C(x_2^G) + R\left(\vartheta^G,\ x_2^G\right)\right\} - \underset{x_2^B}{Max}\left\{\Pi(x_2^B) + f^B(x_2^B) - C(x_2^B) + R\left(\vartheta^G,\ x_2^B\right)\right\} > 0$ (by Assumption 2).[12] Clearly, if $t = t^0$, both $\widetilde{U}^B < \ U_2^{sB^0}$ and $\widetilde{U}^G < \ U_2^{sG^*}$ are satisfied for all $t_2^s \geq 0$. Alternatively, if $t > t^0$, condition (9b) is satisfied for relatively lower t_2^s than is required to satisfy condition (9a), since $\frac{\Lambda^{\mathrm{SG}^*}}{\vartheta^G} > \frac{\Lambda^{\mathrm{SB}^0}}{\vartheta^B}$, i.e., (9a) implies (9b), but not vice-versa.[13] That is, if the regulator chooses to offer more than t^0 payment in the case of no facilitation, the monetary transfer required for r facilitation to be preferred by the green farmer is less than that for a brown farmer.

[Figure 1 is here. See Appendix for the figure.]

We depict conditions (7a) and (8a) in Figure 1, considering that $\Delta^{\mathrm{G}} < \Delta^{\mathrm{B}}$. The bell-shaped curve in Figure 1 plots $\Psi = \Psi(x_1^G)$. Of the two horizontal straight lines, the height of the top one represents Δ^{B}, while the height of the bottom one represents Δ^{G}. It is evident that any

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[12] $\underline{\widetilde{U}^B < \ U_2^{sB^0} \Longrightarrow U^B} + \vartheta^B(t - t^0) < \left[\Pi\left(x_2^{sB^0}\right) + f^B\left(x_2^{sB^0}\right) + \vartheta^B t_2^s - C\left(x_2^{sB^0}\right) + R\left(\vartheta^G, x_2^{sB^0}\right)\right] \Longrightarrow \vartheta^B(t - \ t_2^s) < \left[\Pi\left(x_2^{sB^0}\right) + f^B\left(x_2^{sB^0}\right) - C\left(x_2^{sB^0}\right) + R\left(\vartheta^G, x_2^{sB^0}\right)\right] - \underline{U}^B \ \Longrightarrow \ t_2^s > t - t^0 - \ \frac{\Lambda^{\mathrm{SB}^0}}{\vartheta^B}$. Similarly (9b) also follows.

[13] We rule out the possibility of $t < t^0$. Because, if $t < t^0$, the farmer does not participates unless his biodiversity protection action is facilitated by the regulator.

$x_1^G \in [\,\underline{x}_1^G,\ \overline{x}_1^G\,]$ satisfies condition (7a), whereas condition (8a) is satisfied if x_1^G belongs to outside the interval ($\underline{x}_1^B,\ \overline{x}_1^B$), as shown in Figure 1. Therefore, if $x_1^G \in [\,\underline{x}_1^G,\ \underline{x}_1^B]$ or $x_1^G \in [\,\overline{x}_1^B,\ \overline{x}_1^G\,]$, both conditions (7a) and (8a) are satisfied. That is, by setting any $x_1^G \in [\,\underline{x}_1^G,\ \underline{x}_1^B] \cup [\,\overline{x}_1^B,\ \overline{x}_1^G\,]$ in period 1 the *green*-type farmer can credibly signal his true identity to the regulator. Clearly, there are many possible actions of the *green*-type farmer in period 1 to credibly signal his true identity to the regulator. Among those actions, $x_1^G = \overline{x}_1^B$ deserves special attention. The reason is that the *green*-type farmer is likely to choose x_1^G from the upper interval $[\,\overline{x}_1^B,\ \overline{x}_1^G\,)$, in which $\overline{x}_1^B$ corresponds to minimum deviation from his symmetric information level of action $x_1^{G^*}$; i.e., $x_1^G = \overline{x}_1^B$ gives highest payoff and conveys the information credibly. Therefore, we propose that the *green*-type farmer will choose $x_1^G = \overline{x}_1^B$ in period 1 in order to credibly signal his true identity. For the *brown*-type farmer it is optimal to choose the symmetric information level biodiversity protection action, $x_1^B = x_1^{B^*} = x_0$, in period 1. Therefore, in the separating PBE, the *green*-type farmer undertakes higher level of biodiversity protection action ($\overline{x}_1^B$) in period 1 compared to his optimal choice action under symmetric information ($x_1^{G^*} = x_0 < \overline{x}_1^B$), whereas the *brown*-type farmer does not deviate from his optimal choice of action under symmetric information ($x_1^{B^*}$). In addition, the regulator facilitates the action of only the *green*-type farmer in period 2.

Proposition 1: *Suppose that Assumptions 1 – 7 are satisfied. Suppose that conditions (9a) and (9c) are satisfied. Then the following beliefs and strategies constitute a separating perfect Bayesian equilibrium.*

(i) In period 2 the regulator has beliefs given by $\beta(x_1, t) = \begin{cases} 1, & if \quad x_1 \geq x_1^{G,Sep} \\ 0, & if \quad x_1 < x_1^{G,Sep} \end{cases},$

where $\beta(x_1, t) = Prob\{The\ farmer\ is\ of\ green\ type \mid x_1, t\}$

(ii) The pair of biodiversity protection actions of the farmer in period 1 and period 2 is $(x_1^{G,Sep},\ x_2^{G,Sep}) = (\overline{x}_1^{B},\ x_2^{sG^*})$ *in case the farmer is of green type, and* $(x_1^{B,Sep},\ x_2^{B,Sep}) = (x_0,\ x_0)$ *in case the farmer is of brown type.*

(iii) The regulator facilitates the farmer's biodiversity protection action in period 2, if $x_1 \geq x_1^{G,Sep}$.

Proof: See Appendix.

Proposition 1 implies that, in the separating equilibrium, the green farmer chooses a higher level of biodiversity protection action compared to his equilibrium choice under complete information in period 1, which signals his true type credibly and, thus, ensures facilitation of his action by the regulator in period 2. In period 2 he continues to do the good work and enjoys higher level of social reputation. On the other hand, the brown farmer also participates in biodiversity protection in farmland and chooses the complete information equilibrium level of action in both periods. Therefore, in the separating equilibrium the extent of biodiversity protection by the green farmer is superior to that in the equilibrium under complete information, while in the case of a brown farmer the outcome remains the same as that in the equilibrium under complete information.

Next, note that the regulator can ensure the existence of a separating equilibrium by choosing the amounts of monetary transfers to be offered in period 1 (t) and period 2 (t_2^s) appropriately. It is straightforward to observe that ($t = t^0$, $t_2^s = 0$) satisfies conditions (9a) – (9c). That is, the regulator can ensure the existence of the separating equilibrium by spending the same amount of public resources for biodiversity protection as that under complete information.

Proposition 2: *Suppose that Assumptions 1 – 7 are satisfied. Then, by designing contracts involving only monetary incentives for the brown farmer and a combination of monetary and non-monetary incentives for the green farmer, the regulator can induce superior environmental* *outcomes in the equilibrium under asymmetric information, without incurring any extra cost, compared to that under complete information.*

In the present context the possibility of pooling equilibrium does not arise, which is primarily due to non-monetary incentives offered by the regulator in the case of facilitation of biodiversity protection and the existence of corresponding social reputation of the farmer. In a hypothetical scenario in which the farmer do not get any social reputation, i.e., $R\left(E\left(\vartheta \middle| x_1^i, t_1^i\right), x_2^i\right) = 0$ for all $E\left(\vartheta \middle| x_1^i, t_1^i\right) \in [\vartheta^G, \vartheta^B]$ and $x_2^i \geq 0$, $i = G, B$, the green-type farmer does not have any incentive to signal its true type unless the regulator's prior beliefs are such that $E(W_2) < \underline{W}$. The reason is, if prior beliefs are such that $E(W_2) \geq \underline{W}$, the regulator always facilitates biodiversity protection action of the farmer unless she can update her beliefs and, thus, any deviation in period 1 from the complete information equilibrium choice of action will decrease the green farmer's utility without enhancing his utility in period 2. In this hypothetical scenario, it can be established that, if $E(W_2) \geq \underline{W}$, pooling equilibrium exists and (i) $(x_1^{G,Pool}, x_1^{B,Pool}) = (x_0, x_0)$ is the pair of pooling equilibrium choices of biodiversity protection actions in period 1 of the green farmer and brown farmer (ii) in the pooling equilibrium, in period 2 the type i farmer will choose $x_2^{i\_Pool} = \underset{x_2^i}{argmax}\left[\Pi(x_2^i) + f^i(x_2^i) + \vartheta^i t_2^S - C(x_2^i)\right]$, $i = G, B$. It follows that $x_2^{G\_Pool} < x_2^{G,Sep}$, i.e., the net social benefit from facilitating the green farmer's biodiversity protection action is less in absence of any social reputation. Also, the net social benefit from facilitating the brown farmer's biodiversity protection is always less than $\underline{W}$. The analysis of this paper demonstrates that the regulator can effectively avoid such an inferior outcome by offering appropriate non-monetary incentives to the farmer that enhances his social reputation.

V. Example: unpaid agri-environmental measures in England

The design above is closely based on what is observed in practice. Our example is for the UK where in 2009 the farming organisations launched the Campaign for the Farmed Environment (CFA) to improve the environmental conditions of agricultural habitats and landscapes throughout lowland England.

This Campaign is to be reflected upon against the background of the main representation of the government-led green payment scheme in England since 2005, the Environmental Stewardship Scheme (ESS). The ESS established a right for all farmers to receive payment for the provision of countryside goods[14], whatever their counterfactual position. It represented a clear shift away from previous programs targeted spatially on particular types of area. Thus, the ESS allows all farmers to participate. The literature on the ESS has many references to problems that are consistent with our focus on different types of motivations. The main issue is that there is no incentive for farmers to do more than the minimum necessary since the payment is for the implementation of the specific conservation practices, not for the ecological result. Worse, the prescription of management practices and designation of specific areas for agri-environmental work fails to allow farmers to develop or demonstrate skilled performance (Burton et al., 2008). Thus, farmers might well be interested in conservation as such and have their own ideas but might not engage because current schemes are top-down.

The CFE began as an industry-led approach initially for maintaining the environmental benefits provided by former set-aside[15]. Communications include a website, Campaign leaflets and brochures, CFE led events, as well as a visible presence at a wide range of national, regional

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[14] The scheme's primary objectives are to cconserve wildlife (biodiversity); maintain and enhance landscape quality and character; protect the historic environment; protect natural resources (water and soil), and promote public access and understanding of the countryside.

[15] Set-aside became compulsory in 1992 for large arable farmers as part of the MacSharry reform of the EU's Common Agricultural Policy. It was originally set at 15% and reduced to 10% in 1996. Following the 2005 CAP reform this restriction was removed. The CFA promotes on-farm environmental action through one or more of three options: retaining former set-aside and any other areas of uncropped land (unpaid), putting areas of land outside the ESS into Campaign voluntary measures (unpaid), and choosing key in-field target options in the ESS.

and local events operated by partner organizations. The delivery of program as such is at the local (county) level through local county coordinators (LCC) working with local liaison groups (LLG) made up of farmers and representatives of partner organizations.

There is a wide range of survey data being collected in the evaluation of the CFE (see e.g., Powell et al., 2012). For example during the 2013/14 crop year, 44% of holdings in England had land within one of the 22 CFE-listed unpaid voluntary measures. This totalled to 450 thousand hectares (with an additional 9800 skylark plots and 7400 km of fenced watercourses). Overall 38 % of holdings were not involved in any payment scheme in 2014. Given that an attribute of conservation management on farm land is that it involves some sacrifice of financial profit, the CFE results strongly suggest other non-monetary motives.

Powell et al. (2012) discuss results from a survey with local county coordinators (LCCs) that asked for their views on what makes farmers get involved in the CFE. This resulted in four main categories of reasons that confirm the importance of peer pressure, the concern to be seen to be doing the right thing, and the influence of opinions of other farmers. The level of environmental interest was also clearly important. The interviewed LCCS indicated that the desire to avoid further regulation was a reason some farmers were getting involved. Payments (from ELS) were a driving force for few farmers. Access to advice and learning what others are doing was seen as a more important factor.

Interesting to note is the development in the area under unpaid measures since the start of the Campaign. The number of measures for which this can be analysed is limited because CFE-listed unpaid practices have changed since 2009. From the survey data collected since 2011 it follows that overall areas have tended to fall with the exception of overwintering stubble and selective use of spring herbicides. Thus the decrease in hectares suggests the interest in the CFA is waning but this does not necessarily mean a reduced interest in unpaid conservation per se. In the latter context it is interesting to note that in the farmer survey over 2012/13, 29% of the respondents in the same survey recorded land under some form of unpaid environmental management *outside* the Campaign that 'fully meets or closely resembles the essential management requirements' of CFE'. Obviously this is self-reported data but the 29% strikes as remarkable. It could mean that the CFA recognition has lost its esteem effect since many farmers started participating. Alternatively it could mean that it is specific measures that create esteem for the farmer and that these measures are not covered by the current CFA which has now fewer requirements than at the start.

A final interesting observation to conclude the discussion of this example is with information disclosure. Initially farmers' individual CFA activities were made publicly available on-line on the CFE webpage. This was however soon removed on farmers' request. Our framework would suggest that the on-line information was affecting farmers' reputational gain.

VI. Concluding Remarks

Voluntary green payment schemes are currently the most widely used instrument to enhance biodiversity and other public goods in agricultural areas. We examined how endogenous social preferences affect the workings of such schemes. A 'green' farmer may enjoy esteem from leading by example if there are few farmers who do *the right thing*. In contrast a farmer without social preferences ('brown' farmer) might merely *tick the boxes* and is expected to shirk from the desired environmental actions whenever possible unless this affects their reputation. We analyzed the design of an incentive scheme that takes into account both types of farmers ('green' or brown') under asymmetric information about their true motivation. It follows that under perfect Bayesian equilibrium, the regulator can separate out the farmer types in a two-period setting by monitoring their conservation actions in response to payment in the first period. The optimal mechanism would be a mix of a facilitation contract with small monetary incentive but high visibility to keep 'green' farmers interested, and a higher monetary-incentive contract to attract the brown farmers.

The results from our analysis rest on several stylized assumptions that need further verification through lab and field experiments. Our claim about the cost-effectiveness of the proposed mechanism depends crucially on the relationship between the norms and the mix of incentives. It is important to understand whether the proposed policy instruments and existing social norm are conflicting or complement to each other (e.g., see Acemoglu and Jackson, 2014). Our mechanism works well if there is a well-accepted social-norm that environmental protection is the right thing to do. Otherwise, non-participation will not influence the social costs of disesteem and participation will not ensure esteem or leadership value.

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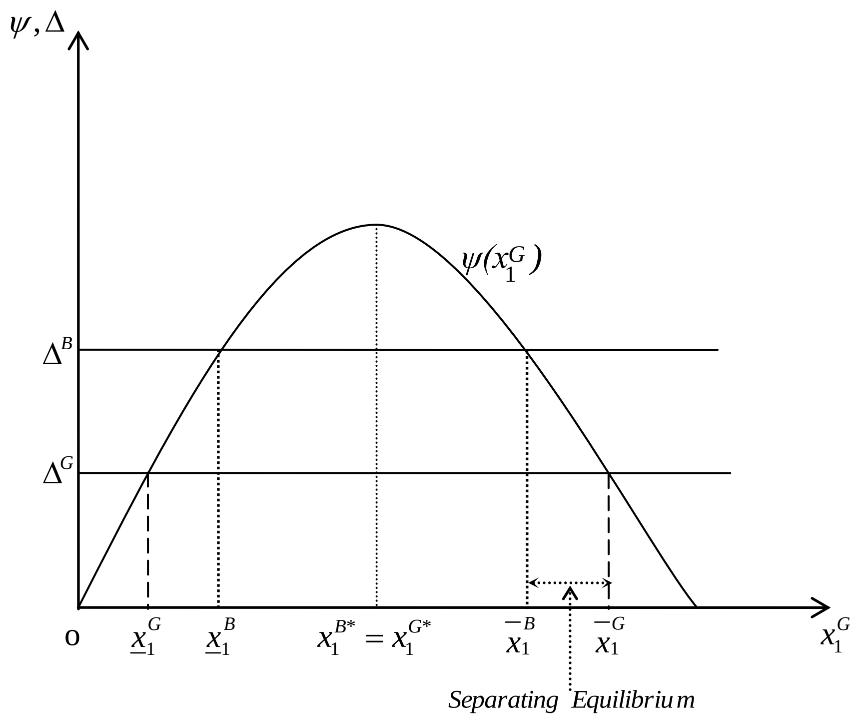

Figure 1: Separating and Pooling Equilibrium Environmental Protection Actions

Appendix.

***Lemma 1**: Proof:*. By Assumption 4, x_2^{si*} is unique and positive. Now, from (5), we can write the following.

$$\left.\frac{\partial U_2^{sG}}{\partial x_2^G}\right|_{x_2^G=x_2^{sB*}} = \Pi'(x_2^{sB*}) + f^{G'}(x_2^{sB*}) - C'(x_2^{sB*}) + \left.\frac{\partial R(\vartheta^G, x_2^G)}{\partial x_2^G}\right|_{x_2^G=x_2^{sB*}}$$

$$= \left.\frac{\partial U_2^{sB}}{\partial x_2^B}\right|_{x_2^B=x_2^{sB*}} + \left[f^{G'}(x_2^{sB*}) - f^{B'}(x_2^{sB*})\right] + \left[\left.\frac{\partial R(\vartheta^G, x_2^G)}{\partial x_2^G}\right|_{x_2^G=x_2^{sB*}} - \left.\frac{\partial R(\vartheta^B, x_2^B)}{\partial x_2^B}\right|_{x_2^B=x_2^{sB*}}\right] > 0,$$

since $\left.\frac{\partial U_2^{sB}}{\partial x_2^B}\right|_{x_2^B=x_2^{sB*}} = 0$ (by (5)), $\left[f^{G'}(x_2^{sB*}) - f^{B'}(x_2^{sB*})\right] > 0$ (by Assumption 4(iii) and $\left[\left.\frac{\partial R(\vartheta^G, x_2^G)}{\partial x_2^G}\right|_{x_2^G=x_2^{sB*}} - \left.\frac{\partial R(\vartheta^B, x_2^B)}{\partial x_2^B}\right|_{x_2^B=x_2^{sB*}}\right] \geq 0$ (by Assumption 2(iv)). It implies that $x_2^{sG*} > x_2^{sB*}$.

Next, since $f^G(x_2) > f^B(x_2)$ and $f^{G'}(x_2) > f^{B'}(x_2) > 0$ (by Assumption 4) and we have shown that $x_2^{sG*} > x_2^{sB*} > 0$, $f^G(x_2^{sG*}) > f^B(x_2^{sB*})$ holds true. [QED]

***Lemma 2:** Proof:* By Assumption 3(a), $[\ \pi(x) + g(x) + \vartheta^i t - C(x)]$ is strictly concave in x and, thus, x_0 exists and is unique. Assumption 3(b) implies that x_0 is positive. From (2) and (3), it follows that $U_1^i(x,t) = U_2^{ni}(x,t) = \pi(x) + g(x) + \vartheta^i t - C(x)$, $i = G, B$. Therefore, we must have $\underset{x_i^i}{argmax}\, U_1^i(x_1^i, t) = \underset{x_2^i}{argmax}\, U_2^{ni}(x_2^i, t) = \underset{x}{argmax}\ [\pi(x) + g(x) + \vartheta^i t - C(x)]$.

It implies that $x_1^{G^*} = x_1^{B^*} = x_2^{nG^*} = x_2^{nB^*} = x_0 > 0$ *and* $g(x_1^{G*}) = g(x_2^{G*}) = g(x_1^{nG*}) = g(x_2^{nG*}) = g(x_0)$. [QED]

***Lemma 3:** Proof:* We have $x_1^{G^*} = x_1^{B^*} = x_2^{nG^*} = x_2^{nB^*} = x_0 > 0$ by Lemma 2. It implies that $U_1^i(x_1^{i*}, t_1^i) = U_1^i(x_0, t_1^i)$ and $U_2^{ni}(x_2^{ni*}, t_2^{ni}) = U_2^{ni}(x_0, t_2^{ni}), i = G, B$. Now, The participation constraints of type i farmer (a) in period 1 and (b) in period 2 in absence of facilitation services can be written as $U_1^i(x_1^i, t_1^i) \geq \underline{U}^i$ and $U_2^{ni}(x_2^{ni}, t_2^{ni}) \geq \underline{U}^i$, $i = G, B$, respectively. Therefore, at the optimal choice of action, these participation constraints are satisfied, if $U_1^i(x_0, t_1^i) \geq \underline{U}^i$ and $U_2^{ni}(x_0, t_2^{ni}) \geq \underline{U}^i$ hold.

Next, $U_1^i(x_0, t_1^i) \geq \underline{U}^i \Leftrightarrow \pi(x_0) + g(x_0) + \vartheta^i t_1^i - C(x_0) \geq \underline{U}^i$

$$\Leftrightarrow \vartheta^i t_1^i \geq \underline{U}^i - \frac{\vartheta^{\mathrm{B}}\, \underline{U}^G - \vartheta^{\mathrm{G}}\, \underline{U}^B}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} \text{ (by Assumption 6(i))}$$

$$\Leftrightarrow t_1^G \geq \frac{(\underline{U}^B - \underline{U}^G)}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} \text{ and } t_1^B \geq \frac{(\underline{U}^B - \underline{U}^G)}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}}.$$

$$U_2^{ni}(x_0, t_2^{ni}) \geq \underline{U}^i \Leftrightarrow \pi(x_0) + g(x_0) + \vartheta^i t_2^{ni} - C(x_0) \geq \underline{U}^i$$

$$\Leftrightarrow \vartheta^i t_2^{ni} \geq \underline{U}^i - \frac{\vartheta^{\mathrm{B}}\, \underline{U}^G - \vartheta^{\mathrm{G}}\, \underline{U}^B}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} \text{ (by Assumption 6(i))}$$

$$\Leftrightarrow t_2^{nG} \geq \frac{(\underline{U}^B - \underline{U}^G)}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} \text{ and } t_2^{nG} \geq \frac{(\underline{U}^B - \underline{U}^G)}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}}.$$

It follows that both $U_1^i(x_0, t_1^i) \geq \underline{U}^i$ and $U_2^{ni}(x_0, t_2^{ni}) \geq \underline{U}^i$ are satisfied with equality if $t_1^i = t_2^{ni} = t^0 = \frac{(\underline{U}^B - \underline{U}^G)}{\vartheta^{\mathrm{B}} - \vartheta^{\mathrm{G}}} > 0$, since $\vartheta^{\mathrm{B}} > \vartheta^{\mathrm{G}}$ and $\underline{U}^B > \underline{U}^G$.

Since net social benefit from biodiversity protection $W(.)$) is strictly decreasing in monetary transfer to the farmer (by Assumption 5) and the farmer's optimal choice of biodiversity protection action x_0 once participated does not vary with the amount of monetary transfer, it is optimal for the regulator to set $t_1^i = t_2^{ni} = t^0$, $i = G, B$. [QED]

Corollary 2: *Proof:* We have $f^G(x_2^{sG*}) > f^B(x_2^{sB*})$ by Lemma 1. Therefore, $W(f^G(x_2^{sG*}),\ 0,\ I) > W(f^B(x_2^{sB*}),\ 0,\ I)$, since $W(.)$ is strictly increasing in its first argument (by Assumption 5), and thus, we get $O^{sG*} > O^{sB*}$, for all $\delta_0 \in (0, 1]$. [QED]

Proposition 1: *Proof*: The green farmer can signal its true type credibly to the regulator iff conditions (7a) and (8a) are satisfied. That is, given monetary transfers t and t_s, the green farmer's choice of action in the first period, x_1^G, must satisfy both (7a) and (8a). Now, $\Psi(x_1^G) = \pi\,(x_1^G) + g(x_1^G) - C(x_1^G)$ is strictly concave in x_1^G (by Assumptions 2 & 3) and has a unique maximum at $x_1^G = x_0$, since $\underset{x}{Argmax}\, \Psi(x) = \underset{x}{Argmax}\, [\pi(x) + g(x) + \vartheta^i t - C(x)] = x_0$ (by Lemma 2).

$$\Delta^{\mathrm{B}} < \Psi(x_0) \Rightarrow (1+\delta)\,\widetilde{U}^B - \delta\, U_2^{sB^0} - \vartheta^B\, t < \pi\,(x_0) + g(x_0) - C(x_0)$$

$$\Rightarrow (1+\delta)\,\widetilde{U}^B - \delta\, U_2^{sB^0} < \pi\,(x_0) + g(x_0) - C(x_0) + \vartheta^B\, t$$

$$\Rightarrow (1+\delta)\,\widetilde{U}^B - \delta\, U_2^{sB^0} < \widetilde{U}^B, since\ \widetilde{U}^B = U_1^B(x_0, t) = U_2^{nB^*} = U_1^{B^*} \Rightarrow \widetilde{U}^B$$

$$< U_2^{sB^0}, \qquad since\ \delta \in (0, 1], \qquad which\ is\ always\ true\ (by\ (9a)).$$

It follows that the equation $\Psi(x) = \Delta^{\mathrm{B}}$ has two roots, $\underline{x}_1^B$ and $\overline{x}_1^B$, such that $\underline{x}_1^B < x_0 < \overline{x}_1^B$ and $\forall\, x_1^G \in [0, \underline{x}_1^B] \cup [\overline{x}_1^B, \infty)$ brown farmer's incentive compatibility condition (8a) is satisfied.

Next, note that condition (9c) implies $\Delta^G < \Delta^B$ and we have shown that $\Delta^{\mathrm{B}} < \Psi(x_0)$. Therefore, the equation $\Psi(x) = \Delta^{\mathrm{G}}$ has two roots, $\underline{x}_1^G$ and $\overline{x}_1^G$, such that $\underline{x}_1^G < \underline{x}_1^B < x_0 < \overline{x}_1^B < \overline{x}_1^G$ holds. The green farmer's incentive compatibility condition (7a) is satisfied $\forall\, x_1^G \in [\underline{x}_1^G, \overline{x}_1^G]$. Putting together, both (7a) and (8a) are satisfied $\forall\, x_1^G \in [\underline{x}_1^G, \underline{x}_1^B] \cup [\overline{x}_1^B, \overline{x}_1^G]$. Therefore, from discussions in the text, it follows that the green farmer will choose $x_1^G = \overline{x}_1^B$ in period 1, signal his true type credibly to the regulator and choose $x_2^{sG^*}$ in period 2; while the brown farmer will choose x_0 in both periods.

Let us now establish that "the pair of biodiversity protection actions of the farmer in period 1 and period 2 $(x_1^{G,Sep}, x_2^{G,Sep}) = (\overline{x}_1^B, x_2^{sG^*})$ in case the farmer is of green type, and $(x_1^{B,Sep}, x_2^{B,Sep}) = (x_0, x_0)$ in case the farmer is of brown type" is a perfect Bayesian equilibrium (PBE). Note that a PBE consists of a strategy profile and a set of beliefs such that (a) given the beliefs, the strategies form a sub-game perfect Nash equilibrium and (b) given these strategies the beliefs satisfy the Bayes rule. In general, we can specify a PBE in the following manner. The *green*-type farmer will choose $x_1^{G,Sep}$ with probability μ^G and $x_1^{B,Sep}$ with probability $(1-\mu^G)$, and the *brown*-type farmer will choose $x_1^{G,Sep}$ with probability $(1-\mu^B)$ and $x_1^{B,Sep}$ with probability μ^B. Further, the regulator will be required to update his beliefs via the Bayes rule and decide whether to facilitate biodiversity protection action in period 2 or not, based on expected social welfare corresponding to his updated beliefs.

Let $\beta(x_1)$ be the updated probability the regulator attaches to the farmer being *green*-type after he observes the farmer's period 1 action x_1. In the case of separating equilibrium, we have seen that the optimal biodiversity protection actions are as follows: $x_1^{G,Sep} = \overline{x}_1^B$ and $x_1^{B,Sep} = x_0$; and $\mu^G = 1$ and $\mu^B = 1$. Then by Bayes rule, $\beta(\overline{x}_1^B) = \frac{\rho\,\mu^G}{\rho\,\mu^G + (1-\rho)\,(1-\mu^B)} = 1$ and $\beta(x_1^{B^*}) = \frac{\rho\,(1-\mu^B)}{\rho\,(1-\mu^G) + (1-\rho)\,\mu^B} = 0$. The signals are fully revealing and, thus, the regulator will facilitate the green-type farmer's biodiversity protection action. We can specify the out-of-equilibrium beliefs of the regulator as, $\beta(x_1) = \begin{cases} 1, & \text{if } x_1 \geq \overline{x}_1^B, \\ 0, & \text{if } x_1 < \overline{x}_1^B. \end{cases}$ [QED]

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