Biodiversity conservation, asymmetric information and the role of fixed costs

Carmen Arguedas[*], Gerdien Meijerink[§] and Daan van Soest[‡]

Abstract

Payment for Ecosystem Services programs offer financial compensation to farmers in exchange for environmental services. Farmers typically differ with respect to the opportunity costs of providing such services, and unless the donor has perfect information about each individual farmer's opportunity cost function, the amounts paid are larger for some (or even many) farmers than strictly necessary. Incentive-compatible contracts can be used to reduce the total amount of compensation paid, but despite their theoretical appeal, such contracts are not used often in practice. The main reasons are that (i) information requirements are large, and (ii) the net savings on subsidies paid is always (much) smaller than in the first-best (complete information) case. We contribute to this literature by not only focusing on variable conservation costs but also on fixed costs. We find that if high fixed cost farmers have low variable costs and vice versa, the first-best savings on subsidies spent can actually be achieved. We identify the conditions under which these maximum savings can be obtained, and conclude that in those circumstances the net savings of providing incentive-compatible contracts may be sufficiently large to warrant gathering all information needed.

Key words: Asymmetric information, environmental benefits, green payments, mechanism design.

JEL Codes: D82, H23, Q57.

[*]Universidad Autonoma de Madrid, [§]LEI Wageningen UR [‡]Tilburg University. Please send all comments to Daan van Soest, d.p.vansoest@uvt.nl.

1 Introduction

Over the past decade, so–called Payment for Ecosystem Services (PES) programs have become increasingly popular as a means to induce landowners to undertake environmentally beneficial activities on their private lands, which they would not have undertaken otherwise. Such activities include, among others, implementing measures to conserve soils or to protect biodiversity, and these programs have been implemented in developed and developing countries alike (see for example OECD 1997 and Ferraro 2001). PES programs usually take the form of contracts between the donor (or regulator) and individual landowners, which specify the type and level of conservation activities the landowner is required to undertake on her land, as well as the amount of money she receives in compensation. Participation is in most instances voluntary, and that means that in order for the landowner to sign the contract, the amount of money offered in compensation should at least cover the extra costs she incurs.

The problem is that in many instances (i) some landowners can provide conservation services at lower costs than others, and (ii) landowners have better information about these costs than the donor (cf. Ferraro 2005). That means that the more efficient landowners have an incentive to overstate the costs of providing specific levels of conservation activity in order to secure more generous compensation payments. Overgenerous payments are typically costly to the donor or regulator either because the available funds are limited (in case of a fixed conservation budget) or because there are non–zero costs to raising funds (cf. for example Smith and Tomasi 1999). Hence, the donor or regulator has a stake in separating the low– from the high–cost landowners.

In essence, this is a classical mechanism design problem, and over the past years many papers have been published that build on the seminal work of, among others, Mirrlees (1971), Groves (1973), Dasgupta et al. (1979), Harris and Townsend (1981), and Guesnerie and Laffont (1984). Early papers include Smith (1995) who analyzed how mechanism design theory could be applied to the US Conservation Reserve Program, aiming to return a specific amount of agricultural land to nature while minimizing the total amount of compensation payments paid; Smith and Tomasi (1995) who analyzed the problem of limiting pollution runoff from farm land when compensation payments are funded by means of distortionary taxation; and Wu and Babcock (1995 and 1996) who looked at the problem of reducing polluting input use when land quality differs across farmers and where raising funds for compensation is socially costly.

The general conclusion of this literature is that if the donor has full information about the economic characteristics of the various farm types (specifically, those characteristics that affect the farmer's opportunity cost of providing conservation services, such as their agricultural production functions, their land quality, etc.) but is unable to identify what type each individual farmer is, offering a menu of contracts specifying management prescriptions and associated compensation payments can indeed result in higher social welfare than, for example, a uniform policy applicable to all farmers –but not always (see for example Wu and Babcock 1996: 943).

Despite the fact that these incentive–compatible contracts can be welfare–enhancing, their use is all but widespread (Ferraro 2005). Two reasons may explain this lack of application: (i) the information requirements for the donor are substantial, and (ii) the savings in payments (or subsidies) achieved are fairly small. The first reason is obvious, but the second needs somewhat more explanation. The theoretical literature on this topic indeed shows that separating the low– from the high–cost farmers is possible at least in some circumstances, but that this separating policy under asymmetric information coincides with the first–best (complete information) solution only under very restrictive conditions.[1] That means that in practice the optimal policy is nearly always a second–best policy, and separation is achieved at a double cost. To ensure incentive–compatibility, contracts targeted at low–cost farmers pay informational rents to these types (that is, the low–cost farmers receive more money in compensation than the extra costs they incur when complying), and the contracts intended for high–cost farmers impose a level of conservation effort that is below the first–best level. Because of these considerations, the net benefits of designing incentive–compatible contracts are likely to be low, and attention seems to have shifted towards alternative instruments, such as for example procurement auctions for PES contracts (cf. Ferraro 2005: 7; Latacz–Lohmann 2004, Latacz–Lohmann and Schilizzi 2006).

The double cost of incentive–compatible contracts materializes because of one key characteristic of the models developed in the PES literature, and that is their focus on variable conservation costs. Typically, agents are assumed to differ with respect to a certain characteristic, and this characteristic is assumed to affect the marginal benefits (or costs) of the input to be regulated. For example, in case of Wu and Babcock (1996), the regulated input is the amount of polluting inputs used in agriculture, and farmers differ with respect to the quality of their

[1] For example, Wu and Babcock (1996) find that the first-best level of reduction in polluting input use can only be implemented under asymmetric information if the deadweight loss of providing subsidies are zero. In that case, subsidies are effectively straightforward (zero-cost) transfers from the regulator to the farmer, and hence paying too much subsidies is not socially costly.

land. The higher a farmer's land quality, the larger her marginal productivity of polluting input use. That means that farmers with high (low) quality land are high–cost (low–cost) producers of conservation services. The presence of these variable costs of conservation services implies that the first–best (i.e., complete information) solution is typically not incentive–compatible. The first–best allocation of conservation effort across farmers is that the amount of land conserved is a decreasing function of land quality; high–cost conservers should conserve less. This should also be the case in the presence of asymmetric information. But whereas in the first best the associated compensation payments would be increasing in land quality (implying that high–cost farmers receive more money in compensation than low–cost farmers), the second–best contracts under asymmetric information require payments to *fall* with land quality. Indeed, under asymmetric information the first–best solution is not incentive compatible because it gives low–cost farmers a double incentive to report themselves as high–cost farmers: they would not just be offered less stringent management practices (i.e., less reduction in input use), but larger compensation payments as well (Wu and Babcock 1996: 939).

This paper contributes to this literature by not only taking into account heterogeneity regarding variable conservation costs but also with respect to fixed costs. While these fixed compliance costs can be substantial in practice, they have been largely ignored by researchers and policy makers alike (cf. European Commission 2005: 22). Examples of fixed costs (in addition to variable costs) in conservation programs are not difficult to find. Soil conservation on steeply sloped land can be improved by intercropping the main crop with crops that have a root structure that better retains soils. Here, costs vary with the amount of services provided; the larger the share of the latter crop type in the area cultivated, the better soils are retained but also the higher the farmer's opportunity costs in terms of output foregone of her preferred crop. But farmers can also invest in constructing terraces. Then, less land needs to be allocated to growing the crops with the better root structure to achieve the same amount of soil conservation. And fixed costs (in addition to variable costs) play a role in biodiversity conservation programs too. For example geese management schemes require farmers to delay the moment at which farmers bring out their cattle to the pastures to allows these migratory birds to feed on their land (cf. MacMillan et al. 2004). Delaying implies having to feed the herd in the stables. Hence, the costs of complying depend on the length of the delay as well as on the size of the herd while the damage inflicted by the geese only depends on the number of birds stopping by. Therefore, the delay costs are variable in nature, while the damage inflicted is largely fixed.

We find that accounting for both fixed and variable conservation costs has important consequences for the efficiency of offering a menu of management requirements and compensation payments targeted at the various farmer types. We find that separating contracts always result in lower subsidy costs than uniform policies, and that the first–best contract can even be incentive compatible –under circumstances that may well occur in practice. Our policy conclusion is therefore contrary to the one drawn by Ferraro (2005). Even though the information requirements may be quite substantial, the benefits of implementing separating policies may be sufficiently large after all because the incentive–compatible outcome may not always involve the double costs identified above. Therefore, our main conclusion is that incentive–compatible contracts deserve a second look.

Our approach is admittedly simplified in several respects. First, we abstract from the moral hazard problem that is inherently present in real world situations –that compliance is hard to detect (but see among others Ozanne et al. 2001 and White 2002). Second, we assume that the donor has perfect information about the (economic) characteristics of the various farmer types but does not know which farmer is of what type, and that the individual farmers have perfect information about their compliance costs. We therefore focus on an asymmetry in status information but not in information collection ability (cf. Goeschl and Lin 2003). Third, we assume that the donor just knows the distribution of types, but does not have any farmer–specific information on the basis of which she could assign prior believes regarding the farmer's type (but see Moxey et al. 1999). Fourth, our model is such that even under asymmetric information, the amount of conservation effort is always higher in case of a PES scheme than in its absence because we assume that the privately optimal level of conservation effort is zero (but see Motte et al. 2004 and di Corato 2006).

The setup of this paper is as follows. We present the model in section 2, and provide the solution to the complete information problem (that is, the first–best solution) in section 3. In section 4 we analyze whether the least–cost incentive–compatible contract under asymmetric information is uniform or separating, and in section 5 we address the question under what circumstances the first–best solution is incentive compatible. Section 6 concludes.

2 The model

The objective of the donor is to induce a group of farmers to undertake a certain amount of biodiversity conservation effort. There are two types of farmers, indexed $i = 1, 2$, where $n_i > 0$ denotes the total number of farmers of type i. Conservation effort of a farmer of type i is denoted by b_i. The minimum aggregate level of conservation effort required is $\overline{B} > 0$. Therefore, the donor wants to ensure that $\overline{B} \leq \sum_{i=1}^{2} n_i b_i$.

To provide positive levels of conservation services (i.e., $b_i > 0$), the farmer needs to incur both fixed and variable costs. These two types of costs are denoted by F_i and $c_i(b)$, respectively, and hence total private conservation costs are $C_i(b) = F_i + c_i(b)$. Here, $F_i \geq 0$, and $c_i(b)$ is assumed to be increasing and convex in b with $c_i(0) = c_i'(0) = 0$. Also, without loss of generality, we assume that $c_2'(b) > c_1'(b)$ for all $b > 0$.

Participation is voluntary, which means that farmers of type i need to receive compensation payments (or subsidies, S_i) that are at least as large as the amount of conservation costs incurred for the effort prescribed ($S_i \geq C_i(b_i)$). Subsidies are costly in the sense that money spent on the current project cannot be spent elsewhere. Therefore, the objective of the donor is to achieve total conservation effort $\overline{B}$ at minimum budget.

If the donor has perfect information about each particular farmer, the problem is to find the menu $\{(S_1, b_1), (S_2, b_2)\}$ which satisfies the following:

$$\min \ \tilde{S} = n_1 S_1 + n_2 S_2, \tag{1a}$$

$$s.t. \quad \overline{B} \leq n_1 b_1 + n_2 b_2, \tag{1b}$$

$$F_i + c_i(b_i) - S_i \leq 0, \ i = 1, 2. \tag{1c}$$

However, in case of asymmetric information, the donor has to take into account the incentive compatibility constraints. This means that the menu offered by the donor has to be such that each farmer actually prefers the particular policy targeted at its type. That is, the donor needs to ensure that

$$c_i(b_i) - S_i \leq c_i(b_j) - S_j, \tag{2}$$

where $i = 1, 2$ and $i \neq j$.

The donor can design a uniform policy, that is a single combination of b and S that is offered to all farmers. Such a uniform policy, (S^u, b^u), is trivially incentive compatible and that means that one of the participation constraints will not be binding. Since the donor wants to achieve $\overline{B}$, the uniform policy is straightforward:

$$b^u = \frac{\overline{B}}{n_1 + n_2}; \; S^u = \max\{C_1(b^u), C_2(b^u)\}. \tag{3}$$

The donor may also offer a menu of policies consisting of specific combinations of S and b targeted at the different farmer types. In case of two farmer types, a separating policy would thus consist of two combinations of subsidies and management requirements, (S_1^s, b_1^s) and (S_2^s, b_2^s). The key question is whether such a separating scheme can be welfare–improving as compared to the uniform policy, that is to achieve the same level of aggregate conservation effort at lower aggregate subsidies.

3 Complete Information

Let us first determine the menu of subsidies and management requirements $\{(S_1^c, b_1^c), (S_2^c, b_2^c)\}$ which yields the first–best (i.e., complete information) solution to problem (**??**). The Lagrangian is the following:

$$L = n_1 S_1 + n_2 S_2 + \mu\left[\overline{B} - n_1 b_1 - n_2 b_2\right] + \sum_{i=1}^{2} \lambda_i \left[F_i + c_i(b_i) - S_i\right],$$

where $\mu \geq 0$, $\lambda_i \geq 0$ are the Kuhn–Tucker multipliers associated with the conservation objective and the participation constraints, respectively.

The first–order conditions are:[2]

$$\lambda_i c_i'(b_i) + \mu n_i = 0; \tag{4}$$

$$n_i - \lambda_i = 0; \tag{5}$$

$$\mu\left[\overline{B} - n_1 b_1 - n_2 b_2\right] = 0;\; \overline{B} - n_1 b_1 - n_2 b_2 \leq 0; \tag{6}$$

$$\lambda_i\left[F_i + c_i(b_i) - S_i\right] = 0;\; F_i + c_i(b_i) - S_i \leq 0. \tag{7}$$

where $i = 1, 2$. From (5), we obtain $\lambda_i = n_i > 0$. This implies $F_i + c_i(b_i^c) - S_i^c = 0$ (see (7)) and $\mu = c_1'(b_1^c) = c_2'(b_2^c)$ (see (4)). In words, the required conservation efforts are such that marginal costs are equal, and subsidies are paid to exactly cover conservation costs. Since $c_2'(b) > c_1'(b)$ for all $b > 0$, we trivially have $b_1^c > b_2^c$. Thus, the effort level required from type 1 farmers is larger than that of type 2 farmers. However, there is no trivial ranking with respect to the required subsidy levels because of the presence of fixed costs. Clearly, $c_1(b_1^c) > c_2(b_2^c)$.[3] Therefore, $S_1^c > (<)\, S_2^c$ iff $F_2 - F_1 < (>)\, c_1(b_1^c) - c_2(b_2^c)$.

4 Asymmetric Information: Uniform versus Separating Policies

Before being able to determine whether the first–best solution is ever incentive compatible (in the next section), we first determine whether the least–cost solution under asymmetric information is separating, or uniform. We assume that each individual farmer knows her type, but that the donor only knows the characteristics of the two types (F_i and $c_i(b)$, $i = 1, 2$) and the total number of farmers (n_1 and n_2) but does not know which farmer is of what type. Hence, the donor needs to take

[2] Our assumptions ensure that these are necessary and sufficient conditions for an optimum.

[3] This can be seen as follows. The first order condition is that $(\mu =)\; c_1'(b_1^c) = c_2'(b_2^c)$, and hence $db_1^c/db_2^c = c_2''/c_1'' > 1$. Now for any level of b_2^c (with corresponding b_1^c), we have $d(c_1(b_1^c(b_2^c)) - c_2(b_2^c))/db_2^c = c_1'(b_1^c)\, db_1^c/db_2^c - c_2'(b_2^c) = \mu[db_1^c/db_2^c - 1] > 0$. Straightforward integration yields $c_1(b_1^c) - c_2(b_2^c) > 0$ for all $b_2^c > 0$.

into account the incentive compatibility constraints given in (2), and the problem is to find the menu $\{(S_1, b_1), (S_2, b_2)\}$ which satisfies the following:

$$\begin{aligned} \min \quad & \tilde{S} = n_1 S_1 + n_2 S_2, \\ s.t. \quad & \overline{B} \leq n_1 b_1 + n_2 b_2, \\ & F_i + c_i(b_i) - S_i \leq 0, \; i = 1, 2, && (8) \\ & c_i(b_i) - S_i \leq c_i(b_j) - S_j, \quad i, j = 1, 2, i \neq j && (9) \end{aligned}$$

The full analysis of this optimization problem is provided in the appendix; in the main text we resort to a graphical analysis. Here, isocost functions are a useful tool to evaluate farmer preferences when comparing multiple policy combinations. Isocost functions represent the sets of policy combinations (S, b) such that total (net) costs for farmer type i are constant: $k_i = F_i + c_i(b) - S$. Since $\left.\frac{db}{dS}\right|_{k_i} = \frac{1}{c_i'(b)}$, isocost functions are upward–sloping and concave in (S, b) space; see Figure 1. Because $c_2'(b) > c_1'(b)$, the isocost function of a type 1 farmer is strictly steeper in any policy combination (S, b) than that of a type 2 farmer; $\left.\frac{db}{dS}\right|_{k_1} > \left.\frac{db}{dS}\right|_{k_2}$. Finally, costs decrease whenever the required effort level is lower and the subsidy is larger, and hence isocost functions located to the south–east are preferred to those located to the north–west (as is illustrated in Figure 1 for type 1 farmers, where $\bar{k}_1' > \bar{k}_1$). Or, put differently, for a given isocost function, all policy combinations located to the south–east (north–west) of this function result in lower (higher) costs.

This figure allows us to show the intuition behind the result that the second–best policy is never a uniform policy. Recall that the optimal uniform policy is the combination of S and b where the target level of conservation is achieved ($\bar{B}$), where all farmers implement the same level of conservation (b^u) and where the amount of subsidies provided is equal

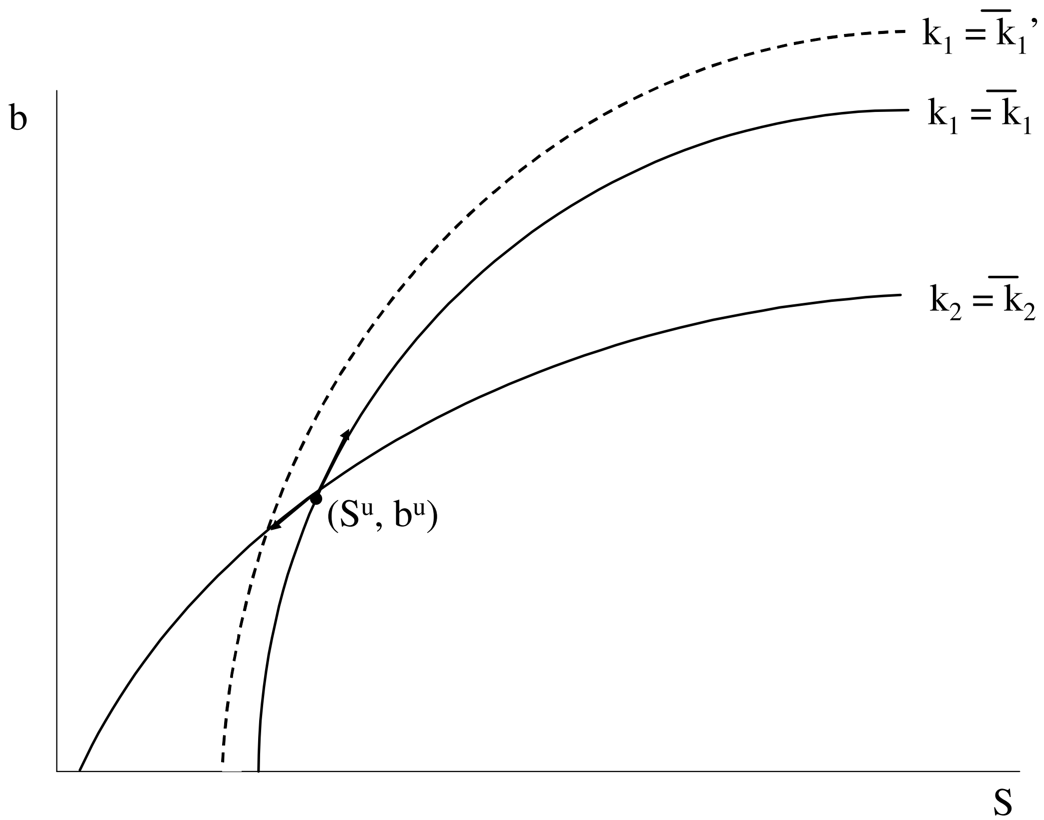

Figure 1: A subsidy-saving deviation from the least-cost uniform policy.

to the total costs ($C_i(b^u)$) of the type for which meeting the b^u target is most expensive (see equation (3)). Depending on the levels of fixed costs incurred, this may be type 1 or type 2. If we assume that the optimal uniform policy is (S^u, b^u) as depicted in Figure 1, we have either $\bar{k}_1 = 0$ (if $C_1(b^u) > C_2(b^u)$, implying $\bar{k}_2 < 0$) or $\bar{k}_2 = 0$ (if $C_1(b^u) < C_2(b^u)$, implying $\bar{k}_1 < 0$).

Let us proceed by proving that the total amount of subsidies can always be decreased (as compared to the uniform case) by designing a menu of policy combinations. We do this by showing that the aggregate amount of subsidies offered falls if the donor sets the policy combination targeted at type 1 farmers on the $k_1 = \bar{k}_1$ line to the north–east of (S^u, b^u), and the combination targeted at type 2 farmers on the $k_2 = \bar{k}_2$ line to the south–west of (S^u, b^u).[4] Such a set of combinations is both incentive–compatible and decreases the total amount of subsidies paid.

The analysis is as follows. First note that decreasing b_2 implies increasing b_1 as the aggregate conservation objective $\bar{B}$ remains unchanged. Totally differentiating the conservation constraint yields $db_1/db_2 = -(n_2/n_1)$. Next, we can infer the required increases in subsidies (dS_i) for the amount of db_i imposed; this equals $\partial S_i(b^u)/\partial b = c_i'(b^u)$. The aggregate amount of subsidies required ($\tilde{S}$) varies with b_2 as follows: $d\tilde{S}/db_2 = n_1 \frac{\partial S_1(b^u)}{\partial b_1} \frac{db_1}{db_2} + n_2 \frac{\partial S_2(b^u)}{\partial b_2} = n_2(c_2'(b^u) - c_1'(b^u)) > 0$. Therefore, starting from (S^u, b^u), marginally decreasing b_2 (and concomitantly increasing b_1) reduces the total amount of subsidies paid. Finally, when moving along the two $k_i = \bar{k}_i$ lines (to the north–east for type 1 and to the south–west for type 2), each farmer strictly prefers the new policy

[4] Note that this is just the proof that separating policies exist and are preferred to the least-cost uniform policy. Moving the policy combinations along $k_i = \bar{k}_i$ ($i = 1, 2$) in opposite directions reduces aggregate subsidies but does not necessarily yield the least–cost policy menu.

combination targeted at her type.

Hence, the uniform policy is never socially optimal; independent of the number of farmers being of type 1 or type 2 (n_1 and n_2), it is always cheaper to induce the low–cost (high–cost) farmers to undertake slightly more (less) conservation effort. Also note that incentive compatible policies are then characterized by higher (lower) effort levels and subsidies intended for the low (high) variable cost type. Note that this result is independent of the level of the fixed costs.

5 The Optimal Policy under Asymmetric Information

Let us now address the question whether the first–best (complete information) can be incentive compatible in the presence of fixed costs. The first–best policy is incentive compatible if and only if (8) holds with strict equality for $i = 1, 2$, and (9) is met for (i, j) is $(1, 2)$ and $(2, 1)$ simultaneously. Combining these four equations, we find that the first–best solution is incentive–compatible if and only if

$$c_2\left(b_2^c\right) - c_1\left(b_2^c\right) \leq F_1 - F_2 \leq c_2\left(b_1^c\right) - c_1\left(b_1^c\right). \tag{10}$$

A necessary condition for (10) to hold is that $F_1 > F_2 \geq 0$. The reason is that $c_2'(b) > c_1'(b)$ for all $b > 0$, and hence $c_2(b) - c_1(b) > 0$. That means that when $F_2 \geq F_1 \geq 0$, the first inequality in condition (10) never holds. In case $F_1 > F_2 \geq 0$, the condition is met for at least some values of F_1 and F_2: because $b_1^c > b_2^c$ and $c_2'(b) > c_1'(b)$ for all $b > 0$, we have $c_2\left(b_2^c\right) - c_1\left(b_2^c\right) < c_2\left(b_1^c\right) - c_1\left(b_1^c\right)$.[5]

The reason why the two fixed costs appear in the incentive compatibility constraint is that their levels affect the amount of subsidies pro-

[5]Note that together with $c_1'(b) > c_2'(b)$ for all $b > 0$, the cases $F_2 \geq F_1$ and $F_1 > F_2$ exhaust all possible combinations of levels of fixed costs being high or low, and the levels of variable costs being high or low.

vided. This result is clear when analyzing the two inequalities in (10) separately. The first inequality can be rewritten as $c_2(b_2^c) + F_2 \leq F_1 + c_1(b_2^c)$, and hence $0 \leq F_1 + c_1(b_2^c) - S_2^c$. In words, this inequality is about the incentives for type 1 farmers to misrepresent their type under the first–best solution. Their net costs are zero if they choose the policy combination aimed at their type, and this is incentive compatible if their net costs are positive if they misrepresent themselves. So, even though $c_1(b_2^c) < c_1(b_1^c)$, type 1 farmers may still prefer the policy targeted at their type if S_2^c is sufficiently small compared to S_1^c, and this is the case if F_2 is sufficiently small compared to F_1. And a similar analysis applies to the second inequality, which can be rewritten as $c_1(b_1^c) + F_1 \leq c_2(b_1^c) + F_2$ so that $0 \leq F_2 + c_2(b_1^c) - S_1^c$. Type 2 farmers have an incentive to choose the combination aimed at their type because $c_2(b_2^c) < c_2(b_1^c)$, but they will only do so if S_1^c (S_2^c) is sufficiently low (high), which is the case if F_1 (F_2) is sufficiently small (large).[6]

This can also be shown graphically. Let us first consider the case where $F_2 \geq F_1 \geq 0$, so that $C_2(b) > C_1(b)$ for all $b > 0$. This case is represented graphically in Figure 2. Here, the $k_1 = 0$ line is strictly located to the north–west of the $k_2 = 0$ line. Therefore, type 1 farmers prefer the contract intended for type 2 farmers. For $b = 0$, the minimum amount of subsidies required when farmers are forced to invest is equal to $S_i = F_i$, and $F_2 \geq F_1$ implies that the horizontal intercept of the $k_1 = 0$ is (weakly) to the left of that of the $k_2 = 0$ line. Next, because $\left.\frac{db}{dS}\right|_{k_1} > \left.\frac{db}{dS}\right|_{k_2}$ for all $b > 0$, the $k_1 = 0$ line is located strictly to the north of the $k_2 = 0$ line. Therefore, in this case the first–best solution is never incentive compatible, and the second–best policy is always separating (as shown in section 4).

[6]Note that this case includes $F_1 = F_2 = 0$; the first best is never incentive

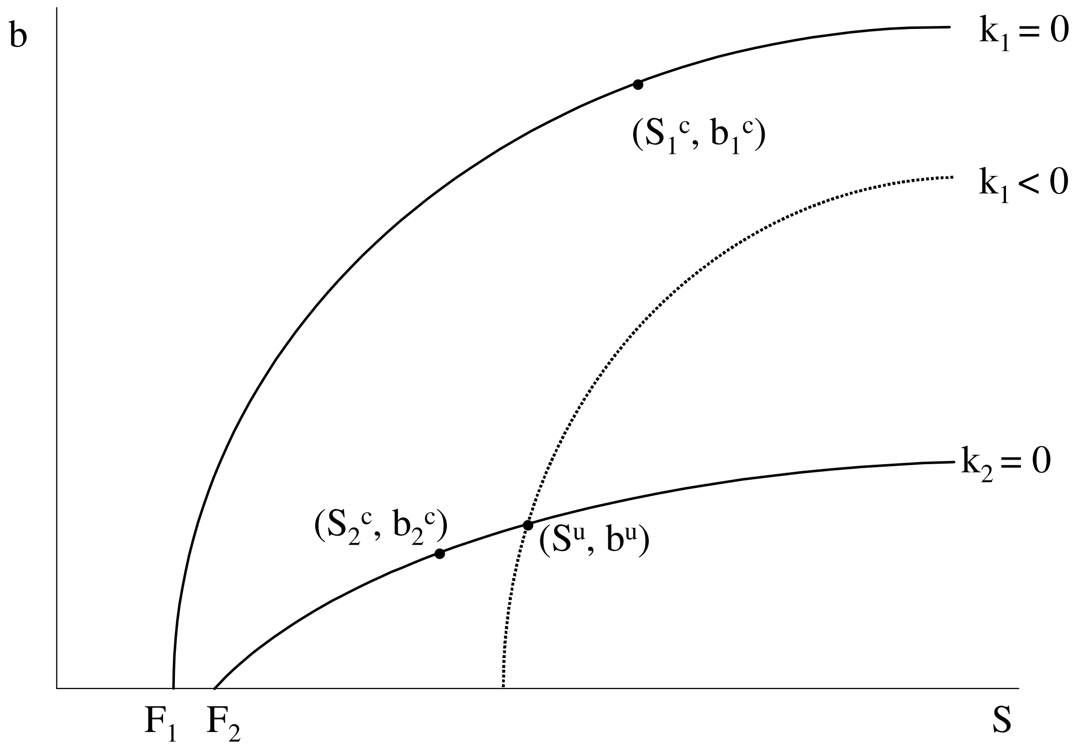

Figure 2: Incentive compatibility of the first-best policy if $F_2 \geq F_1 \geq 0$.

This (second–best) optimal policy when $F_2 \geq F_1 \geq 0$ is characterized by the following conditions (for a formal proof see the Appendix):

$$n_1 \left[c_2' \left(b_2^s\right) - c_1' \left(b_2^s\right)\right] = n_2 \left[c_1' \left(b_1^s\right) - c_2' \left(b_2^s\right)\right], \tag{11a}$$

$$\overline{B} = n_1 b_1^s + n_2 b_2^s, \tag{11b}$$

$$S_2^s = F_2 + c_2 \left(b_2^s\right), \tag{11c}$$

$$c_1 \left(b_1^s\right) - S_1^s - c_1 \left(b_2^s\right) + S_2^s = 0. \tag{11d}$$

In this case, type 1 farmers have an incentive to misrepresent their type under the complete information solution, but type 2 farmers do not. Therefore, the farmers of the latter type receive a subsidy that just covers their conservation costs (11c), whereas the second–best policy gives the former type an informational rent so that their incentive compatibility constraint is binding (11d). Therefore, the optimal policy is that the subsidy intended for type 1 farmers (S_1^s) more than covers their private costs of exerting the effort level b_1^s, and the informational rent equals $R_1 \equiv S_1 - F_1 - c_1\left(b_1\right) \geq 0$. The question is then what levels of conservation effort should be imposed on the two farmer types. Substituting (11c) into (11d), adding and subtracting F_1 and rewriting yields $R_1 = c_2(b_2) - c_1(b_2) + F_2 - F_1 > 0$. Changing b_1 affects R_1 and, using $db_2/db_1 = -\left(n_1/n_2\right)$ (because of (11b)), we have $dR_1/db_1 = [c_2'(b_2) - c_1'(b_2)](db_2/db_1) = -(n_1/n_2)[c_2'(b_2) - c_1'(b_2)] < 0$. Increasing the amount of conservation effort required from type 1 farmers increases their conservation costs and thus lowers the informational rent they receive. Therefore, the 'golden rule' of $c_1'\left(b_1\right) = c_2'\left(b_2\right)$ needs to be modified by adding dR/db_1 to the LHS, which yields:

$$c_1' \left(b_1^s\right) - \frac{n_1}{n_2} \left[c_2' \left(b_2^s\right) - c_1' \left(b_2^s\right)\right] = c_2' \left(b_2^s\right), \tag{12}$$

compatible if there are only variable conservation costs.

and this is identical to $(11a)$. The net marginal cost of type 1 farmers are larger than those of type 2 farmers: $c_1'(b_1^s) > c_2'(b_2^s)$. Therefore, $b_1^s > b_1^c$ and $b_2^s < b_2^c$ and, consequently, $S_1^s > S_1^c$ and $S_2^s < S_2^c$. Since there is a fixed aggregate conservation objective, $\overline{B}$, both individual effort levels are adjusted to satisfy the optimality condition and the constraint $\overline{B}$.

Now, let us consider the case where $F_1 > F_2 \geq 0$, so that the total costs incurred by type 2 farmers are not always larger than those incurred by type 1 farmers. This case implies that $k_2 = 0$ and $k_1 = 0$ intersect at one particular level of b, labelled $\tilde{b}$ in Figure 3. We know from the previous section that the optimal solution is always a separating policy, and we show that in this case the first–best separating policy may even be incentive compatible. Here, the outcome depends on the relative values of the fixed costs incurred, the aggregate conservation objective and on the variable cost functions.

Suppose that the first–best solution is such that either $b_2^c < b_1^c < \tilde{b}$, or $\tilde{b} < b_2^c < b_1^c$. That means that in either case, one of the two policy combination is located on the dotted part of either of the two isocost functions in Figure 3, and the first–best policy is not incentive compatible. If $\tilde{b} < b_2^c < b_1^c$, the situation is analogous to the one depicted in Figure 2 and hence here type 1 farmers strictly prefer the contract intended for type 2 farmers. In fact, condition $\tilde{b} < b_2^c < b_1^c$ is equivalent to $F_1 - F_2 < c_2(b_2^c) - c_1(b_2^c)$, which violates (10). In that case, the optimal separating policy is again (11), that is an informational rent must be given to type 1 farmers.

If, however, $b_2^c < b_1^c < \tilde{b}$, type 2 farmers strictly prefer the contract intended for type 1 farmers. Here, condition $b_2^c < b_1^c < \tilde{b}$ is equivalent to $F_1 - F_2 > c_2(b_1^c) - c_1(b_1^c)$. The second–best policy is then again a

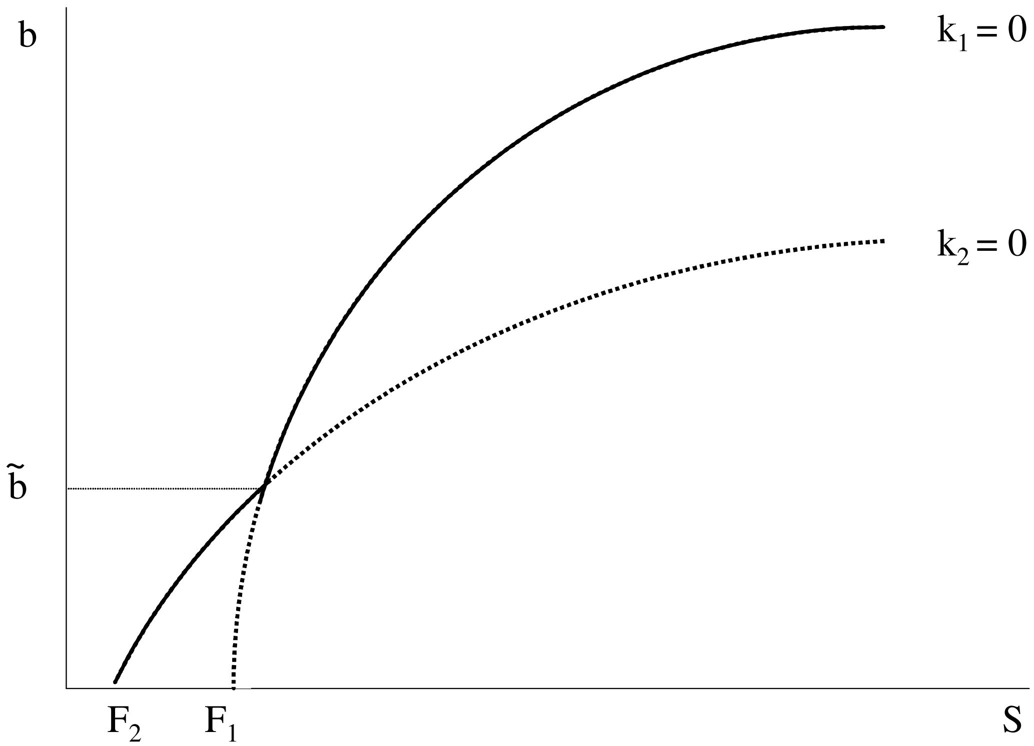

Figure 3: Incentive compatibility of the first-best policy if $F_1 > F_2 \geq 0$.

separating contract, characterized now by the following conditions:

$$n_2\left[c_2'\left(b_1^s\right) - c_1'\left(b_1^s\right)\right] = n_1\left[c_1'\left(b_1^s\right) - c_2'\left(b_2^s\right)\right], \tag{13a}$$

$$\overline{B} = n_1 b_1^s + n_2 b_2^s, \tag{13b}$$

$$S_1^s = F_1 + c_1\left(b_1^s\right), \tag{13c}$$

$$c_2\left(b_2^s\right) - S_2^s - c_2\left(b_1^s\right) + S_1^s = 0. \tag{13d}$$

The interpretation is analogous to that of (11). Type 1 farmers have no incentive to misrepresent their type when facing the first-best policy menu, but type 2 farmers do. Therefore, type 1 farmers are just compensated for their extra costs (13c), but type 2 farmers receive an informational rent such that their incentive compatibility constraint (13d) is binding. These rents are $R_2 \equiv S_2 - F_2 - c_2\left(b_2\right) \geq 0$. Using (13c) and (13d) and adding and subtracting F_2, we have $R_2 = c_1(b_1) - c_2(b_1) + F_1 - F_2 > 0$. Differentiating yields $dR_2/db_2 = [c_1'(b_1) - c_2'(b_1)](db_1/db_2) = (n_2/n_1)[c_2'(b_1) - c_1'(b_1)] > 0$; the donor can save on the amount of subsidies paid by decreasing b_2 and increasing b_1, rendering the policy combination aimed at type 1 farmers less attractive to type 2 farmers. Modifying the 'golden rule' of $c_1'(b_1) = c_2'(b_2)$ by adding dR_2/db_2 to the RHS, we obtain (13a). In this case, we also have $b_1^s > b_1^c$, $b_2^s < b_2^c$, $S_1^s > S_1^c$ and $S_2^s < S_2^c$.

If, however, $b_2^c \leq \tilde{b} \leq b_1^c$ (with at least one of the two inequalities being strict), the first–best solution is incentive–compatible, since condition (10) holds. For type 2 farmers the difference in subsidies $(S_1^c - S_2^c)$ is always smaller than the increase in variable costs they incur when representing themselves as type 1 farmers; for type 1 farmers the change in subsidies is always larger than the variable cost savings they obtain because of having to meet less strict management requirements (b_2^c versus b_1^c).

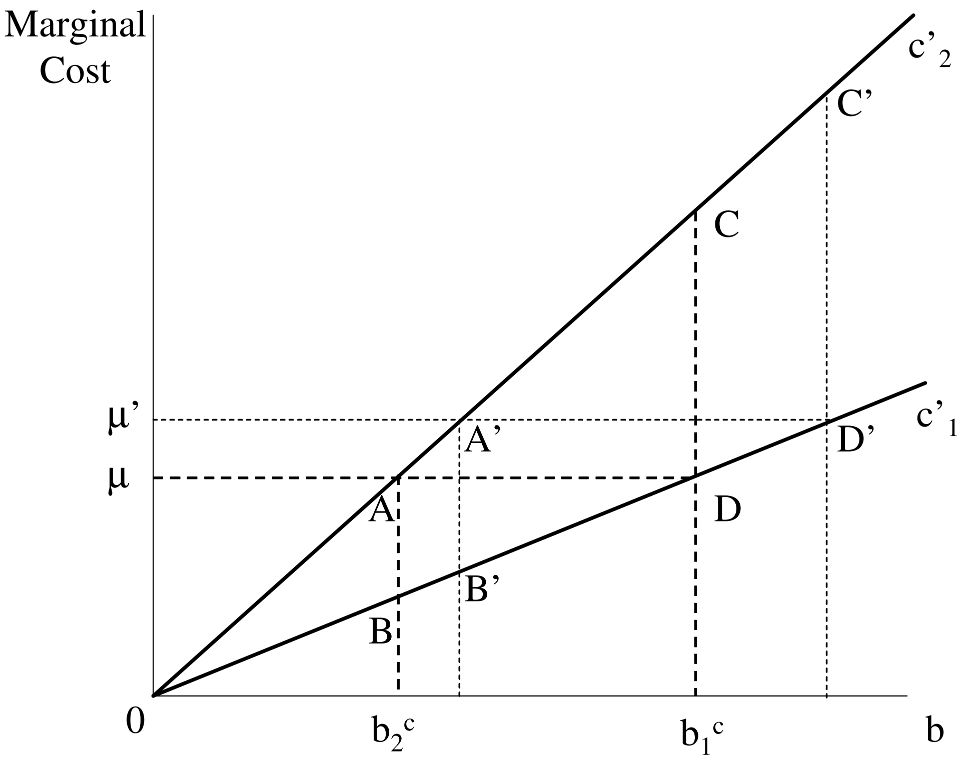

Figure 4: The range of differences in fixed costs (ABCD and A'B'C'D') for which the first–best solution is incentive–compatible, as a function of the minimum required level of conservation.

Next, we address the question how likely it is that $b_2^c \leq \tilde{b} \leq b_1^c$. Or, equivalently, how likely is it that condition (10) holds in practice? As seen before, a necessary condition is that the farmer type with low marginal conservation costs has larger fixed costs, i.e., $F_1 > F_2$. For a certain level of aggregate conservation, $\bar{B}$, the difference $F_1 - F_2 > 0$ must lie between two bounds, as shown in (10).

Consider Figure 4, where we depict the complete information solution. If the Kuhn–Tucker multiplier associated with the aggregate conservation objective (1b) is equal to μ, the left–hand side of (10) equals area 0AB, while its right–hand side equals 0CD. If $F_1 - F_2$ is larger than 0AB but smaller than 0CD, the first–best solution is incentive compatible. Now assume an increase in the required level of conservation effort, $\overline{B}$, increasing the corresponding Kuhn–Tucker multiplier to μ'. Graphically, it is easy to see that both the left– and right–hand side bounds of (10) increase, but that the increase in the right–hand side bound is larger (as $db_1^c/db_2^c > 1$).[7]

This analysis shows that, on the one hand, the interval for the 'allowable' difference in fixed costs (i.e., the range of differences in fixed costs that result in the first best being incentive compatible) increases if aggregate conservation effort $\overline{B}$ increases. On the other hand, a higher $\overline{B}$ also implies that the lower bound of the interval is increased, so that smaller differences in fixed costs are no longer incentive compatible. As a consequence, when $F_1 > F_2$, only intermediate levels of aggregate conservation can be implemented without any informational distortions. Obviously, this range of intermediate aggregate conservation levels is directly related to the difference in farmers' marginal costs. Therefore, the larger this difference, the larger the range of aggregate conservation levels which are implementable by the first–best.

6 Conclusions

This paper revisits the conclusions of the literature on incentive–compatible contracts and finds that, when taking into account the presence of fixed conservation costs, the dual cost of separation do not necessarily occur. While in the case of just variable costs the low–cost farmers always obtain an informational rent whereas the high–cost farmers are

[7] Mathematically, the bandwidth for $F_1 - F_2$ is given by $Z \equiv [c_2(b_1^c) - c_1(b_1^c)] - [c_2(b_2^c) - c_1(b_2^c)]$. If $\bar{B}$ increases by $d\bar{B}$, then $db_2 = d\bar{B}/[n_1(c_2''/c_1'') + n_2] > 0$, and $db_1 = (c_2''/c_1'')db_2 > db_2 > 0$. Hence, $dZ/d\bar{B} = \frac{1}{[n_1(c_2''/c_1'')+n_2]}[c_2'(b_1^c) - c_1'(b_1^c)](c_2''/c_1'') - [c_2'(b_2^c) - c_1'(b_2^c)] > 0$.

confronted with less strict management requirements than in the first–best, this is not necessarily the case when conservation entails fixed costs too. Then, if farmers with lower variable conservation costs face higher fixed costs (and vice versa), the first best can be incentive compatible. Given the relevance of fixed costs in conservation issues, we conclude that incentive–compatible contracts should be given a second chance as a policy measure to induce conservation.

7 Appendix 1

The Lagrangian of the problem is the following

$$L = n_1 S_1 + n_2 S_2 + \mu \left[\overline{B} - n_1 b_1 - n_2 b_2\right] + \sum_i \lambda_i \left[F_i + c_i\left(b_i\right) - S_i\right] + \gamma_1 \left[c_1\left(b_1\right) - S_1 - c_1\left(b_2\right) + S_2\right] + \gamma_2 \left[c_2\left(b_2\right) - S_2 - c_2\left(b_1\right) + S_1\right],$$

where $\mu \geq 0$, $\lambda_i \geq 0$, $\gamma_i \geq 0$ are the corresponding Kuhn–Tucker multipliers.

The corresponding conditions for an optimum are:

$$\lambda_1 c_1'\left(b_1\right) - \mu n_1 + \gamma_1 c_1'\left(b_1\right) - \gamma_2 c_2'\left(b_1\right) = 0, \tag{14}$$

$$\lambda_2 c_2'\left(b_2\right) - \mu n_2 - \gamma_1 c_1'\left(b_2\right) + \gamma_2 c_2'\left(b_2\right) = 0, \tag{15}$$

$$n_1 - \lambda_1 - \gamma_1 + \gamma_2 = 0, \tag{16}$$

$$n_2 - \lambda_2 + \gamma_1 - \gamma_2 = 0, \tag{17}$$

$$\mu \left[\overline{B} - n_1 b_1 - n_2 b_2\right] = 0;\ \overline{B} - n_1 b_1 - n_2 b_2 \leq 0, \tag{18}$$

$$\lambda_i \left[F_i + c_i\left(b_i\right) - S_i\right] = 0;\ F_i + c_i\left(b_i\right) - S_i \leq 0,\ i = 1, 2, \tag{19}$$

$$\gamma_1 \left[c_1\left(b_1\right) - S_1 - c_1\left(b_2\right) + S_2\right] = 0;\ c_1\left(b_1\right) - S_1 - c_1\left(b_2\right) + S_2 \leq 0, \tag{20}$$

$$\gamma_2 \left[c_2\left(b_2\right) - S_2 - c_2\left(b_1\right) + S_1\right] = 0;\ c_2\left(b_2\right) - S_2 - c_2\left(b_1\right) + S_1 \leq 0, \tag{21}$$

The case where $\lambda_1 \geq 0$, $\lambda_2 \geq 0$, $\gamma_1 = \gamma_2 = 0$ corresponds to the first–best solution, where $\mu = c_1'\left(b_1^c\right) = c_2'\left(b_2^c\right) > 0$, $\overline{B} = n_1 b_1^c + n_2 b_2^c$ and $F_i + c_i\left(b_i^c\right) - S_i^c = 0$ for all i, and has been discussed already in section 3. The first–best policy is incentive compatible if and only if (20) and (21) hold, that is, when $c_1(b_1^c) - S_1^c - c_1(b_2^c) + S_2^c \leq 0$ and $c_2(b_2^c) - S_2^c - c_2(b_1^c) + S_1^c \leq 0$. Since $S_i^c = F_i + c_i(b_i^c)$ for all i, the two conditions reduce, respectively, to $F_1 - F_2 \geq c_2(b_2^c) - c_1(b_2^c)$ and $F_1 - F_2 \leq c_2(b_1^c) - c_1(b_1^c)$. Since $c_1'(b_1^c) = c_2'(b_2^c)$ and $c_2'(b) > c_1'(b)$ for all $b > 0$, we then have $b_1^c > b_2^c$. Integrating over the relevant range, we can conclude that $c_2(b_1^c) - c_1(b_1^c) > c_2(b_2^c) - c_1(b_2^c)$. Therefore, there exists a range of values for $F_1 - F_2$ such that the first–best policy is incentive compatible, which is the following:

$$c_2(b_2^c) - c_1(b_2^c) \leq F_1 - F_2 \leq c_2(b_1^c) - c_1(b_1^c). \tag{22}$$

Now assume that $F_1 - F_2 < c_2(b_2^c) - c_1(b_2^c)$. Then, condition $c_1(b_1^c) - S_1^c - c_1(b_2^c) + S_2^c \leq 0$ does not hold. In the first–best solution, type 1 prefers the policy targeted at type 2. By (20), the incentive compatibility constraint for type 1 must be binding and $\gamma_1 > 0$. Note that $\lambda_1 = \lambda_2 = 0$ is not possible since (16) and (17) then yield $n_1 = -n_2$. Therefore, we can have either (i) $\lambda_1 > 0$, $\lambda_2 = 0$ or (ii) $\lambda_1 = 0$, $\lambda_2 > 0$.

Consider case (i) where $\lambda_1 > 0$ and $\lambda_2 = 0$. There are two subcases, (ia) $\gamma_1 > 0$ and $\gamma_2 > 0$ and (ib) $\gamma_1 > 0$ and $\gamma_2 = 0$. Clearly, subcase (ib) is not possible because, by (17), $n_2 = -\gamma_1 < 0$, which is a contradiction. Subcase (ia) corresponds to the uniform policy described in (3), where both incentive compatibility constraints are binding. In that case, conditions (14) and (15) reduce to:

$$\lambda_1 c_1'(b^u) - \mu n_1 + \gamma_1 c_1'(b^u) - \gamma_2 c_2'(b^u) = 0, \tag{23}$$

$$-\mu n_2 - \gamma_1 c_1'(b^u) + \gamma_2 c_2'(b^u) = 0. \tag{24}$$

Combining both conditions we obtain $\mu = c_1'(b^u)$. From (16) and (17), we have $\lambda_1 = n_1 + n_2$ and $\gamma_1 = \gamma_2 - n_2$. Substituting these expressions in (23), we then obtain $\gamma_2 [c_2'(b^u) - c_1'(b^u)] = 0$, which is only possible when $\gamma_2 = 0$, since we assume that $c_2'(b) > c_1'(b)$ for all $b > 0$. But we were assuming $\gamma_2 > 0$, and therefore we obtain a contradiction. Thus, subcase (ia) is impossible either.

Now consider case (ii) where $\lambda_1 = 0$, $\lambda_2 > 0$. Again, two subcases are possible: (iia) $\gamma_1 > 0$, $\gamma_2 > 0$ and (iib) $\gamma_1 > 0$, $\gamma_2 = 0$. Subcase (iia) corresponds again to the possibility of a uniform policy. A similar procedure to the one described for subcase (ia) lead us to conclude that $\gamma_1 = 0$, which is a contradiction. Finally, we explore case (iib) $\gamma_1 > 0$, $\gamma_2 = 0$. The combination of equations (14) to (17) lead us to the optimality condition:

$$n_1 \left[c_2'\left(b_2^s\right) - c_1'\left(b_2^s\right)\right] = n_2 \left[c_1'\left(b_1^s\right) - c_2'\left(b_2^s\right)\right],$$

which characterizes the optimal separating policy, together with the conditions $\overline{B} = n_1 b_1^s + n_2 b_2^s$, $S_2^s = F_2 + c_2\left(b_2^s\right)$ and $c_1\left(b_1^s\right) - S_1^s - c_1\left(b_2^s\right) + S_2^s = 0$.

Now, consider the case where $F_1 - F_2 > c_2\left(b_1^c\right) - c_1\left(b_1^c\right)$. Then, condition $c_2\left(b_2^c\right) - S_2^c - c_2\left(b_1^c\right) + S_1^c \leq 0$ does not hold and, by (21), the incentive compatibility constraint for type 2 must be binding and $\gamma_2 > 0$. Now, in the first–best solution, type 2 prefers the policy targeted at type 1. A similar proof as the one described before lead us to conclude that the optimum in this case is characterized by $\gamma_1 = 0$, $\lambda_1 > 0$ and $\lambda_2 = 0$. Thus, combining equations (14) to (17), we now obtain the following optimality condition:

$$n_2 \left[c_2'\left(b_1^s\right) - c_1'\left(b_1^s\right)\right] = n_1 \left[c_1'\left(b_1^s\right) - c_2'\left(b_2^s\right)\right],$$

together with the conditions $\overline{B} = n_1 b_1^s + n_2 b_2^s$, $S_1^s = F_1 + c_1\left(b_1^s\right)$ and $c_2\left(b_2^s\right) - S_2^s - c_2\left(b_1^s\right) + S_1^s = 0$. So, again, the optimal policy is a separating one.

Summarizing, the optimal policy under incomplete information is always separating. If $F_1 - F_2$ is sufficiently small, there is a distortion:

the complete information policy is not incentive compatible, and an informational rent is needed for type 1 farmers. Conversely, if $F_1 - F_2$ is sufficiently large, an informational rent is needed for type 2 farmers. Only for intermediate values of $F_1 - F_2$, the first–best solution can be implemented.

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