Appendix A.

The discrete approach is not novel in this context and has been used many times in the context of farmers (see e.g., Ruto and Garrod, 2009; Broch and Vedel, 2012; Kuhfuss *et al.*, 2015; Vaissiere *et al*, 2018, for examples).The discrete choice approach is in accordance with Lancaster (1966)'s theory of consumer choice in which consumption decisions are determined by the individual characteristics of the good, rather than the good in its entirety. The utility derived from a good can be classified as a linear function of its attributes. The functionality of the discrete choice contingent valuation approach is based on random utility theory as described in (McFadden, 1974).

The utility is defined by an observable part and a random part represented by error terms. In the Conditional Logit (CL) model, it is supposed that the error terms are independently and identically distributed (IID) among the alternatives and across the population and that irrelevant alternatives are independent (IIA).

Let A_{jit} be a dummy variable that takes the value of 1 if alternative j is chosen by farmer i in the choice card C_t, the probability related to this choice then is (see Kuhfuss *et al*., 2016; Vaissiere *et al*., 2018):

$$P\left(A_{jit} = 1\right) = \frac{\exp\,(X'_{jit}\beta)}{\sum_{m\in C_t} \exp\,(X'_{mit}\beta)} \qquad \text{(A.1)}$$

where X_{jit} denotes the attributes of alternative j faced by farmer i, and β is the vector of k preference parameters, representing the average importance of each attribute of the contract on farmers' preferences.

The Mixed Logit (ML) model relaxes the assumption of the CL model and allows assessing the β_{ki} that are specific to each respondent and randomly distributed across the population. The Mixed Logit (ML) model thus captures the heterogeneity of farmers' preferences. Conditional on vector β_i, the probability that farmer i chooses alternative j in choice card C_t is (see Kuhfuss *et al.*, 2016; Vaissiere *et al*., 2018):

$$P\left(A_{jit} = 1 \middle| \beta_i\right) = \frac{\exp\,(X'_{jit}\beta_i)}{\sum_{m\in C_t} \exp\,(X'_{mit}\beta_{i})} \qquad \text{(A.2)}$$

Then, the probability of observing a sequence of T choices by individual i is:

$$P\left(A_{ji1} = 1, \dots, A_{jiT} = 1\right) = \int \prod_{t=1}^{T} \left(\frac{\exp\left(X'_{jit}\beta\right)}{\sum_{m\in C_t} \exp\,(X'_{mit}\beta)}\right) f(\beta)d\beta \qquad \text{(A.3)}$$

Where $f(\beta)$ can be specified to be normal or lognormal: $\beta \sim N(b, W)$ or $\ln\beta \sim N(b, W)$.The mean b and the covariance W are to be estimated by simulation (Train, 2009).

Including payment as one of the attributes is primarily for the ability to calculate the marginal rate of substitution (MRS) between the choice attributes and money. In our choice experiment, the payment was per acre payment of land used in the scheme and so utility is increasing with payment. Therefore, MRS estimated translates to the change in a farmer's per acre of payment for certain features of the scheme. Negative results can therefore be interpreted as payment foregone to avoid (WTA) certain features of the scheme while positive results can be interpreted as payment forgone to acquire certain aspects of the scheme (WTP). [1]

The individual farmer's Willingness To Accept/Pay for attribute k in contracts is computed from equation (A.4).

$$WTP_{ki} = -\frac{\beta_{ki}}{\beta_{price}} \tag{A.4}$$

Where β_{ki} and β_{price} are the parameters associated with attribute k for farmer i and the monetary attribute for the full sample, respectively.

Thus, if a positive and significant WTP for the signage of recognition is achieved, this will highlight that for the farmers in the sample, R as defined in our paper does in fact exist as it will show that individuals are willing to buy reputation.

[1] The exception of this case being the "payment" characteristic which was formulated as a binary response in which 1 depicted payment after the scheme. Therefore, a negative result would in fact represented the Willingness to avoid (WTA) to have payment after the schemes completion.

Survey Questions

Introductory Paragraphs:

Hello, and thank-you for agreeing to participate in this short survey. The main idea behind this survey is to understand more deeply how farmers and Landowners In the UK perceive Agri-Environmental Climate Schemes and how they could be improved to better suit your desires. My name is James Asher and I am an Economics Masters Graduate at the University of Manchester and this was originally research for my thesis, which is being supervised by Dr Prasenjit Banerjee. On successful completion of the Thesis, The University of Manchester have provided further funding to extend the research. I hope you enjoy this survey and if successful it will result in these schemes being tailored more to suit you.

Each participant will be given £8 compensation for their time in completing the survey. There is also 5 x £50 rewards for the individuals who provide the answers which are closest to the average answers across the whole farming community. All information is stored privately and anonymously and your responses will not be seen by anyone. It should last between 10-15 minutes and doesn't involve much more than clicking buttons!

Interactive Questions:

If you are still happy to complete this survey could you please sign/write your first name in the box below or simply write "I consent". You do not have to answer any question you do not want to and are free to leave at any time and when the results are withdrawn from the system your name will be automatically transformed into a random group of letters and numbers for complete anonymity.

“From 25 May 2018 the University of Manchester are collecting and storing this information in accordance with the General Data Protection Regulation (GDPR) and Data Protection Act 2018 which legislate to protect your personal information. The legal basis upon which we are using your personal information is “public interest task” and “for research purposes” if sensitive information is collected. For more information about the way we process your personal information and comply with data protection law please see our Privacy Notice for Research Participants.”

Thanks! Could you now please provide a contact email address? If you do not wish to be contacted further just leave this section blank.

And most importantly, payment. Please state the method you would like to be paid by - Bank transfer or paypal.

-Paypal
-Bank transfer
And could you please now provide the relevant details required for us to process the payment - i.e bank details or paypal address.

Section 1

We will now ask a you a few short questions about yourself if that is okay.

1. Firstly, what is your gender?

    - male
    - female
    - other

2. What is your age?

3. How many years of formal education do you have?

4. How large is the size of the farm you work on/own in acres?
(You may also use a different unit of measurement, if so please make sure to specify which unit.)

5. What is your most prominent farming activity? (e.g cattle,sheep, crops etc)

6. Is your farmland owned, rented, or both.
    - owned
    - rented
    - both

7. Is the farm work your primary source of income?

8. How many miles is your farm from the nearest town?

9. Do you live on the farm?

“Thanks, that’s all from Section 1!

Section 2

This section asks you to rate each statement from 1 - strongly disagree to 5 - strongly agree.”

10. I feel that it is very important to protect bio-diversity on farmland.

11. I take action to protect biodiversity on my land due to the fact that others do the same.

12. I want others to consider me as an environmentally responsible and concerned person.

13. I feel that there is too much environmental protection going on.

14. I feel that money is required to compensate for action made by farmers to improve the environment.

15. I often partake in pro-environmental activities voluntarily without any monetary compensation.

16. I feel that government funded agri- environmental schemes are too complicated.

17. I feel that government funded agri-environmental schemes do not pay enough.

18. I feel that taking up pro-environmental activities can have a benefit to my land and profits from my land.

19. I feel that taking up pro-environmental activities can have a benefit socially (out with you and your land).

20. Have you heard about Agri-Environmental Schemes?

- Yes [continues to Q21]
- No [Logic Jumps to Q26]

21. Have you ever participated in such a scheme with the intention of increasing bio-diversity protection?

- Yes [continues to Q22]
- No [Logic Jumps to Q26]

22. Can you please give a short description?

23. How many acres were used?
(Again, if you would like you can use another measurement unit - but please specify which one.)

24. Were you compensated with money?

- Yes [continues to Q25]
- No [Logic Jumps to Q30]

25. Did the money cover the full cost?

- Yes
- No

“Thanks again! That’s all for section 2! Again, this next section asks you to rank outcomes varying from very socially unacceptable (1) to very socially acceptable (5)

<u>Section 3</u>

This section is where you can earn some extra money. The individuals who, in this section, provide the responses that are closest to the average response will receive £50 each."

26. Consider a fictional farmland and there is a protected/endangered species found on this farmland and there is a significant cost of protecting it. The fictional farmer decides to take **no action** and continue his work as normal. How do you feel about the farmers actions? For each of the choices, please indicate whether you believe choosing that option is very socially inappropriate, somewhat socially inappropriate, somewhat socially appropriate, or very socially appropriate.

27. Consider the same protected/endangered species is found on the same farmland and there is a significant cost of protecting it. The farmer informs the relevant authorities and **takes swift action** to protect the species, how do you feel about this response? For each of the choices, please indicate whether you believe choosing that option is very socially inappropriate, somewhat socially inappropriate, somewhat socially appropriate, or very socially appropriate.

28. Consider, finally, the same endangered species is found on the same farmland. Action is urgently required for its preservation. The Farmer refuses to act upon, and pay the costs of, supporting the protection of the species unless he is given **funding up front**. How do you feel about his response? For each of the choices, please indicate whether you believe choosing that option is very socially inappropriate, somewhat socially inappropriate, somewhat socially appropriate, or very socially appropriate.

Thanks again.

Section 4

This section is short and asks you to consider situations and tell us how you feel about certain actions of imaginary people."

"Imagine that two persons "A" and "B" voluntarily participate in a research study. They are paired randomly. They sit in two separate rooms and they didn't know each other before and will never meet each other in the future.

They will play a game in the study. A is randomly chosen as 'decision maker' and B is 'recipient'. Imagine also that the person A receives £10 that he decides whether to share with the other person B. A keeps for himself the amount he does not **give** to B. B has no decision to make.

In this scenario,

A's earnings = £10 – the amount transferred to B.

B's earnings = the amount transferred by A.

The next questions ask you to rate A's actions from very socially appropriate to very socially inappropriate."

		Very Socially Inappropriate	Somewhat Socially inappropriate	Somewhat socially appropriate	Very Socially appropriate
Q29	A gives £0 to B and keeps £10 for themselves.				
Q30	A gives £1 to B and keeps £9 for themselves.				
Q31	A gives £2 to B and keeps £8 for themselves.				
Q32	A gives £3 to B and keeps £7 for themselves.				
Q33	A gives £4 to B and keeps £6 for themselves.				
Q34	A gives £5 to B and keeps £5 for themselves.				
Q35	A gives £6 to B and keeps £4 for themselves.				
Q36	A gives £7 to B and keeps £3 for themselves.				
Q37	A gives £8 to B and keeps £2 for themselves.				
Q38	A gives £9 to B and keeps £1for themselves.				
Q39	A gives £10 to B and keeps £1 for themselves.				

Thanks!

Section 5

Now if you could imagine the same situation as above but in this instance instead of A being able to decide how much money he can give to B, B is the decision maker and can decide how much he can **take** from A. "

		Very Socially Inappropriate	Somewhat Socially inappropriate	Somewhat socially appropriate	Very Socially appropriate
Q40	B takes £10 from A and leaves £0 for A.				
Q41	B takes £9 from A and leaves £1 for A.				
Q42	B takes £8 from A and leaves £2 for A.				
Q43	B takes £7 from A and leaves £3 for A.				
Q44	B takes £6 from A and leaves £4 for A.				
Q45	B takes £5from A and leaves £5 for A.				
Q46	B takes £4 from A and leaves £6 for A.				
Q47	B takes £3 from A and leaves £7 for A.				
Q48	B takes £2 from A and leaves £8 for A.				
Q49	B takes £1 from A and leaves £9 for A.				
Q50	B takes £0 from A and leaves £10 for A.				

Thanks.

Section 6

And finally the last section. Please consider that you are approached by the Scottish Government to take part in their Beef Efficiency Scheme. The objective of the Beef Efficiency Scheme is to assist in the development of your suckler herd to become as efficient as possible. Increasing efficiency will reduce the emissions from beef production and also improve overall herd profitability making your herd more sustainable both economically and environmentally. Full impacts and potential profits will not be realised for several years so the payments outlined are to cover transition and labour costs. **If you do not have experience raising cattle please click the finish button.**

If you chose the "other" option, please place an "x" in the text box if it does not let you continue.

- I have experience raising cattle.
- I do not have experience raising cattle - finish survey.

The main objective here is to understand which parts of the schemes you, the farming community, value and which you don't. Most of the aspects of the schemes are self explanatory. The "publicity notice" aspect is a recognition of participation. You would be published on the Scottish government website and you would be given a large billboard (which highlighted your efforts and contribution to the scheme) which could be place anywhere of your choice on your land.

Full details of the Beef Efficiency Scheme can be seen at: https://www.ruralpayments.org/publicsite/futures/topics/all-schemes/beef-efficiency-scheme/"

	Option 1	Option 2
Q51	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:8 hours • Publicity notice: Yes • Payment per hectare: £42	• Length of Contract: 10 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:6 hours • Publicity notice: No • Payment per hectare: £47
Q52	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:6 hours • Publicity notice: Yes • Payment per hectare: £46	• Length of Contract: 10 Years • Right to not uphold certain aspects of the scheme: Yes • Time spent on scheme per week:8 hours • Publicity notice: No • Payment per hectare: £42
Q53	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week: 6 hours • Publicity notice: Yes • Payment per hectare: £42	• Length of Contract: 15 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:4 hours • Publicity notice: No • Payment per hectare: £38
Q54	• Length of Contract: 20 Years • Right to not uphold certain aspects of the scheme: Yes • Time spent on scheme per week:6 hours • Publicity notice: Yes • Payment per hectare: £32	• Length of Contract: 10 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:8 hours • Publicity notice: No • Payment per hectare: £42
Q55	• Length of Contract: 15 Years • Right to not uphold certain aspects of the scheme: Yes • Time spent on scheme per week:10 hours • Publicity notice: Yes • Payment per hectare: £42	• Length of Contract: 10 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:6 hours • Publicity notice: Yes • Payment per hectare: £40
Q56	• Length of Contract: 20 Years • Right to not uphold certain aspects of the scheme: No	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No

	• Time spent on scheme per week:6 hours • Publicity notice: Yes • Payment per hectare: £42	• Time spent on scheme per week:10 hours • Publicity notice: Yes • Payment per hectare: £36
Q57	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: Yes • Time spent on scheme per week:6 hours • Publicity notice: Yes • Payment per hectare: £42	• Length of Contract: 15 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:6 hours • Publicity notice: No • Payment per hectare: £42
Q58	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:8 hours • Publicity notice: Yes • Payment per hectare: £32	• Length of Contract: 10 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:6 hours • Publicity notice: No • Payment per hectare: £42
Q59	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:6 hours • Publicity notice: Yes • Payment per hectare: £42	• Length of Contract: 20 Years • Right to not uphold certain aspects of the scheme: yes • Time spent on scheme per week:4 hours • Publicity notice: Yes • Payment per hectare: £28
Q60	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:8 hours • Publicity notice: Yes • Payment per hectare: £42	• Length of Contract: 5 Years • Right to not uphold certain aspects of the scheme: No • Time spent on scheme per week:8 hours • Publicity notice: No • Payment per hectare: £40

Thank-you for completing the survey, it has been very helpful for me and hopefully you too! If you have any comments about the survey or any further information to provide, please enter it below! if not, leave the box blank and thanks again.

END

Appendix B.

Symmetric Information

B1. Proof of Lemma 1

From Definition 1 and Equation 2 we have $x_F^{i*} = \underset{x}{argmax}\, U_F^i\left(x, t_F^i\right)$, where $U_F^i\left(x, t_F^i\right) = f^i(x) + \vartheta^i t_F^i - C(x) + R\left(v^i, x;\ \theta_F\right), i = G, B$; since $E\left(\vartheta \middle| x,\ t^i\right) = v^i$ under symmetric information. Therefore, the first order condition of the problem $\underset{x}{max}\, U_F^i\left(x, t_F^i\right)$ is satisfied at $x = x_F^{i*}, i = G, B.$, i.e.

$$\left.\frac{\partial U_F^G(x,t_F^G)}{\partial x}\right|_{x=x_F^{G*}} = \left.\frac{\partial f^G(x)}{\partial x}\right|_{x=x_F^{G*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_F^{G*}} + \left.\frac{\partial R\left(v^G,x;\theta_F\right)}{\partial x}\right|_{x=x_F^{G*}} = 0, \qquad (i)$$

and

$$\left.\frac{\partial U_F^B(x,t_F^G)}{\partial x}\right|_{x=x_F^{B*}} = \left.\frac{\partial f^B(x)}{\partial x}\right|_{x=x_F^{B*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_F^{B*}} + \left.\frac{\partial R\left(v^B,x;\theta_F\right)}{\partial x}\right|_{x=x_F^{B*}} = 0. \qquad (ii)$$

It is evident that $x_F^{G*},\ x_F^{B*} > 0$ (by Assumptions 1, 2 and 3). Now,

$$\left.\frac{\partial U_F^G(x,t_F^G)}{\partial x}\right|_{x=x_F^{B*}}$$

$$= \left.\frac{\partial f^G(x)}{\partial x}\right|_{x=x_F^{B*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_F^{B*}} + \left.\frac{\partial R\left(v^G,x;\theta_F\right)}{\partial x}\right|_{x=x_F^{B*}}$$

$$= \left.\frac{\partial f^B(x)}{\partial x}\right|_{x=x_F^{B*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_F^{B*}} + \left.\frac{\partial R\left(v^B,x;\theta_F\right)}{\partial x}\right|_{x=x_F^{B*}} + \left[\frac{\partial f^G(x)}{\partial x} - \frac{\partial f^B(x)}{\partial x}\right]_{x=x_F^{B*}}$$

$$+ \left[\frac{\partial R\left(v^G,x;\theta_F\right)}{\partial x} - \frac{\partial R\left(v^B,x;\theta_F\right)}{\partial x}\right]_{x=x_F^{B*}}$$

$$= 0 + \left[\frac{\partial f^G(x)}{\partial x} - \frac{\partial f^B(x)}{\partial x}\right]_{x=x_F^{B*}} + \left[\frac{\partial R\left(v^G,x;\theta_F\right)}{\partial x} - \frac{\partial R\left(v^B,x;\theta_F\right)}{\partial x}\right]_{x=x_F^{B*}}, \text{ by } (i)$$

$> 0,$ by Assumptions 1 and 2.

$\left.\frac{\partial U_F^G(x,t_F^G)}{\partial x}\right|_{x=x_F^{B*}} > 0$ and equation (i) together imply that $x_F^{G*} > x_F^{B*} > 0$. Therefore, by Assumptions 1 and 3, it follows that $f^G(x_F^{G*}) > f^B(x_F^{B*})$. [QED]

B2. Proof of Lemma 2

From Definition 2 and Equation 2 we have $x_N^{i*} = \underset{x}{argmax}\, U_N^i\left(x, t_N^i\right)$, where $U_N^i\left(x, t_F^i\right) = g(x) + \vartheta^i t_N^i - C(x) + R\left(v^i, x;\ \theta_N\right), i = G, B$; since $E\left(\vartheta \middle| x,\ t^i\right) = v^i$ under symmetric information. Therefore, the first order condition of the problem $\underset{x}{max}\, U_N^i\left(x, t_N^i\right)$ is satisfied at $x = x_N^{i*}, i = G, B.$, i.e.

$$\left.\frac{\partial U_N^G(x,t_N^G)}{\partial x}\right|_{x=x_N^{G*}} = \left.\frac{\partial g(x)}{\partial x}\right|_{x=x_N^{G*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_N^{G*}} + \left.\frac{\partial R(v^G,x;\theta_N)}{\partial x}\right|_{x=x_N^{G*}} = 0, \qquad (i)$$

and

$$\left.\frac{\partial U_N^B(x,t_N^G)}{\partial x}\right|_{x=x_N^{B*}} = \left.\frac{\partial g(x)}{\partial x}\right|_{x=x_N^{B*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_N^{B*}} + \left.\frac{\partial R(v^B,x;\theta_N)}{\partial x}\right|_{x=x_N^{B*}} = 0. \qquad (ii)$$

It is evident that $x_N^{G*},\ x_N^{B*} > 0$ (by Assumptions 1, 2 and 3). Now,

$$\left.\frac{\partial U_N^G(x,t_N^G)}{\partial x}\right|_{x=x_N^{B*}}$$

$$= \left.\frac{\partial g(x)}{\partial x}\right|_{x=x_N^{B*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_N^{B*}} + \left.\frac{\partial R(v^G,x;\theta_N)}{\partial x}\right|_{x=x_N^{B*}}$$

$$= \left.\frac{\partial g(x)}{\partial x}\right|_{x=x_N^{B*}} - \left.\frac{\partial C(x)}{\partial x}\right|_{x=x_N^{B*}} + \left.\frac{\partial R(v^B,x;\theta_N)}{\partial x}\right|_{x=x_N^{B*}} + \left[\frac{\partial R(v^G,x;\theta_N)}{\partial x} - \frac{\partial R(v^B,x;\theta_N)}{\partial x}\right]_{x=x_N^{B*}}$$

$$= 0 + \left[\frac{\partial R(v^G,x;\theta_N)}{\partial x} - \frac{\partial R(v^B,x;\theta_N)}{\partial x}\right]_{x=x_N^{B*}}, \text{ by } (i)$$

≥ 0, where the equality holds true iff $\frac{\partial}{\partial v}\left(\frac{\partial R(v,x;\theta_N)}{\partial x}\right) = 0$, by Assumption 2.

Note that $\left.\frac{\partial U_N^G(x,t_N^G)}{\partial x}\right|_{x=x_N^{B*}} \geq 0$ and equation (i) together imply that $x_N^{G*} \geq x_N^{B*} > 0$, where the equality holds true iff $\frac{\partial}{\partial v}\left(\frac{\partial R(v,x;\theta_N)}{\partial x}\right) = 0$. Therefore, by Assumptions 1 and 3, it follows that $g(x_N^{G*}) > g(x_N^{B*})$, if $\frac{\partial}{\partial v}\left(\frac{\partial R(v,x;\theta_N)}{\partial x}\right) > 0$; otherwise, if $\frac{\partial}{\partial v}\left(\frac{\partial R(v,x;\theta_N)}{\partial x}\right) = 0$, $g(x_N^{G*}) = g(x_N^{B*})$. [QED]

B3. Proof of Lemma 3

a) We know $\left.\frac{\partial U_F^G(x,t_F^G)}{\partial x}\right|_{x=x_F^{G*}} = 0$ and $\left.\frac{\partial U_N^G(x,t_N^G)}{\partial x}\right|_{x=x_N^{G*}} = 0$. Now, by equation (2),

$$\left.\frac{\partial U_F^G(x,t_F^G)}{\partial x}\right|_{x=x_N^{G*}}$$

$$= \left.\frac{\partial U_N^G(x,t_N^G)}{\partial x}\right|_{x=x_N^{G*}} + \left.\left[\frac{\partial f^G(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\right]\right|_{x=x_N^{G*}} + \left.\left[\frac{\partial R(v^G,x;\theta_F)}{\partial x} - \frac{\partial R(v^G,x;\theta_N)}{\partial x}\right]\right|_{x=x_N^{G*}}$$

$$= 0 + \left.\left[\frac{\partial f^G(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\right]\right|_{x=x_N^{G*}} + \left.\left[\frac{\partial R(v^G,x;\theta_F)}{\partial x} - \frac{\partial R(v^G,x;\theta_N)}{\partial x}\right]\right|_{x=x_N^{G*}}$$

> 0, by Assumptions 1, 2 and 3.

Therefore, $x_F^{G*} > x_N^{G*}$, which implies that $f^G(x_F^{G*}) > g(x_N^{G*})$, since $f^G(x) > g(x)$ and ${f^G}'(x) > g'(x) > 0$ for all $x > 0$.

b) We have $\left.\frac{\partial U_F^B(x,t_F^B)}{\partial x}\right|_{x=x_F^{B*}} = 0$ and $\left.\frac{\partial U_N^B(x,t_N^B)}{\partial x}\right|_{x=x_N^{B*}} = 0$. Now, by equation (2),

$$\frac{\partial U_F^B(x,t_F^B)}{\partial x}_{x=x_N^{B*}}$$

$$= \left.\frac{\partial U_N^B(x,t_N^B)}{\partial x}\right|_{x=x_N^{B*}} + \left.\left[\frac{\partial f^B(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\right]\right|_{x=x_N^{B*}} + \left.\left[\frac{\partial R(v^B,x;\,\theta_F)}{\partial x} - \frac{\partial R(v^B,x;\,\theta_N)}{\partial x}\right]\right|_{x=x_N^{B*}}$$

$$= 0 + \left.\left[\frac{\partial f^B(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\right]\right|_{x=x_N^{B*}} + \left.\left[\frac{\partial R(v^B,x;\,\theta_F)}{\partial x} - \frac{\partial R(v^B,x;\,\theta_N)}{\partial x}\right]\right|_{x=x_N^{B*}}$$

Now, $\left.\left[\frac{\partial f^B(x)}{\partial x} - \frac{\partial g(x)}{\partial x}\right]\right|_{x=x_N^{B*}} \geq 0$, where the equality holds true if $f^B(x) = g(x)$. Also, $\left.\left[\frac{\partial R(v^B,x;\,\theta_F)}{\partial x} - \frac{\partial R(v^B,x;\,\theta_N)}{\partial x}\right]\right|_{x=x_N^{B*}} > (=)0$, if $\frac{\partial\,(R(v^B,x;\,\theta_F)-R(v^B,x;\,\theta_N))}{\partial x} > (=)0$.

It implies that $\frac{\partial U_F^B(x,t_F^B)}{\partial x}_{x=x_N^{B*}} \geq 0$, where the equality holds true only if $f^B(x) = g(x)$ and $\frac{\partial}{\partial x}[R(v^B,x;\,\theta_F) - R(v^B,x;\theta_N)] = 0$.

Therefore, by Assumptions 1, 2 and 3, we get $x_F^{B*} \geq x_N^{B*}$ *and* $f^B(x_F^{B*}) \geq g(x_N^{B*})$, where equalities hold true only if $f^B(x) = g(x)$ and $\frac{\partial}{\partial x}[R(v^B,x;\,\theta_F) - R(v^B,x;\theta_N)] = 0\ \forall\, x \geq 0$.

[QED]

B4. Proof of Lemma 4

a) For any given $x(>0)$, we have the following.

(i) $\Psi_F^i(x) > \Psi_N^i(x)$, since $f^G(x) > f^B(x) \geq g(x)$ (by Assumption 1) and $R(v^i,x;\,\theta_F) > R(v^i,x;\,\theta_N)$ (by Assumption 2),

(ii) $\Psi_F^i(x)$ and $\Psi_N^i(x)$ are strictly concave in x (by Assumptions 2 and 3),

(iii) $\Psi_F^i(x)$ and $\Psi_N^i(x)$ are maximum at $x = x_F^{i*}$ and $x = x_N^{i*}$, respectively (by Definitions 1, 2 and 4), and

(iv) $x_F^{G*} > x_N^{G*} > 0$ and $x_F^{B*} \geq x_N^{B*} > 0$ (by Lemma 3).

From (i), (ii), (iii) and (iv), it follows that $\Psi_F^{i*} > \Psi_N^{i*},\ i = G, B$.

(b) We know $\Psi_F^G(x) > \Psi_F^B(x), \forall x > 0$, since $f^G(x) > f^B(x)$ (by Assumption 1) and $R(v^G,x;\,\theta_F) \geq R(v^B,x;\,\theta_F)$ (by Assumption 2). $\Psi_F^G(x)$ and $\Psi_F^B(x)$ are strictly concave in x (by Assumptions 2 and 3) and are maximum at $x = x_F^{G*}$ and $x = x_F^{B*}$, respectively. Further, $x_F^{G*} > x_F^{B*} > 0$ (by Lemma 1). Therefore, we must have $\Psi_F^{G*} > \Psi_F^{B*}$.

(c) We know $\Psi_N^G(x) > \Psi_N^B(x), \forall x > 0$, since $R(v^G,x;\,\theta_N) > R(v^B,x;\,\theta_N)$ (by Definition 4 and Equation 2). $\Psi_N^G(x)$ and $\Psi_N^B(x)$ are strictly concave in x (by Assumptions 2 and 3) and are maximum at $x = x_N^{G*}$ and $x = x_N^{B*}$, respectively. Further, $x_N^{G*} \geq x_N^{B*} > 0$ (by Lemma 2). Therefore, it follows that $\Psi_N^{G*} > \Psi_N^{B*}$.

[QED]

B5. Proof of Lemma 5

When the regulator offers monetary transfer of amount t_N^i to type-i ($i = G, B$) farmer and does not offer him any facilitation services or social reward, if type-i farmer accepts the contract, it is optimum for him to undertake biodiversity protection action x_N^{i*} and obtain utility $U_N^i(x_N^{i*}, t_N^i)$. The regulator cannot induce the type-i farmer to choose any other level of action that is different from x_N^{i*}, since farmers actions are non-verifiable. Thus, the type-i farmer will choose action x_N^{i*} and obtain utility $U_N^i(x_N^{i*}, t_N^i)$, if he accepts the contract. Now, the farmer will choose the contract, if his utility from the contract is no less than his reservation utility, i.e., if $U_N^i(x_N^{i*}, t_N^i) \geq \underline{U}^i$. Now,

$U_N^i(x_N^{i*}, t_N^i) \geq \underline{U}^i$

$\Leftrightarrow \Psi_N^{i*} + v^i t_N^i \geq \underline{U}^i$, by Definition 4

$\Leftrightarrow t_N^i \geq \frac{\underline{U}^i - \Psi_N^{i*}}{\vartheta^i} = \underline{t_N^i}$, by Definition 3.

Clearly, $t_N^i = \underline{t_N^i}$ is the minimum amount of money that the regulator needs to offer in order to induce the farmer of type-i to undertake biodiversity protection action in absence of any non-monetary incentive offered to him and, thus, $t_N^{i*} = \underline{t_N^i}, i = G, B$.

Next, if the regulator facilitates type-i ($= G, B$) farmer's biodiversity protection action and the farmer accepts the contract, his optimal level of action is x_F^{i*} and his utility corresponding to this action choice is $U_F^i(x_F^{i*}) = \Psi_F^{i*} + v^i t_F^i$, where t_F^i is the monetary transfer offered to him in this case. Therefore, the type-i farmers accepts this contract, if $\Psi_F^{i*} + v^i t_F^i \geq \underline{U}^i \Leftrightarrow t_F^i \geq \frac{\underline{U}^i - \Psi_F^{i*}}{\vartheta^i}$. Now, by Assumption 5, $\underline{U}^i - \Psi_F^{i*} < 0$. Therefore, the type-$i$ farmer's participation constraint is satisfied for all $t_F^i \geq 0$, implying that it is optimum for the regulator to set $t_F^i = 0$ in the equilibrium.

[QED]

Asymmetric Information

***Claim 1**: If the regulator offers a single contract (t, N) under asymmetric information, G-type farmer cannot signal its true identity and in the equilibrium, if he accepts the contract, he chooses the B-type's symmetric information optimal action in absence of facilitation, x_N^{B*}, and obtains the utility $U_N^G(x_N^{B*} | E(v|x_N^{B*}, t) = v^B) = \Psi_N^{B*} + v^G t$, while the B-type obtains utility $U_N^B(x_N^{B*} | E(v|x_N^{B*}, t) = v^B) = \Psi_N^{B*} + v^B t$ in case he receives the contract.*

Proof: Suppose that the regulator offers a single contract (t, N) under asymmetric information. Then, if the G-type accepts the contract, G-type will be able to credibly signal his true type by choosing action x_N^G , if conditions (i) and (ii) are satisfied.

$$\Psi_N^G\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right) + v^G t > \Psi_N^G\left(x_N^{G*,B} \middle| E\left(v \middle| x_N^{G*,B}, t\right) = v^B\right) + v^G t, \qquad (i)$$
$$\Psi_N^B\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right) + v^B t \leq \Psi_N^B(x_N^{B*} \middle| E(v \middle| x_N^{B*}, t) = v^B) + v^B t, \qquad (ii)$$

where (a) $\Psi_N^G\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right)$ is the gross utility of the G-type, when it can credibly signals its true type, (b) $\Psi_N^B\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right)$ is the gross utility of the B-type, when it hides its true identity by choosing x_N^G, (c) $x_N^{G*,B}$ denotes the G-type's optimal action, when it cannot signal its true type and he is perceived as B-type, and, thus, $\Psi_N^G\left(x_N^{G*,B} \middle| E\left(v \middle| x_N^{G*,B}, t\right) = v^B\right)$ is the maximum gross utility that G-type can earn, when he cannot signal his true type, and (b) $\Psi_N^B(x_N^{B*} \middle| E\left(v \middle| x_N^{G*}, t\right) = v^B)$ is the maximum gross utility of the B-type, when it cannot hide his true identity.

Condition (i) is the incentive compatibility condition of G-type to signal its true type, which states that the G-type's utility from signalling is greater than that from not signalling his true type. Condition (ii) is the incentive compatibility condition of the B-type not to hide its true identity, which states that the B-type does not get anything more by hiding its true identity compared to revealing its identity.

$$(i) \Leftrightarrow \Psi_N^G\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right) > \Psi_N^G\left(x_N^{G*,B} \middle| E\left(v \middle| x_N^{G*,B}, t\right) = v^B\right) \qquad (i')$$
$$(ii) \Leftrightarrow \Psi_N^B\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right) \leq \Psi_N^B(x_N^{B*} \middle| E\left(v \middle| x_N^{G*}, t\right) = v^B) \qquad (ii')$$

Now, note that $x_N^{G*,B} = x_N^{B*}$ and $\Psi_N^G\left(x_N^{G*,B} \middle| E\left(v \middle| x_N^{G*,B}, t\right) = v^B\right) = \Psi_N^B(x_N^{B*} \middle| E\left(v \middle| x_N^{G*}, t\right) = v^B) = \Psi_N^{B*}$, since each type is perceived as B-type by all and in absence of facilitation services public goods production functions are the same for both types of farmers. Also, $\Psi_N^G\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right) = \Psi_N^B\left(x_N^G \middle| E\left(v \middle| x_N^G, t\right) = v^G\right)$, since each type is perceived as G-type. It follows that (i') and (ii') cannot hold together, implying that (i) and (ii) cannot hold together.

Therefore, when the regulator offers a single contract (t, N) under asymmetric information, in the equilibrium, G-type will not be able to signal its true type.

Given the off the equilibrium beliefs, each type of farmers will be regarded as B-type under asymmetric information, unless the G-type credibly signals its true identity. Thus, when the regulator offers a single contract (t, N) under asymmetric information, in the equilibrium each type will choose the B-type's symmetric information optimal contract in absence of facilitation, x_N^{B*} , provided that $t \geq \frac{U^i - \Psi_N^{B*}}{\vartheta^i}$, $i = G, B$. Thus, if the G-type accepts the contract, his equilibrium utility is $U_N^G(x_N^{B*} \mid E(v \mid x_N^{B*}, t) = v^B) =$

$\Psi_N^{B*} + v^G t$; and the B-type's equilibrium utility, if he participates, is $U_N^B(x_N^{B*}\,|E(v|x_N^{B*}, t) = v^B) = \Psi_N^{B*} + v^B t$

Claim 2*: Under asymmetric information, if the regulator offers only the symmetric information equilibrium contract for the G-type in absence of non-monetary incentives ($t_N^{G*} = \underline{t_N^G} = \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^G}$, N), the G-type farmer does not participate in the biodiversity protection action, while the B-type farmer may or may not participate. In order to induce the G-type to participate, the regulator needs to offer him more than symmetric information equilibrium amount of monetary transfer in order to appropriately compensate him for his loss in social reputation.*

Proof: First we prove that $U_N^G(x_N^{B*}\,|E(v|x_N^{B*}, t) = v^B) < U_N^G(x_N^{G*}\,|E(v|x_N^{G*}, t) = v^G)$.

Note that we have the following.

(a) $x_N^{G*} = \underset{x_N^G > 0}{argmax}\, U_N^G(x_N^G, t)$,

(b) $x_N^{B*} = \underset{x_N^B > 0}{argmax}\, U_N^B(x_N^B, t) = \underset{x>0}{argmax}\, U_N^G(x|E(v|x, t) = v^B)$, by Assumptions 1-3 and equation (2),

(c) $U_N^G(x|E(v|x, t) = v^G) > U_N^G(x|E(v|x, t) = v^B)\ \forall x > 0$, by Assumptions 1-3,

(d) $x_N^{G*} \geq x_N^{B*} > 0$, by Lemma 2.

From (a)-(d) it follows that $U_N^G(x_N^{B*}\,|E(v|x_N^{B*}, t) = v^B) < U_N^G(x_N^{G*}\,|E(v|x_N^{G*}, t) = v^G)$.

In order to induce the G-type farmer to participate, t must be such that $\Psi_N^{B*} + v^G t \geq \underline{U}^G \Rightarrow t \geq \frac{\underline{U}^G - \Psi_N^{B*}}{v^G}$ is satisfied. However, $\Psi_N^{G*} > \Psi_N^{B*}$ by Lemma 4, implying that $t_N^{G*} < \frac{\underline{U}^G - \Psi_N^{B*}}{v^G}$, thus G-type does not participate.

The B-type participates, if $\Psi_N^{B*} + v^B t_N^{G*} \geq \underline{U}^B \Rightarrow t_N^{G*} \geq \frac{\underline{U}^B - \Psi_N^{B*}}{v^B} \Rightarrow \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^G} \geq \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}$, which may or may not hold true since $\vartheta^G < \vartheta^B$ and $\underline{U}^G > (=) < \underline{U}^B$ by construction. [QED]

Claim 3*: Under asymmetric information, if the regulator offers only the symmetric information equilibrium contract for the B-type ($t_N^{B*} = \underline{t_N^B} = \frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^B}$, N), the B-type farmer participates in the* *biodiversity protection action, since he does not suffer from any loss in social reputation due to asymmetric information in this case, while the G-type may or may not participate.*

***Proof**: By accepting the contract, the B-type receives utility* $U_N^B(x_N^{B*}|E(v|x_N^{B*},t) = v^B) = \Psi_N^{B*} + v^B t_N^{B*} = \underline{U}^B$*, implying that B-type will accept the contract. On the other hand, G-type accepts the contract, if his utility* $U_N^G(x_N^{B*}|E(v|x_N^{B*},t) = v^B) = \Psi_N^{B*} + v^G t_N^{B*} \geq \underline{U}^G \Rightarrow \frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^B} \geq \frac{\underline{U}^G - \Psi_N^{B*}}{\vartheta^G}$, which does not necessarily hold true since $\vartheta^G < \vartheta^B$ and $\underline{U}^G > (=) < \underline{U}^B$ by construction. [QED]

***Claim 4**: Under asymmetric information, if the regulator offers the contract* (t, N)*, such that* $t \geq \max\{t_N^{B*}, \frac{\underline{U}^G - \Psi_N^{B*}}{v^G}\}$*, each type participates in biodiversity protection action. That is, in absence of facilitation services, the regulator needs to offer more money under asymmetric information to induce both types to participate in biodiversity protection action, if she offers a single contract involving only monetary incentives.*

Proof: Follows immediately from Claims 1-3 and the proof of Claim 2.

***Lemma 6**: Suppose that Assumptions 1 – 4 hold true and the regulator offers the menu of contracts* $\{(t_N^G, N), (t_N^B, N)\}$*, where* N *indicates no non-monetary incentives and superscript* $i\ (= G, B)$ *indicates that the contract is meant for the type-*i *farmer;* $t_N^G \neq t_N^B$ *and* $t_N^B, t_N^G \geq 0$*. Then in the equilibrium under asymmetric information each type of farmers self-selects the contract meant from him as well as chooses his 'symmetric information equilibrium level of biodiversity protection action in absence of any non-monetary incentive', if the following inequalities hold true.*

(i) $t_N^B \geq \frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^B}$,

(ii) $t_N^G \geq \frac{\underline{U}^G - \Psi_N^{G*}}{v^G}$ and

(iii) $\frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_N^G < \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^G}$

where Ψ_N^{G*} *and* Ψ_N^{B*} *are as in Definition 4.*

Proof: We have proved that, if both G-type and B-type chooses the same contract, i.e. if both choose (t_N^B, N) or both choose (t_N^G, N), then it is not possible for the G-type to signal its true identity (Claim 1). From Claim 1 it also follows that each type's optimum is to choose action x_N^{B*}, regardless of which particular contract both have chosen. Further, if both choose (t_N^G, N), utilities of the G-type and B-type are, respectively, $U_N^G(x_N^{B*} | E(v|x_N^{B*}, t_N^G) = v^B) = \Psi_N^{B*} + v^G t_N^G$ and $U_N^B(x_N^{B*} | E(v|x_N^{B*}, t) = v^B) = \Psi_N^{B*} + v^B t_N^G$. On the other hand, if both choose (t_N^B, N), utilities of the G-type and B-type are, respectively, $U_N^G(x_N^{B*} | E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^G t_N^B$ and $U_N^B(x_N^{B*} | E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^B t_N^B$. Thus, when it is not possible for the G-type to signal its true identity, both G-type and B-type will choose the contract that offers higher monetary transfer.

Now, each type will choose the contract meant for him and the G-type will be able to credibly signal its true identity by choosing his symmetric information optimal action in absence of non-monetary incentives, x_N^{G*}, if each type's participation constraint and incentive compatibility constraint are satisfied, i.e. if the following conditions holds true.

Participation Constraints:

Green farmer: $\Psi_N^G(x_N^{G*}|E(v|x_N^{G*}, t_N^G) = v^G) + v^G t_N^G \geq \underline{U}^G$ $\quad (i)$

Brown farmer: $\Psi_N^B(x_N^{B*}|E(v|x_N^{B*}, t_N^B) = v^B) + v^B t_N^B \geq \underline{U}^B,$ $\quad (ii)$

where x_N^{i*}, $i = G, B$, is type- i's symmetric information optimal action.

Incentive Compatibility Constraints:

Green farmer:

$$\Psi_N^G(x_N^{G*}|E(v|x_N^{G*}, t_N^G) = v^G) + v^G t_N^G > \Psi_N^G\left(x_N^{G*,B}\middle|E\left(v\middle|x_N^{G*,B}, t_N^B\right) = v^B\right) + v^G t_N^B \quad (iii)$$

Brown farmer:

$$\Psi_N^B(x_N^{G*}|E(v|x_N^{G*}, t_N^G) = v^G) + v^B t_N^G \leq \Psi_N^B(x_N^{B*}|E(v|x_N^{B*}, t_N^B) = v^B) + v^B t_N^B \quad (iv)$$

In condition (iii), $x_N^{G*,B}$ denotes the G-types optimal action when he cannot signal his true type and others perceive him as B-type. Conditions (iii) and (iv) together imply that it is optimal for the G-type to choose the contract (t_N^G, N) and then undertake biodiversity protection action x_N^{G*} that signals his true type compared to choosing the contract (t_N^B, N) and not being able to signal his true type, whereas it is optimal for the B-type to choose the contract (t_N^B, N) and then choose action x_N^{B*} that reveals his identity compared to choosing the contract (t_N^G, N) and then choose x_N^{G*} to pretend that his is actually G-type.

From (2) and Definition 4, it follows that $x_N^{G*,B} = x_N^{B*}$, $\Psi_N^G\left(x_N^{G*,B} \middle| E\left(v \middle| x_N^{G*,B}, t_N^B\right) = v^B\right) = \Psi_N^B(x_N^{B*}|E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*}$ and $\Psi_N^B(x_N^{G*}|E(v|x_N^{G*}, t_N^G) = v^G) = \Psi_N^G(x_N^{G*}|E(v|x_N^{G*}, t_N^G) = v^G) = \Psi_N^{G*}$ Therefore, conditions (iii) and (iv) implies that

$$\frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_N^G < \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^G} \qquad (v)$$

Now, since $\Psi_N^{G*} > \Psi_N^{B*} > 0$ (by Lemma 4) and $0 < v^G < v^B$ (by construction), $0 < \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} < \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^G}$ Thus, it is possible to satisfy condition (v) by choosing t_N^B and t_N^G appropriately. Note that for condition (v) to be satisfied we must have $t_N^B > t_N^G$.

Further t_N^B and t_N^G should satisfy conditions (i) and (ii), respectively. That is, we must have $t_N^G \geq \frac{\underline{U}^G - \Psi_N^{G*}}{v^G}$ and $t_N^B \geq \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}$ satisfied as well.

[QED]

***Lemma* 7:** *Suppose that Assumptions 1 – 4 hold true and the regulator does not offer any non-monetary incentives. Then under asymmetric information the regulator can implement the symmetric information equilibrium outcomes, $x_N^{G**} = x_N^{G*}$ and $x_N^{B**} = x_N^{B*}$, at the least cost by offering the menu of contracts $\{ (t_N^{G**,s}, N),\ (t_N^{B**,s}, N)\}$ such that*

(a) $t_N^{G**,s} = \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}} = \underline{t_N^G}$ *and* $t_N^{B**,s} = \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} + \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}} > \underline{t_N^B}$, *if* $\frac{\underline{U}^B - \Psi_N^{G*}}{\vartheta^{\mathrm{B}}} < \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}}$.

(b) $t_N^{G**,s} = \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}} = \underline{t_N^G}$ *and* $t_N^{B**,s} = \frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^{\mathrm{B}}} = \underline{t_N^B}$, *if* $\frac{\underline{U}^B - \Psi_N^{G*}}{\vartheta^{\mathrm{B}}} \geq \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}}$ *and* $\frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^{\mathrm{B}}} \leq \frac{\underline{U}^G - \Psi_N^{B*}}{\vartheta^{\mathrm{G}}}$ *with at least one strict inequality.*

(c) $t_N^{G**,s} = \frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^{\mathrm{B}}} - \frac{\Psi_N^{G*} - \Psi_N^{B*}}{\vartheta^{\mathrm{G}}} + \varepsilon > \underline{t_N^G}$ *and* $t_N^{B**,s} = \frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^{\mathrm{B}}} = \underline{t_N^B}$, *where* $\varepsilon(> 0)$ *is very small, if* $\frac{\underline{U}^B - \Psi_N^{G*}}{\vartheta^{\mathrm{B}}} > \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}}$ *and* $\frac{\underline{U}^B - \Psi_N^{B*}}{\vartheta^{\mathrm{B}}} > \frac{\underline{U}^G - \Psi_N^{B*}}{\vartheta^{\mathrm{G}}}$.

Proof: From Lemma 5, under asymmetric information, the regulator can induce the type- i farmer to choose 'his symmetric information optimal choice of action in absence of any non-monetary incentive', i.e. the regulator can enforce $x_N^{i**} = x_N^{i*}, i = G, B$, in the equilibrium, by offering the menu of contracts $\{(t_N^G, N),\ (t_N^B, N)\},\ t_N^G \neq t_N^B$ *and* $t_N^B, t_N^G > 0$, if (a) $t_N^G \geq \frac{\underline{U}^G - \Psi_N^{G*}}{v^G}$, (b) $t_N^B \geq \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}$ and (c) $\frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_N^G < \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^G}$ hold true.

Now, total cost of implementation is given by $[(1-\rho)\, t_N^B + \rho\, t_N^G]$, $0 < \rho < 1$. Therefore, monetary transfers in the least cost menu of contracts $\{(t_N^{G**,s}, N),\ (t_N^{B**,s}, N)\}$, which enforces $x_N^{G**} = x_N^{G*}$ and $x_N^{B**} = x_N^{B*}$ in the equilibrium under asymmetric information, is given by the solution of the following minimization problem.

$$(A)\begin{cases} \underset{t_N^B,\ t_N^G}{Minimize}[(1-\rho)t_N^B + \rho\, t_N^G] & \\ Subject\ to\ the\ constraints & \\ t_N^B \geq \dfrac{\underline{U}^B - \Psi_N^{B*}}{v^B} & (i) \\ t_N^G \geq \dfrac{\underline{U}^G - \Psi_N^{G*}}{v^G} & (ii) \\ t_N^B \geq \dfrac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} + t_N^G & (iii) \\ t_N^B < \dfrac{\Psi_N^{G*} - \Psi_N^{B*}}{v^G} + t_N^G & (iv) \\ t_N^B \geq 0 & (v) \\ t_N^G \geq 0 & (vi) \end{cases}$$

It is easy to verify that problem (A) has a unique solution, since $\underline{U}^B > \Psi_N^{B*}$, $\underline{U}^G > \Psi_N^{G*}$, $v^B > v^G > 0$ and $\Psi_N^{G*} > \Psi_N^{B*}$, and the solution is given by $t_N^G = t_N^{G**,s}$ and $t_N^B = t_N^{B**,s}$, where $t_N^{G**,s}$ and $t_N^{B**,s}$ are as in Lemma 6. [QED]

Lemma 8: *Suppose that Assumptions 1 – 4 hold true and the regulator offers the single contract* (t_F^G, F), *under asymmetric information, where* F *indicates non-monetary incentives (facilitation of biodiversity protection action coupled with social reward) and* t_F^G (≥ 0) *denotes the amount of monetary transfer to be made. Then, the following is true.*

(a) In the equilibrium under asymmetric information, each type of farmers chooses his 'symmetric information optimal action in the presence of non-monetary incentives', i.e.

$x_F^{i**} = x_F^{i*}$ $(i = G, B)$, *if in the presence of non-monetary incentives the reputational advantage of the green farmer in the equilibrium under symmetric information does not exceed a critical level:* $0 < \Delta R_F^* \le \widehat{\Delta R}$, *where* $\Delta R_F^* = R(v^G, x_F^{G*}, \theta_F) - R(v^B, x_F^{B*}, \theta_F)$ *and* $\widehat{\Delta R} = [f^B(x_F^{B*}) - C(x_F^{B*})] - [f^B(x_F^{G*}) - C(x_F^{G*})]$.

(b) If $\Delta R_F^* > \widehat{\Delta R}$, *the green farmer he cannot signal his true type by choosing the action* x_F^{i*} *and he may not accept the contract. However, the brown farmer always accepts the contract.*

Proof*:* Suppose that both types of farmers accept the contract. Then the green farmer can signal his true identity by choosing action x_F^{G*}, if the following two conditions are satisfied.

$$\Psi_F^G(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) + v^G t_F^G > \Psi_F^G\left(x_F^{G*,B}\middle|E\left(v\middle|x_F^{G*,B}, t_F^G\right) = v^B\right) + v^G t_F^G, \quad (i)$$

and

$$\Psi_F^B(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) + v^B t_F^G \le \Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^B t_F^G, \quad (ii)$$

where $x_F^{G*,B} = \underset{x}{\text{Argmax}}[\Psi_F^G(x|E(v|x, t_F^G) = v^B) + v^G t_F^G]$ is the G-types optimal action when others perceive him as brown. Note that $\Psi_F^G(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) > \Psi_F^G\left(x_F^{G*,B}\middle|E\left(v\middle|x_F^{G*,B}, t_F^G\right) = v^B\right)$, by Assumption 2. Thus, the G-types incentive compatibility condition to signal his true type by choosing action x_F^{G*}, i.e. condition (i), is always satisfied. However, the B-type's incentive compatibility condition (condition (ii)) for not to mimic G-type's action is satisfied if only if $\Psi_F^B(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) \le \Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) \Leftrightarrow R(v^B|v^G, x_F^{G*}, \theta_F) - R(v^B, x_F^{B*}, \theta_F) \le [f^B(x_F^{B*}) - C(x_F^{B*})] - [f^B(x_F^{G*}) - C(x_F^{G*})] \Leftrightarrow \Delta R_F^* \le \widehat{\Delta R}$. Thus, both conditions (i) and (ii) are satisfied, provided that $\Delta R_F^* \le \widehat{\Delta R}$.

If $\Delta R_F^* > \widehat{\Delta R}$, by choosing action x_F^{G*}, the green farmer cannot signal his true type. In such a situation, to signal his true type the green farmer needs to choose action $x_F^G > x_F^{G*}$, which may not be optimal for him. In case signalling is not feasible, the G-type's utility is given by $\Psi_F^G\left(x_F^{G*,B}\middle|E\left(v\middle|x_F^{G*,B}, t_F^G\right) = v^B\right) + v^G t_F^G$, which must be no less than his reservation utility $\underline{U}^i$. Since $\Psi_F^G\left(x_F^{G*,B}\middle|E\left(v\middle|x_F^{G*,B}, t_F^G\right) = v^B\right) < \Psi_F^{G*}$, $\Psi_F^G\left(x_F^{G*,B}\middle|E\left(v\middle|x_F^{G*,B}, t_F^G\right) = v^B\right) + v^G t_F^G \ge \underline{U}^G$ is not guaranteed for all $t_F^G \ge 0$. Thus, G-type may not accept the contract.

The B-type's utility is $\Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^B t_F^G = \Psi_F^{B*} + v^B t_F^G$, regardless of whether G-type can signal or not. Further, $\Psi_F^{B*} + v^B t_F^G > \underline{U}^B \;\forall\, t_F^G \ge 0$ (by Assumption 5). Clearly, B-type always accept the contract. [QED]

Lemma 9: *Suppose that Assumptions 1 – 4 hold true and the regulator offers the menu of contracts* $\{ (t_F^G, F), (t_N^B, N)\}$, *where F indicates non-monetary incentives (facilitation of biodiversity protection action coupled with social reward), N indicates no non-monetary incentive, and* $t_F^G (\geq 0)$ *and* t_N^B (≥ 0) *denote monetary transfers under F and N, respectively. Then, under asymmetric information, the regulator can ensure that in the equilibrium the green farmer chooses the contract* (t_F^G, F) *and undertakes biodiversity protection action* $x_F^{G**} = x_F^{G*}$, *while the brown farmer chooses the contract* (t_N^B, N) *undertakes the action* $x_N^{B**} = x_N^{B*}$, *if* $t_F^G(\geq 0)$ *and* $t_N^B(\geq 0)$ *satisfy the condition*

$$\frac{Max\{\Psi_F^{B*},\ \Psi_F^B(x_F^{G*}|\, E(v|x_F^{G*}, t_F^G\ ) = v^G)\} -\ \Psi_N^{B*}}{v^B} \leq t_N^B - t_F^G < \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G};$$

where x_F^{G*} *and* Ψ_F^{G*}*are, respectively, green farmer's symmetric information equilibrium actions and gross utility (total utility minus the utility from monetary transfer, if any) when he receives non-monetary incentives;* x_N^{B*} *and* Ψ_N^{B*} *are, respectively, brown farmers symmetric information equilibrium actions and gross utility when he does not receive any non-monetary incentive;* Ψ_F^{B*} *is the equilibrium gross utility of the brown farmer under symmetric information when he receives non-monetary incentives;* $\Psi_F^B(x_F^{G*}|\, E(v|x_F^{G*}, t_F^G\ ) = v^G)$ *is the gross utility of the brown farmer when he is successful in pretending that he is actually green by choosing the contract* (t_F^G, F) *and action* x_F^{G*}.

Proof: In this case there are four possibilities: (a) both choose the contract (t_N^B, N), (b) both choose the contract (t_F^G, F), (c) G-type chooses the contract (t_F^G, F), but B-type choose the contract (t_N^B, N), and (d) B-type chooses the contract (t_F^G, F), but G-type choose the contract (t_N^B, N). Note that a farmer decides his biodiversity protection action after he has chosen a contract. Therefore, while choosing the contract, a farmer needs to correctly anticipate his subsequent action choice and its implications to others' belief about his type, since his social reputation crucially depends on that. In what follows, we first characterize optimal action choice of each type of farmer, given his choice of contract. Next, we solve the contract choice problem in order to characterize the Subgame Perfect Bayesian Nash Equilibrium.

Case 1: Both choose the contract (t_N^B, N)

In this case, G-type cannot signal his true identity, both types of farmers choose the biodiversity protection action x_N^{B*} and utilities of the G-type and B-type farmers are, respectively, $U_N^G(x_N^{B*}|E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^G t_N^B$ and $U_N^B(x_N^{B*}|E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^B t_N^B$ (by Claim 1).

Case 2: Both choose the contract (t_F^G, F)

When both choose the contract (t_F^G, F), the equilibrium choice(s) of action(s) are as in Claim 7. Thus, if $\Delta R_F^* \leq \widehat{\Delta R}$ holds true, then the optimal action of type-i farmer is $x_F^{i**} = x_F^{i*}$, $i = G, B$, and utilities of the G-type and B-type farmers are, respectively, $U_F^G(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) = \Psi_F^{G*} + v^G t_F^G$ and $U_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) = \Psi_F^{B*} + v^B t_F^G$.

Otherwise, if $\Delta R_F^* > \widehat{\Delta R}$ holds true, G-type may or may not be able to signal his true type.

Suppose that $\Delta R_F^* > \widehat{\Delta R}$ and there exists an action $x_F^{G,sig}$ which credibly signals that the farmer is of G-type. Then $x_F^{G,sig}$ must satisfy the incentive compatibility conditions of G-type (condition (i)), and B-type (condition (ii)), which are as follows.

$$\Psi_F^G\left(x_F^{G,sig}\middle|E\left(v\middle|x_F^{G,sig}, t_F^G\right) = v^G\right) + v^G t_F^G > \Psi_F^G\left(x_F^{G*,B}\middle|E\left(v\middle|x_F^{G*,B}, t_F^G\right) = v^B\right) + v^G t_F^G \quad (i)$$

$$\Psi_F^B\left(x_F^{G,sig}\middle|E\left(v\middle|x_F^{G,sig}, t_F^G\right) = v^G\right) + v^B t_F^G \leq \Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^B t_F^G, \quad (ii)$$

Then the equilibrium utility of the B-type is $U_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) = \Psi_F^{B*} + v^B t_F^G$ and the utility of the G-type is $U_F^G\left(x_F^{G,Sig}\middle|E\left(v\middle|x_F^{G,Sig}, t_F^G\right) = v^G\right) = \Psi_F^G\left(x_F^{G,sig}\middle|E\left(v\middle|x_F^{G,sig}, t_F^G\right) = v^G\right) + v^G t_F^G$.

Next, suppose that $\Delta R_F^* > \widehat{\Delta R}$ and there does not exist any action $x_F^{G,sig}$ which credibly signals that the farmer is of G-type. Then, in the equilibrium both types of farmers choose action x_F^{B*}. B-type receives utility $U_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) = \Psi_F^{B*} + v^B t_F^G$, while G-type receives utility $U_F^G(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) = \Psi_F^G(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^G t_F^G$.

Therefore, when both type of farmers choose the contract (t_F^G, F), the B-types utility is $U_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) = \Psi_F^{B*} + v^B t_F^G$, regardless of whether G-type can signal his true type or not.

Case 3: One type chooses (t_F^G, F), while the other type chooses (t_N^B, N)

First, suppose that G-type has chosen the contract (t_F^G, F) and B-type has chosen the contract (t_N^B, N). Then, if $t_F^G \neq t_N^B$, B-type cannot hide his true identity by mimicking G-types action. Because, in order to pretend to be G-type both action and monetary transfer (x, t) of the B-type must be the same as that of G-type. Further, $x_F^{G*} = Argmax_x U_F^G(x|E(v|x, t_F^G) = v^G)$. Therefore, if $t_F^G \neq t_N^B$, it is optimal for G-type to choose action x_F^{G*} and obtain utility $U_F^G(x_F^{G*} | E(v|x_F^{G*}, t_F^G) = v^G) = \Psi_F^{G*} + v^G t_F^G$. On the other hand, B-type's optimal action is x_N^{B*}, which gives him the utility $U_N^B(x_N^{B*} | E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^B t_N^B$.

Next, suppose that B-type has chosen the contract (t_F^G, F) and G-type has chosen the contract (t_N^B, N). Then, if B-type tries to pretend that he is actually G-type, he will have to choose action x_F^{G*}. This is because, when G-type chooses the contract (t_F^G, F) his optimal action is x_F^{G*}. Now, B-type will prefer to choose action x_F^{G*} and pretend to be G-type compared to choosing his symmetric information optimal action x_F^{B*} and reveal his identity, if $\Psi_F^B(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) + v^B t_F^G > \Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^B t_F^G$ is satisfied. Note that $\Psi_F^B(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) + v^B t_F^G > \Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^B t_F^G \Leftrightarrow \Delta R_F^* > \widehat{\Delta R}$. That is, if $\Delta R_F^* > \widehat{\Delta R}$, B-type has the incentive to pretend that he is actually G-type by choosing action x_F^{G*}. Further, the G-type cannot match the action-money pair (x_F^{G*}, t_F^G) by choosing the contract (t_N^B, N), if $t_F^G \neq t_N^B$. Thus, if $t_F^G \neq t_N^B$ and $\Delta R_F^* > \widehat{\Delta R}$, optimal utilities of G-type and B-type, respectively, are $U_N^G(x_N^{B*} | E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^G t_N^B$ and $U_F^B(x_F^{G*} | E(v|x_F^{G*}, t_F^G) = v^G) = \Psi_F^B(x_F^{G*}|E(v|x_F^{G*}, t_F^G) = v^G) + v^B t_F^G$.
Otherwise, if $\Delta R_F^* < \widehat{\Delta R}$, it is optimal for B-type to choose x_F^{B*} and obtain utility $U_F^B(x_F^{B*} | E(v|x_F^{B*}, t_F^G) = v^B) = \Psi_F^{B*} + v^B t_F^G$, while G-type's optimal action is x_N^{B*} and his corresponding utility is $U_N^G(x_N^{B*} | E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^G t_N^B$.

<u>*Optimal contract choice:*</u>

From the above analysis, it follows that, if $t_F^G \neq t_N^B$ and $Max\{\Psi_F^{B*}, \Psi_F^B(x_F^{G*}| E(v|x_F^{G*}, t_F^G) = v^G)\} + v^B t_F^G \leq \Psi_N^{B*} + v^B t_N^B$, B-type does not have any incentive to choose the contract (t_F^G, F), which is actually meant for the G-type, regardless of whether G-type chooses the contract (t_F^G, F) or (t_N^B, N). In such a situation, B-type chooses the contract (t_N^B, N), which is actually meant for him, provided that $\Psi_N^{B*} + v^B t_N^B \geq \underline{U}^B$.

Suppose that B-type does not choose the contract (t_F^G, F), instead he chooses the contract (t_N^B, N), then G-type is better off by choosing the contract (t_F^G, F) compared to choosing the contract (t_N^B, N) provided that $U_F^G(x_F^{G*} \,|E(v|x_F^{G*}, t_F^G) = v^G) > U_N^G(x_N^{B*} \,|E(v|x_N^{B*}, t_N^B) = v^B)$ holds true. The contract (t_F^G, F) satisfies G-type's participation constraint, if $U_F^G(x_F^{G*} \,|E(v|x_F^{G*}, t_F^G) = v^G) \geq \underline{U}^G$.

Note that

$$\Psi_N^{B*} + v^B t_N^B \geq \underline{U}^B \Leftrightarrow t_N^B \geq \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}, \qquad (i)$$

$$U_F^G(x_F^{G*} \,|E(v|x_F^{G*}, t_F^G) = v^G) \geq \underline{U}^G \Leftrightarrow t_F^G \geq \frac{\underline{U}^G - \Psi_F^{G*}}{v^G}, \qquad (ii)$$

$$Max\{\Psi_F^{B*},\ \Psi_F^B(x_F^{G*}|\, E(v|x_F^{G*}, t_F^G) = v^G)\} + v^B t_F^G \leq \Psi_N^{B*} + v^B t_N^B$$

$$\Leftrightarrow \frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*}|\, E\left(v\middle|x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_F^G, \qquad (iii)$$

and

$$U_F^G(x_F^{G*} \,|E(v|x_F^{G*}, t_F^G) = v^G) > U_N^G(x_N^{B*} \,|E(v|x_N^{B*}, t_N^B) = v^B)$$

$$\Leftrightarrow \Psi_F^{G*} + v^G t_F^G > \Psi_N^{B*} + v^G t_N^B$$

$$\Leftrightarrow t_N^B - t_F^G < \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G}. \qquad (iv)$$

Condition (ii) is satisfied for all $t_F^G \geq 0$, since $\underline{U}^G < \Psi_F^{G*}$ (by Assumption 5). Further, note that $\Psi_F^{B*} > \underline{U}^B$ (by Assumption 5), which implies that $Max\{\Psi_F^{B*},\ \Psi_F^B(x_F^{G*}|\, E(v|x_F^{G*}, t_F^G) = v^G)\} > \underline{U}^B$ and, thus, $\frac{\underline{U}^B - \Psi_N^{B*}}{v^B} < \frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*}|\, E\left(v\middle|x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B}$. Therefore, $\frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*}|\, E\left(v\middle|x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_F^G \Rightarrow t_N^B \geq \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}\ \forall\, t_F^G \geq 0$, which implies that the condition (i) is always satisfied whenever condition (iii) is satisfied.

Next, since $\Psi_N^{B*} < \Psi_F^{B*} < \Psi_F^{G*}$ (by Lemma 4) and $\Psi_N^{B*} < \Psi_F^B(x_F^{G*}|\, E(v|x_F^{G*}, t_F^G) = v^G) < \Psi_F^{G*}$ (by Assumptions 1-3) and $v^B > v^G > 0$, we have $0 < \frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*}|\, E\left(v\middle|x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B} < \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G}$. Clearly, there exists $t_F^G (\geq 0)$ and $t_N^B (> t_F^G)$ such that both (iii) and (iv) hold together.

It follows that, if $t_F^G (\geq 0)$ and $t_N^B (\geq 0)$ are such that conditions (iii) and (iv) are satisfied, in the sub-game perfect Bayesian Nash equilibrium each type of farmers self-select the contract meant for him and undertakes the corresponding symmetric information level of biodiversity protection action. [QED]

Lemma 10: *Suppose that Assumptions 1 – 4 hold true. Then even under asymmetric information the regulator can ensure that only the green farmer receives facilitation services and social rewards and the corresponding symmetric information equilibrium level of biodiversity protection action is chosen by him, while the brown farmer also participates in biodiversity protection activity by choosing his symmetric information equilibrium level of biodiversity protection action in absence of any non-monetary incentive, at the least cost by offering the menu of contracts* $\left\{ (t_F^{G**,O}, F), (t_N^{B**,O}, N) \right\}$, *where* $t_F^{G**,O} = 0$ *and* $t_N^{B**,O} = \frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*} \mid E\left(v \middle| x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B} > t_N^{B*}$.

$t_N^{B**,S} = \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} + \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{G}}$ $t_N^{G**,S} = \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{G}}$

(d) $\Psi_N^{i*} < \Psi_F^{i*},\ i = G, B$;

(e) $\Psi_F^{G*} > \Psi_F^{B*}$ and

(f) $\Psi_N^{G*} > \Psi_N^{B*}$.

$$\frac{\underline{U}^i - \Psi_N^{i*}}{\vartheta^{i}}$$

Proof: *We know, from Lemma 9, that the menu of contracts* $\{ (t_F^G, F), (t_N^B, N)\}$, where $t_F^G, t_N^B \geq 0$ and the first (second) contract is meant for G-type (B-type), ensures that (a) the G-type chooses the contract (t_F^G, F) and undertakes biodiversity protection action $x_F^{G**} = x_F^{G*}$, and (b) the brown farmer chooses the contract (t_N^B, N) undertakes the action $x_N^{B**} = x_N^{B*}$, *if* $\frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*} \mid E\left(v \middle| x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_F^G < \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G}$ hold true. It is evident that $t_F^G = 0$ and $t_N^B = \frac{Max\left\{\Psi_F^{B*},\ \Psi_F^B\left(x_F^{G*} \mid E\left(v \middle| x_F^{G*}, t_F^G\right)=v^G\right)\right\} - \Psi_N^{B*}}{v^B}$ involves the least cost for the regulator to implement the desired environmental outcome. Since $\Psi_F^{B*} > \Psi_N^{B*}$, $t_N^{B**,O} > t_N^{B*}$. [QED]

Claim 5: *Suppose that Assumptions 1 – 5 hold true. Also suppose that the regulator offers the menu of contracts involving socially optimal contracts under symmetric information* $\{(t_F^G = 0, F), (t_N^B = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}, N)\}$*, where* $(t_F^G = 0, F)$ *is meant for the green farmer and* $(t_N^B = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}, N)$ *is meant for the brown farmer. Then it is optimal for the brown farmer to choose the contract that is actually meant for the green farmer, while the green farmer may not participate.*

Proof: First, note that the menu of contracts $\{(t_F^G = 0, F), (t_N^B = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}, N)\}$ does not satisfy the condition $\frac{Max\{\Psi_F^{B*},\ \Psi_F^B(x_F^{G*} |\, E(v|x_F^{G*}, t_F^G) = v^G)\} - \Psi_N^{B*}}{v^B} \leq t_N^B - t_F^G$. Therefore, under asymmetric information, the brown farmer is better off by choosing the contract $(t_F^G = 0, F)$ compared to choosing the contract meant for him (see the proof of Claim 9).

Next, given that the brown farmer will always choose $(t_F^G = 0, F)$, the green farmer's utility if he chooses the contract $(t_N^B = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B}, N)$ is $U_N^G(x_N^{B*} |E(v|x_N^{B*}, t_N^B) = v^B) = \Psi_N^{B*} + v^G t_N^B$, which is not necessarily greater than his reservation utility. Alternatively, if the green farmer chooses the contract $(t_F^G = 0, F)$, his utility is as follows (see proof of Claim 9).

$U_F^G(x_F^{G,Sig} |E(v|x_F^{G,Sig}, t_F^G) = v^G) = \Psi_F^G(x_F^{G,sig} |E(v|x_F^{G,sig}, t_F^G) = v^G) + v^G t_F^G$ in case by choosing action $x_F^{G,Sig}$ he can credibly signal his true type, which is possible if $R(v^G, x_F^{G,Sig}, \theta_F) - R(v^B, x_F^{B*}, \theta_F) \leq [f^B(x_F^{B*}) - C(x_F^{B*})] - [f^B(x_F^{G,Sig}) - C(x_F^{G,Sig})]$ and $U_F^G(x_F^{G,Sig} |E(v|x_F^{G,Sig}, t_F^G) = v^G) > U_F^G(x_F^{B*} |E(v|x_F^{B*}, t_F^G) = v^B)$. Otherwise, green farmers' utility is $U_F^G(x_F^{B*} |E(v|x_F^{B*}, t_F^G) = v^B)$. Since $U_F^G(x_F^{B*} |E(v|x_F^{B*}, t_F^G) = v^B) \gtreqless \underline{U}^G$, the green farmer may not participate. It can be checked that the green farmer chooses the contract meant for him only in case he can credibly signalling his true type by choosing some $x_F^{G,Sig}$ such that $(x_F^{G,Sig} - x_F^{G*})$ is less than a critical level. [QED]

Lemma 11. *Suppose that Assumptions 1-4 hold true. Also suppose that* $\frac{\underline{U}^B - \Psi_N^{G*}}{\vartheta^B} < \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^G}$ *. Then, a sufficient condition for* $t_N^{B**,O} < t_N^{B**,S}$ *to hold true is* $R(v^G, x, \theta_N) - R(v^B, x, \theta_N) > R(v^B, x, \theta_F) - R(v^B, x, \theta_N)$ *whenever* $f^B(x) = g(x)$*. Otherwise, if* $f^B(x) > g(x)$, $t_N^{B**,O} < t_N^{B**,S}$ *holds true whenever relative reputation of a green farmer,* $R(v^G, x, \theta_N) - R(v^B, x, \theta_N)$*, is greater than a critical level. Further,* $t_N^{G**,S} + t_N^{B**,S} > t_N^{G**,O} + t_N^{B**,O}$ *holds true for weaker condition.*

Proof.

We have, from Lemma 7, $t_N^{B**,S} = \frac{\Psi_N^{G*} - \Psi_N^{B*}}{v^B} + \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}}$, whenever $\frac{\underline{U}^B - \Psi_N^{G*}}{\vartheta^{\mathrm{B}}} < \frac{\underline{U}^G - \Psi_N^{G*}}{\vartheta^{\mathrm{G}}}$.

Now, first consider that $\Psi_F^{B*} > \Psi_F^B(x_F^{G*} |\, E(v|x_F^{G*}, t_F^G) = v^G)$. Then, from Lemma 10, $t_N^{B**,O} = \frac{\Psi_F^{B*} - \Psi_N^{B*}}{v^B}$. Thus, $t_N^{B**,O} < t_N^{B**,S}$ always holds true, if $\Psi_F^{B*} < \Psi_N^{G*}$, since $\underline{U}^G > \Psi_N^{G*}$ (by Assumption 5).

Now,

$\Psi_F^{B*} < \Psi_N^{G*}$

$\Leftrightarrow f^B(x_F^{B*}) - C(x_F^{B*}) + R(\vartheta^{\mathrm{B}}, x_F^{B*},\ \theta_F) < g(x_N^{G*}) - C(x_N^{G*}) + R(\vartheta^{\mathrm{G}}, x_N^{G*},\ \theta_N)$

$\Leftrightarrow f^B(x_F^{B*}) - g(x_N^{G*}) - \left(C(x_F^{B*}) - C(x_N^{G*})\right) < R(\vartheta^{\mathrm{G}}, x_N^{G*},\ \theta_N) - R(\vartheta^{\mathrm{B}}, x_F^{B*},\ \theta_F)$, which always hold true, if $f^B(x) = g(x)$ and $(\vartheta^{\mathrm{G}}, x,\ \theta_N) - R(\vartheta^{\mathrm{B}}, x,\ \theta_F) > 0$ (by Assumption 2).

It is straightforward to check that $R(\vartheta^{\mathrm{G}}, x,\ \theta_N) - R(\vartheta^{\mathrm{B}}, x,\ \theta_F) > 0 \Leftrightarrow R(v^G, x, \theta_N) - R(v^B, x, \theta_N) > R(v^B, x, \theta_F) - R(v^B, x, \theta_N)$. Alternatively, if $f^B(x) > g(x)$, then a sufficient condition for $\Psi_F^{B*} < \Psi_N^{G*}$ to hold true is $R(\vartheta^{\mathrm{G}}, x,\ \theta_N) - R(\vartheta^{\mathrm{B}}, x,\ \theta_F) > f^B(x) - g(x)$, implying that there exists a critical value of $R(\vartheta^{\mathrm{G}}, x,\ \theta_N) - R(\vartheta^{\mathrm{B}}, x,\ \theta_F)$ above which $\Psi_F^{B*} < \Psi_N^{G*}$ will always hold true.

Next, consider that $\Psi_F^{B*} < \Psi_F^B(x_F^{G*} |\, E(v|x_F^{G*}, t_F^G) = v^G)$. Then, from Lemma 10, $t_N^{B**,O} = \frac{\Psi_F^B\left(x_F^{G*} |\, E\left(v|x_F^{G*}, t_F^G\right) = v^G\right) - \Psi_N^{B*}}{v^B}$. Thus, $t_N^{B**,O} < t_N^{B**,S}$ always holds true, if $\Psi_F^B(x_F^{G*} |\, E(v|x_F^{G*}, t_F^G) = v^G) < \Psi_N^{G*}$, which is always true if $f^B(x) = g(x)$ or $f^G(x)$ is sufficiently larger than $f^B(x)$.

Finally, since $t_N^{G**,S} > 0$ and $t_N^{G**,O} = 0$, $t_N^{G**,S} + t_N^{B**,S} > t_N^{G**,O} + t_N^{B**,O}$ holds true even if $t_N^{B**,S} \leq t_N^{B**,O}$ implying that $t_N^{G**,S} + t_N^{B**,S} > t_N^{G**,O} + t_N^{B**,O}$ holds true for a weaker condition.

[QED]

Relaxing Assumption 5

Assumption 5: $\boldsymbol{\Psi_N^{i*} < \underline{U}^i < \Psi_F^{i*},\ \ i = G, B.}$

We know that $\Psi_N^{B*} < \Psi_F^{B*} < \Psi_F^{G*}$ and $\Psi_N^{B*} < \Psi_N^{G*} < \Psi_F^{G*}$ (By Lemma 4). However, $\Psi_N^{G*} \gtreqless \Psi_F^{B*}$. Suppose that the above does not hold true. Instead the following is true.

Assumption 5A: $\boldsymbol{\Psi_N^{B*} < \Psi_F^{B*} < \underline{U}^B}$ and $\boldsymbol{\Psi_N^{G*} < \underline{U}^B < \Psi_F^{G*}}$

Assumption 5A implies that, under symmetric information, the brown farmer does not accept the contract even if the regulator offers to facilitate his action, unless he receives money. That is, facilitation service does not improve the brown farmers productivity in public good creation sufficiently. In contrast, the green farmer does not need any money to participate under symmetric information in case his action is facilitated.

Suppose that Assumption 5 does not hold true, instead Assumption 5A holds. Then, under symmetric information, *if the regulator does not provide facilitation services to the farmer, the optimal monetary transfer would be the same as in Lemma 5, i.e.* $t_N^{i*} = \underline{t_N^i} = \frac{\underline{U}^i - \Psi_N^{i*}}{\vartheta^i} > 0, i = G, B$. *On the other hand, if the regulator facilitates the farmer's biodiversity protection action, while it is optimal for the regulator to offer to offer no monetary transfer to the green farmer, i.e.* $t_F^{G*} = \underline{t_F^G} = 0$, *as in Lemma 5, the brown framer needs to be paid the amount* $t_F^{B*} = \frac{\underline{U}^B - \Psi_F^{B*}}{\vartheta^B} > 0$ *under symmetric information. Note that* $\frac{\underline{U}^B - \Psi_F^{B*}}{\vartheta^B} < \underline{t_N^B}$, *i.e. the regulator needs to pay less to the brown farmer in case his action is facilitated, since facilitation helps him to enhance his social reputation to some extent. Needless to mention here that the equilibrium public good creation will be the same regardless of whether Assumption 5 or Assumption 5A holds true.*

Under asymmetric information, if Assumption 5A holds, then the following is true.

Case 1: The regulator offers the single contract (t_F^G, F)

In this case, if $0 < \Delta R_F^* \leq \widehat{\Delta R}$, *G-type can credibly signal his true type by choosing* $x_F^{G**} = x_F^{G*}$ *and by doing so he obtains utility more than his reservation utility* $\underline{U}^B$ *for all* $t_F^G \geq 0$ *. B-type is left with no option but to choose* $x_F^{B**} = x_F^{B*}$, *in case he accepts the contract. Thus, his utility from accepting the contract is* $\Psi_F^B(x_F^{B*}|E(v|x_F^{B*}, t_F^G) = v^B) + v^B t_F^G = \Psi_F^{B*} + v^B t_F^G$. *Thus, the B-type will accept the contract only if* $t_F^G \geq \frac{\underline{U}^B - \Psi_F^{B*}}{\vartheta^B}$.

Alternatively, if $\Delta R_F^* > \widehat{\Delta R}$, *then G-type cannot signal his true type by choosing* x_F^{G*} *and, thus, he may not accept the contract. While B-type also does not accept the contract unless* $t_F^G \geq \frac{\underline{U}^B - \Psi_F^{B*}}{\vartheta^{\mathrm{B}}}$.

Case 2: The regulator offers the menu of contracts $\{ (t_F^G, F), (t_N^B, N)\}$

In this case, Claim 8 holds true (which follows directly from the proof of Claim 8). Claim 9 also hold true, provided that $\Psi_F^{B*} < \underline{U}^B < \Psi_F^B(x_F^{G*} |\, E(v|x_F^{G*}, t_F^G) = v^G)$. *Otherwise, if* $\underline{U}^B > \Psi_F^B(x_F^{G*} |\, E(v|x_F^{G*}, t_F^G) = v^G)$ *, then optimal transfers are as follows.*

$$t_N^{B**,O} = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B} = t_N^{B*} \text{ and } t_F^{G**,O} = 0, \text{ if } \frac{\underline{U}^B - \Psi_N^{B*}}{v^B} < \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G}.$$

$$t_N^{B**,O} = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B} = t_N^{B*} \text{ and } t_F^{G**,O} = \frac{\underline{U}^B - \Psi_N^{B*}}{v^B} - \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G} + \varepsilon > 0, \text{ if } \frac{\underline{U}^B - \Psi_N^{B*}}{v^B} > \frac{\Psi_F^{G*} - \Psi_N^{B*}}{v^G},$$

where ε *is a small positive number.*

That is, the regulator can implement the desired environmental outcome albeit the cost involved may be higher in some cases if Assumption 5A holds instead of Assumption 5.

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