The Beijer Institute of Ecological Economics

DISCUSSION PAPER

Beijer Discussion Paper Series No. 196

Set-aside requirements versus production quotas in agro-environmental regulatory contracts

Anne-Sophie Crépin and Pierre-Alain Jayet. 2005.

The Beijer Institute of Ecological Economics
The Royal Swedish Academy of Sciences
Box 50005 SE-104 05 Stockholm Sweden
Phone: +46 8 673 95 00 Fax: +46 8 15 24 64
E-mail: beijer@beijer.kva.se

Set-aside requirements versus production quotas in agro-environmental regulatory contracts

This article deals with regulation of cash-crop production and environmental amenities on farmland when they are correlated. We study the opportunities to use contracts to regulate both goods' production simultaneously when producers hold information about their own farm characteristics — information, which may not be available to the regulator. We characterize two contracts and try to compare their social efficiency in the context of a preexistent price support when public funds are associated with a non-negative excess burden. One contract aims at controlling the input — land; the other aims at controlling the output — cash-crop production. Both contracts are means by which the government can limit its price-support payments. Tax revenues serve to collect public funds that are used as transfers in the contracts. Besides characterizing the contracts explicitly, we address the possible social dominance of one contract over the other. We discuss some consequences of accounting for increasing shadow costs of public funds that reflect alternative allocations of public resources.

We contribute to the theory of voluntary contracts based on incentives — typically transfers that the contract offers. The incentives guarantee that the individual agents do not lose when they accept the contract but these same incentives are associated with information rents creating additional social costs, which the contracts supplying authorities must contain. As the literature shows, one of the open questions is the dominance of input versus output monitoring in terms of social welfare. To some extent, the analysis of our agro-environmental problem indicates that input monitoring dominates.

Government policy that attempts to regulate agricultural markets can be implemented through limits on the quantity of land input hereafter called set-aside programs. We use a broad definition of set aside as an alternative to commercial production — cash crop. Set aside includes using the land for fallow but also to create a wetland or maintain a pasture or a meadow. By assumption, the set-aside policy considered in this article always creates net environmental benefits — positive externalities in the form of improved ecosystem services like biodiversity production or nutrient cleaning. We do not consider situations in which set aside may lead to environmental costs. Our set-aside programs are substantially different and much more general than the set-aside programs in the US, EU and Japanese agricultural policy, which are more like instruments to guarantee crop prices. Set-aside programs were, and still are, important regulation tools in USA with the Farm Bill Act and the Conservation Reserve Program (Wu and Babcock 1996; Babcock et al.1996) and more recently in Europe with the set-aside programs proposed in 1988 and 1992. Quotas are common as well — see agricultural policies in Canada and Europe for milk or sugar beet for instance. Regulatory authorities' traditional objectives were to limit excess of product supply and increasing public expenditure for agriculture support. Recently, other set-aside benefits, like environmental impacts, have been focused on (Wu and Babcock1996).

Bourgeon, Jayet and Picard (1995), Segerson (1998), and Segerson and Miceli(1998), among others, have earlier addressed the question of whether to use voluntary incentives or a mandatory policy. They all reveal that one cannot be sure of which dominates the other if the regulation aims at efficiency. In this article we focus on voluntary policies assuming that they are socially preferable or promote the producers good will for the regulation, thereby increasing its impact. Also it seems that voluntary incentives for environmental protection are usual in many different countries (Khanna 2001).

Most countries either offer a fixed return per surface of land set aside or some fixed quota. In this study we focus on individualized contracts instead because previous research shows that individualized contracts are often socially preferable if efficiency is the goal (Laffont and Tirole 1993; Smith 1995; Babcock et al. 1996). For comparisons between specific environmental individualized contracts and fixed level policies, see Gren (2004), and Crépin (2005).

The question of whether or not one should regulate through input or output in an asymmetric information setting was previously considered. The answer to that seemed to depend highly on the problem studied and on the assumptions made. Maskin and Riley (1985) used a two-goods model and showed, for general, nonlinear incentive schemes, that under a set of assumptions, monitoring the output was better than monitoring the input. Roughly, these assumptions required that more productive agents demanded larger input and produced larger output when only lump sum taxes were used. Kahlil and Lawarrée (1995) found that the residual claimant's identity in the principal-agent relationship determined the choice between input and output monitoring. This result seems less relevant for agricultural regulations because residual claims appear to be more the result of a political process than the regulator's choice variable. In addition, the dichotomy between the principal's objective and the agents' is not as clear in our model because social welfare also includes the agents' profit. Bontems and Bourgeon (2000) found that if both incentive schemes implied the same ranking of agents for the productivity parameter, one instrument always dominated the other, regardless of the agent's type. If the two schemes produced reverse ranking, the principal was always better off using a type-dependent mixed strategy rather than either of the two incentive schemes. None of the previous articles addressed the cost issue associated with public funding although Guesnerie and Laffont (1984) and Laffont and Tirole (1993) highlighted its role.

Our original contribution is to analyze whether or not one should regulate through input or output in a realistic agro-environmental problem. Our setting differs from those previously studied: the nature of goods, the monitoring instruments, the claimant, and the principal, refer to what is expected in such problems so previous results may not necessarily be relevant. We study the regulation of two different agricultural goods — a cash crop and an environmental amenity — using input or output variables, when taxes must be raised and administrative and other costs are incurred. The heavy amount of funds used in agricultural policy as well as the competition in the use of these funds are clear motives to model the shadow cost of public funds. The principal — here the claimant — is a public authority who accounts for amenity production and the agents' profit in the common welfare function, which is her objective. She must choose one monitoring instrument among land set-aside or quota on output. We assume that the agents — the farmers — have positive reservation profits. In other words, the farmers would make a positive profit even if they did not contract. We characterize two contracts that implement this twofold-regulation policy. The first contract focuses on set-aside for the production of an amenity; the second focuses on the quantity of the marketed good to produce. The principal keeps the opportunity to exclude some agents from the contract to improve social welfare. Our assumptions imply rent monotonicity.

The twofold-production aspect — crop and environmental amenity production — implies that the potential yield for crop production and the potential environmental yield together characterize the plots. The regulator must account for both but rational individual producers may focus on private yields only. Private benefit capacities and production costs characterize the plots. Both depend on a farm characteristic that is unknown to the regulator, who only knows its distribution. The article focuses on the information asymmetry that creates adverse selection.

The public choice of crop price was not included so that consumers were not integrated in this analysis; thus, only taxpayers faced producers. This setting fits well in the framework of the Common Agricultural Policy (CAP) in the EU. Previous articles (Bourgeon, Jayet and Picard 1995; Jayet 2001; Innes 2003) have studied the effects of prices in a comparable setting. Innes claims in particular that this approach would capture the real economic cost of acreage reduction programs. Considering price effects would certainly fit better with the realities of the North American market but would require knowledge of the demand and complicate the problem a lot. Jayet showed that price changes could occur when regulators propose contract mechanisms to the producers, and that the price change should limit the informational rent through changes in the contract as well as a decreasing number of contracting producers. Our focus is more modest and concentrates on contract comparisons. In contrast to Innes we introduce production of environmental amenities as a possible target for set-aside or quota policies.

The remainder of the article is organized as follows: The first section presents the model; the following section derives the farmer's program and provides constraints that should apply to the contracts; after that we present the regulator's programs and derive conditions for one contract to be superior to the other; and the final section summarizes the results and concludes the article.

The model

We consider a set of farmers who each own an area normalized to one unit. A parameter θ, called performance index, characterizes the farm, and represents the private information, which is unknown to the regulator. Let $\Theta = [\underline{\theta}, \overline{\theta}]$ be a continuum of mass 1 that defines the set of farmers. Let $F(\theta)$ and $f(\theta)$, respectively, be the cumulative distribution of θ and the corresponding density, which are positive on Θ by assumption. The farmer can produce two types of goods on a plot. Let x be a plot productivity indicator, typically a crop yield, which follows a distribution defined by the density $h(x, \theta)$ and the cumulative function $H(x, \theta)$ common to all farms and parameterized by θ. The parameter θ could, for example, be an indicator of soil productivity in traditional agricultural production or in production of environmental amenities. For any plot characterized by its potential x, the farmer receives either a net yield $a(\theta)$ — benefit net of costs — from production of good 1 — the amenity — or a yield $b(\theta)\, x$ from production of good 2 — the traditional good —, which costs $c(\theta)$ to produce. This cost is assumed to be independent of the plot. We extend the usual pure externality case $(a(\theta) = 0)$ and assume that farmers can increase profit from amenities (Söderqvist 2003). The farmer may for example produce the amenity by creating a wetland, which can be used for irrigation or the amenity may have goodwill effects. Typically, good 1 is produced on low-producing plots and good 2 on high-producing plots. The distribution h is assumed to be positive and independent on θ on the support $X = [\underline{x}, \overline{x}]$. Note the asymmetry between both goods: good 1 yields a constant profit per surface unit whereas good 2's profit is linear in x.

A farmer's profit, signified by $\pi(\theta)$, depends on yields of both goods produced and on production cost for good 2. Let some threshold plot characterized by the performance index $\kappa(\theta)$ define a partition of X so that with no regulation, farmers produce good 1 on the plots with performance index below κ, and they produce good 2 on the plots with performance index above κ. When no regulation process is implemented, the marginal net yields for the two different types of production are identical on the threshold plot. Given the settings of the problem, we will thus have $\kappa(\theta) = \frac{a(\theta)+c(\theta)}{b(\theta)}$. An expression for the unregulated farmer's profit follows.

$$(1) \qquad \pi(\theta) = \int_{\underline{x}}^{\kappa(\theta)} a(\theta)h(x,\theta)dx + \int_{\kappa(\theta)}^{\overline{x}} (b(\theta)x - c(\theta))\, h(x,\theta)dx$$

This analysis builds on a stylized agricultural production model in which all agricultural land is used to produce either cash crops or environmental amenities. This means that we need only regulate one good, and the production of the other good automatically occurs on the remaining land. This assumption is not as restrictive as it may seem because most countries have some kind of land use restrictions. We also assume that the principal cannot regulate amenity production. So we study only two regulations: either imposing restrictions on land available for production of good 1 or a production quota on good 2.

This arbitrary choice is convenient to represent wetland creation or pasture subventions to increase environmental amenities on agricultural land, but could also represent traditional set-aside and production quotas to limit agricultural production. We now consider two types of contracts that the principal proposes to regulate production. The first type is a set-aside contract that provides a transfer t to the farmer when she agrees to set-aside a part s of her land for the production of good 1. The second type is a contract on a quantity ψ that the farmer accepts as a production limit for good 2. The transfer τ is then given as compensation. The regulator's program defines the optimal mechanism design related to the two contracts, $(s(\theta), t(\theta))$ and $(\psi(\theta), \tau(\theta))$, respectively, when there is informational deficit.

The income of all farmers Π, the expected benefit of the amenity B, and the public budget of the regulation J determine the regulator's objective W. The budget J includes direct net transfers from taxpayers to producers T and the cost of public intervention on the market for good 2. We account for the cost λ, associated with public funding and assume that one currency unit costs λ more if public authorities spend it on this regulation rather than on regulations devoted to other public goals: $W = \Pi + B - (1+\lambda)J$.

The sum of all farmers' income is $\Pi = \int_{\Theta} \pi(\theta) dF(\theta)$. The expected benefit of the regulation is a linear function of the quantity of good 1 produced: $B = mQ_1$ because we assume that the amenity's marginal benefit is constant. The public budget is assumed to be linear in Q_2: $J = T + nQ_2$. Q_1 and Q_2, respectively, are the total amount of goods 1 and 2 produced on all farms, and m and n are positive parameters. This means respectively that land set aside is positively correlated to the amount of amenity and that the budget related to the agricultural policy is positively correlated to the level of production of good 2.

The comparison of traditional land set-asides and production quotas to limit agricultural production is easily represented in the model. We just need to define good 1 as set-aside land and good 2 as traditional agricultural production supported by guaranteed price and refunds to export, which are usually implemented by the European Union's Common Agricultural Policy (CAP). For CAP regulation, we must adapt the parameter values and put $a(\theta) = 0$, $b(\theta) = p$, the market price assuming that x is the plot's yield. In the case of CAP without the environmental aspect, n is the unit refunds for exporting good 2 — the difference between the domestic price and the world price — and m is equal to zero.

To clarify and help interpret the results, we introduce two assumptions. Let $l(\theta, x)$ signify the net private profitability of plot x in the production of good 2 — the agricultural product; $l(x, \theta) = bx - (a + c)$, consistently with the definition of the threshold plot $\kappa(\theta)$. The first assumption $(H1)$ means that θ is interpreted as a performance index related to the traditional good. The second assumption is the usual stochastic dominance condition $(H2)$, which a large range of probability laws satisfies. We set for any θ and for any x:

$$\frac{\partial l(x,\theta)}{\partial \theta} \geqslant 0 \tag{H1}$$

$$\frac{\partial H(x,\theta)}{\partial \theta} < 0 \tag{H2}$$

The farmer is always free to reject the contracts and produce a market good in accordance with existing regulation. Thus the regulator must design the contracts following the revelation principle (Dasgupta, Hammond and Maskin 1979; Myerson1979): both contracts must be such that the agents would reveal the true θ — incentive condition — and accept the contracts — rationality condition — if this is socially optimal.

The Farmer's programs

Set-aside contract

Assume that the regulator wants more land set aside either to increase production of environmental amenities — good 1 — or to decrease production of traditional agricultural goods — good 2. In application of the usual revelation principle, previously cited, the optimal mechanism cannot be better than the mechanism that makes the producer reveal her own characteristic. Formally the announcement $\widetilde{\theta}$ of the producer θ accepting the contract $(s(\widetilde{\theta}), t(\widetilde{\theta}))$ depends on a threshold productivity $v(\widetilde{\theta}, \theta)$ that the required set-aside land defines, based on the land that must be set aside for production of good 1: $s(\widetilde{\theta}) = \int_{\underline{x}}^{v(\theta,\widetilde{\theta})} h(x, \theta)dx$. The farmer's program is $\max_{\widetilde{\theta}} \pi_s(\theta, \widetilde{\theta})$ with π_s as follows.

$$\pi_s(\theta, \widetilde{\theta}) = \int_{\underline{x}}^{v(\theta,\widetilde{\theta})} a(\theta)h(x, \theta)dx + \int_{v(\theta,\widetilde{\theta})}^{\overline{x}} (b(\theta) x - c(\theta)) h(x, \theta)dx + t\left(\widetilde{\theta}\right)$$

The solution gives the first- and second-order incentive conditions. The regulator must account for these conditions to ensure that the farmer reports the truth — so it is optimal to report θ. The optimal set-aside productivity threshold is denoted $\overline{v}(\theta)$. The incentive constraints yield:

$$\dot{t}(\theta) = (b(\theta)\,\overline{v}(\theta) - c(\theta) - a(\theta))\,\dot{s}(\theta) \tag{2}$$

$$\left(\dot{a}(\theta) + \dot{c}(\theta) - \dot{b}(\theta)\,\overline{v}(\theta) + b(\theta)\frac{\partial H(\overline{v}(\theta),\theta)/\partial\theta}{h(\overline{v}(\theta),\theta)}\right)\dot{s}(\theta) > 0 \tag{3}$$

The informational rent R_s is the producers' additional gain when they tell the truth. In other word, this rent is the difference in profits between situations with and without regulation. The informational rent is:

$$R_s(\theta) = t(\theta) + \int_{\kappa(\theta)}^{\overline{v}(\theta)} (a(\theta) - b(\theta)\,x + c(\theta))\,h(x,\theta)dx \tag{4}$$

This rent $R_s(\theta)$ is monotonic and decreasing when H1 and H2 hold but less restrictive conditions could also lead to this result (See appendix). If, as assumed, the regulator wants more amenity or less traditional good, the contract should then give incentives to set aside so the optimal set-aside productivity threshold must lie above the productivity of the threshold plot when there is no regulation: $\overline{v}(\theta) \geqslant \kappa(\theta)$. Then the incentive condition (3) together with H1 and H2 imply that the contract's set-aside requirement must be decreasing in θ (See appendix). So according to the contract, if farm productivity is low — low θ —, then set-aside allocation for good-1 production will be high: the lower the productivity the larger the set-aside. The decreasing rent implies that the regulator proposes the contract to a θ subset $[\underline{\theta}, \eta_s]$. The contract will require larger set-asides on the lowest-performing farms.

Quota contract

As previously, the announcement $\widetilde{\theta}$ of the producer θ who accepts the contract $(\psi(\widetilde{\theta}), \tau(\widetilde{\theta}))$ depends on a threshold productivity $u(\widetilde{\theta}, \theta)$ defined by the regulated production. Given the quota $\psi(\widetilde{\theta}) = \int_{u(\widetilde{\theta},\theta)}^{\overline{x}} xh(x,\theta)dx$, the farmer's program is $\max_{\widetilde{\theta}} \pi_q(\theta, \widetilde{\theta})$ with π_q as follows.

$$\pi_q(\theta, \widetilde{\theta}) = \int_{\underline{x}}^{u(\widetilde{\theta},\theta)} a(\theta)h(x,\theta)dx + \int_{u(\widetilde{\theta},\theta)}^{\overline{x}} \left(b\left(\theta\right)x - c(\theta)\right)h(x,\theta)dx + \tau\left(\widetilde{\theta}\right)$$

The optimal threshold yield is denoted $\overline{u}(\theta)$. The incentives conditions are (5) and (6).

$$\dot{\tau}(\theta) = \left(a\left(\theta\right) + c(\theta) - b\left(\theta\right)\overline{u}(\theta)\right)\dot{\psi}(\theta) \tag{5}$$

$$\left(\dot{a}\left(\theta\right) + \dot{c}(\theta) - \dot{b}\left(\theta\right)\overline{u}(\theta) - \frac{a\left(\theta\right) + c(\theta)}{h(\overline{u}(\theta),\theta)\overline{u}(\theta)^2}\int_{\overline{u}(\theta)}^{\overline{x}} x\frac{\partial h(x,\theta)}{\partial\theta}dx\right)\dot{\psi}(\theta) < 0 \tag{6}$$

The informational rent is now $R_q\left(\theta\right)$.

$$R_q(\theta) = \tau(\theta) + \int_{\kappa(\theta)}^{\overline{u}(\theta)} \left(a(\theta) + c(\theta) - b\left(\theta\right)x\right)h(x,\theta)dx \tag{7}$$

This rent is monotonic and decreasing when H1 and H2 hold (see appendix). Similar to the set-aside contract, consider that the regulator wants to increase production of amenities or to reduce traditional agricultural production, so that $\overline{u}(\theta) \geqslant \kappa(\theta)$. The incentive condition (6) together with H1 and H2 imply that the quota requirement for the production of good 2 must be increasing in θ (See appendix). Consequently, if the farm performance index is low, then the good-2 production quota will be low, i.e., the lower the index, the lower the quota. The decreasing rent implies that the regulator proposes the contract to the θ subset $[\underline{\theta}, \eta_q]$. This result means that the contract will require larger quotas on the highest-performing farms.

Incentive conditions

We define the production of the two goods given the production threshold w:

$$q_1(w,\theta) = \int_{\underline{x}}^{w} h(x,\theta)dx = H(w,\theta)$$
$$q_2(w,\theta) = \int_{w}^{\overline{x}} xh(x,\theta)dx$$

Table 1 summarizes the previous results. By assumption, the expected rents are monotonically decreasing. For the set-aside contract this is true if the set-aside requirement s is a decreasing function of θ. For the quota contract, the quota ψ must be increasing in θ.

The regulator's programs

The contracts

Consider now the regulator's programs in both cases. As we previously mentioned in section 2, the regulator accounts for farmers' profit, amenities and regulation cost. So the part of the objective function that depends on the regulation corresponds to the expression $\Pi + mQ_1 - (1+\lambda)(T + nQ_2)$. Q_1 and Q_2 are the total production of good 1 and 2, respectively, on all of the farms; T is the total net transfer due to contracts from taxpayers to all the farms, m and n are positive parameters, and λ is related to the opportunity cost of public funds ($\lambda \geq 0$). Consistent with the application to agricultural policies, we introduce assumption H3 that means that the private benefit $b(\theta)$ from production $q_2(\theta)$ is larger than the public cost n.

$$\text{(H3)} \qquad b(\theta) > n$$

The non-contracting agents obtain profits equivalent to $\pi(\theta)$, null transfers, and a threshold yield equal to $\kappa(\theta)$. By extension of the functions π_s given below, $\overline{v}$ and t — respectively π_q, $\overline{u}$ and τ— the public programs follow.

$$W_s = \max_{\overline{v}(\cdot)} \int_\Theta \left(\pi_s(\theta,\theta) + mq_1(\overline{v}(\theta),\theta) - (1+\lambda)\left(t(\theta) + nq_2(\overline{v}(\theta),\theta)\right)\right) f(\theta)d\theta$$

$$W_q = \max_{\overline{u}(\cdot)} \int_\Theta \left(\pi_q(\theta,\theta) + mq_1(\overline{u}(\theta),\theta) - (1+\lambda)\left(\tau(\theta) + nq_2(\overline{u}(\theta),\theta)\right)\right) f(\theta)d\theta$$

$$\pi_s(\theta,\theta) = a(\theta)q_1(\overline{v}(\theta),\theta) + b\left(\theta\right)q_2(\overline{v}(\theta),\theta) - c\left(\theta\right)\left(1 - q_1\left(\overline{v}(\theta),\theta\right)\right) + t(\theta)$$

$$\pi_q(\theta,\theta) = a(\theta)q_1(\overline{u}(\theta),\theta) + b\left(\theta\right)q_2(\overline{u}(\theta),\theta) - c\left(\theta\right)\left(1 - q_1(\overline{u}(\theta),\theta)\right) + \tau(\theta)$$

Define the function $k\left(x,\theta\right)$ as the social preference for a plot with productivity x used in the production of the amenity rather than in cash crop production. The function $k\left(x,\theta\right)$ contrasts with the function $l(\theta,x)$ that signifies the net private profitability of plot x.

$$\text{(8)} \qquad k(x,\theta) = m + (1+\lambda)\left[a(\theta) + c(\theta) - (b(\theta) - n)x\right]$$

Consider now the change in the threshold that discriminates plots according to their use, when the contracts are implemented. In appendix we solve the public programs using optimal control tools. This gives the following result, which characterizes the threshold productivity $\overline{v}$ — respectively $\overline{u}$ — related to the set-aside contract — respectively the quota contract.

$$(9) \qquad \forall\theta \in [\underline{\theta}, \eta_s] : k(\overline{v}, \theta) = \lambda \frac{F}{f} \left(\frac{\partial l(\overline{v}, \theta)}{\partial \theta} - b \frac{\frac{\partial H(\overline{v}, \theta)}{\partial \theta}}{h(\overline{v}, \theta)} \right)$$

$$(10) \qquad \forall\theta \in [\underline{\theta}, \eta_q] : k(\overline{u}, \theta) = \lambda \frac{F}{f} \left(\frac{\partial l(\overline{u}, \theta)}{\partial \theta} + \frac{b\kappa}{\overline{u}^2} \frac{\int_{\overline{u}}^{\overline{x}} x \frac{\partial h(x,\theta)}{\partial \theta} dx}{h(\overline{u}, \theta)} \right)$$

Under assumptions H1 and H2, the right hand sides of (9) and (10) are positive and under H3 the function k is decreasing with respect to x. Thus the thresholds decrease when the contracts are implemented, compared to what is obtained in the first best. When there is no information asymmetry, the first best threshold is equal to $w(\theta) = \frac{m+(1+\lambda)(a+c)}{(1+\lambda)(b-n)}$, which denotes the social productivity threshold, such that using a plot with productivity x to produce good 1 would be socially equivalent to using that same plot to produce good 2. Thus $w(\theta)$ solves $k(x, \theta) = 0$ where x is the unknown variable and equation (11) together with (9–10) characterize threshold plots.

$$(11) \qquad x = w(\theta) - \frac{k(x, \theta)}{(1 + \lambda)(b - n)}$$

Recall that if productivity x is below — respectively above — the threshold, it is socially preferable to produce an amenity — respectively a cash crop — on the land. Asymmetric information implies that the threshold productivity is lower — k decreasing in x — so amenity production becomes socially less rewarding compared to cash-crop production. The higher the social cost of public funds, the lower is the threshold discriminating the plots according to their use, and the fewer are the plots dedicated to the amenity.

Finally, recall that the pivot farmer η — η_s for the set-aside contract, and η_q for the quota contract — has a rent equal to zero, so the optimal pivot performance index is derived. Proposition 1 states that we could characterize both contracts completely if we were knowledgeable about parameter values and statistical distributions.

Proposition 1 *The mechanism design is completely defined for the two contracts: first by the implicit equation from which the threshold productivity and the two basic terms of each contract can be derived; second, by the relation that defines the pivot farm.*

The set-aside contract is such as:

$$\left|\begin{array}{l} \overline{v}(\theta) = w(\theta) - \frac{\lambda}{1+\lambda}\frac{1}{b-n}\frac{F}{f}\left(\frac{\partial l(\overline{v},\theta)}{\partial\theta} - b\frac{\frac{\partial H(\overline{v},\theta)}{\partial\theta}}{h(\overline{v},\theta)}\right) \\ s(\theta) = H(\overline{v}(\theta),\theta) \\ t(\theta) = t(\eta_s) + \int_{\eta_s}^{\theta} l(\overline{v}(y),y)\dot{s}(y)dy \\ t(\eta_s) = \int_{\kappa(\eta_s)}^{\overline{v}(\eta_s)} l(x,\eta_s)h(x,\eta_s)dx \\ \eta_s = \arg\max\limits_{\eta} W_s \end{array}\right.$$

The quota contract is such as:

$$\left|\begin{array}{l} \overline{u}(\theta) = w(\theta) - \frac{\lambda}{1+\lambda}\frac{1}{b-n}\frac{F}{f}\left(\frac{\partial l(\overline{u},\theta)}{\partial\theta} + \frac{b\kappa}{\overline{u}^2}\frac{\int_{\overline{u}}^{\overline{x}} x\frac{\partial h(x,\theta)}{\partial\theta}dx}{h(\overline{u},\theta)}\right) \\ \psi(\theta) = \int_{\overline{u}}^{\overline{x}} xh(x,\theta)dx \\ \tau(\theta) = \tau(\eta_q) - \int_{\eta_q}^{\theta} \frac{l(\overline{u}(y),y)}{\overline{u}(y)}\dot{\psi}(y)dy \\ \tau(\eta_q) = \int_{\kappa(\eta_q)}^{\overline{u}(\eta_q)} l(x,\eta_q)h(x,\eta_q)dx \\ \eta_q = \arg\max\limits_{\eta} W_q \end{array}\right.$$

Figure 1 summarizes these results and show the functional forms of the pivot rents in respective contract. The regulator's opportunity to design contracts addresses the question of contract comparison. We first focus on the threshold productivity that the contracts define.

Threshold productivity and pivot farms

In both contracts, the social productivity of the threshold plot (10–9) must be proportional to the sum of the marginal private profitability of the plot in cash-crop production and another term. This second term involves the marginal change in private profits due to a marginal change in the land set-aside respectively in the quota. Two results are easily derived. First the threshold yields, related to respective contract and that discriminate farmer θ's plots according to their use are identical in both regulations for the plot of lowest quality, $\overline{v}(\underline{\theta}) = \overline{u}(\underline{\theta}) = w(\underline{\theta})$. Second, the two threshold yields are always equal to w when public funds do not incur extra costs ($\lambda = 0$) that means $\overline{v} = \overline{u} = w$ for any θ. In this last case, asymmetric information creates positive information rents and thus higher transfers to keep the threshold equal to the first best one. This is the only difference compared to the first best case.

Equations (9) and (10) help us compute the difference between the thresholds $\overline{v}(\theta)$ and $\overline{u}(\theta)$ and we can show (see appendix) that, if $b > n$, $\dot{b} > 0$ and $\frac{\partial H(x,\theta)}{\partial \theta}$ is continuous, the thresholds $\overline{v}(\theta)$ and $\overline{u}(\theta)$ cannot be equal when θ is strictly greater than $\underline{\theta}$. By continuity, we expect the threshold productivity to be higher in the set-aside program than in the quota program: $\overline{v} > \overline{u}$ for any θ strictly greater than $\underline{\theta}$.

Further, we rewrite the welfare functions in terms of $k(x, \theta)$ given that $\overline{v}$ and $\overline{u}$ solve

(9) and (10), respectively, and compute the marginal changes in welfare due to a change in the pivot farm: $\frac{\partial W_s}{\partial \eta_s}$ and $\frac{\partial W_q}{\partial \eta_q}$. We find that the pivot of a contract can only be strictly included in the interval $[\underline{\theta}, \overline{\theta}]$ if the threshold productivity equals the private threshold κ, defined on page 8, — which is strictly lower than w. At last, recall that $\overline{v} > \overline{u}$ for any θ greater than $\underline{\theta}$ so the quota pivot is never higher than the set-aside pivot.

Figure 1 — assuming λ is not too high or $\dot{b}$ is close to zero — and proposition 2 summarize these results.

Proposition 2 *Assuming* $(H1)$ *and* $(H2)$, *the set-aside pivot* η_s *— respectively the quota pivot* η_q *— is equal to* $\overline{\theta}$ *when* $\overline{v}(\eta_s) \neq \kappa(\eta_s)$ *— respectively* $\overline{u}(\eta_q) \neq \kappa(\eta_q)$*— and is such that* $\overline{v}(\eta_s) = \kappa(\eta_s)$ *when* $\eta_s < \overline{\theta}$ *— respectively* $\overline{u}(\eta_q) = \kappa(\eta_q)$ *when* $\eta_q < \overline{\theta}$*. The quota pivot* η_q *is never higher than the set-aside pivot* η_s*.*

This implies that the set of farmers who would accept a quota contract is nested within the set of farmers who would accept a set-aside contract. So the set-aside contract leads to higher amenity production $q_1(\theta)$ and lower agricultural production $q_2(\theta)$ compared to the quota contract. The shadow cost of public funds λ and the performance index θ do not affect the hierarchy between threshold yields. Both yields decrease when the performance θ increases, and the yield related to the set-aside contract is higher than the yield related to the quota contract. The absolute value of the curves' slope represents the size of the shadow cost of public funds. In other words, the social cost of the rent implies that the Principal must limit the number of plots set-aside and thus the transfers that compensate farmers.

Rents and welfare

Note first that if one of the pivots η_s or η_q is lower than $\overline{\theta}$, the rent differential and the transfer are equal to zero for this pivot. Let us focus on the function $\Delta(\theta)$ defined as the difference between the individual rents of the contracts: $\Delta(\theta) = R_s(\theta) - R_q(\theta)$. This can be rewritten using the relations extracted from proposition 1 and we can show that under assumption $(H2)$ and because $\overline{v}(\underline{\theta}) = \overline{u}(\underline{\theta}) = w(\underline{\theta})$, the differentiated difference of the rents is positive, $\dot{\Delta}(\underline{\theta}) > 0$. When $\eta_q < \overline{\theta}$ we have $\dot{\Delta}(\eta_q) < 0$. Moreover, $\Delta(\eta_q) > 0$ $(R_q(\eta_q) = 0$ and $R_s(\eta_q) > 0)$. (See appendix). This implies that the set-aside contract offers a higher rent to contracting farms characterized by high θ compared to the quota contract.

We examine now the special case $\lambda = 0$, which implies $\eta_s = \eta_q = \overline{\theta}$, $\Delta(\overline{\theta}) = R_s(\overline{\theta}) = R_q(\overline{\theta}) = 0$ — by the definition of the pivot — and $\overline{v}(\theta) = \overline{u}(\theta) = w(\theta)$ for any θ. Moreover, $\dot{\Delta}(\theta) > 0$ for any θ. Then $\Delta(\theta)$ is increasing and we must have $\Delta(\theta) < 0$ for any θ. In other words, the set-aside contract offers the farm θ a lower rent than the quota contract, while contract choice does not affect production.

By continuity of the functions involved, figure 2 shows the two contrasted situations in the case of λ small, and in the case of λ high. Proposition 3 and its corollary together with the figure summarize the previous results.

Proposition 3 *Assuming* $(H1)$, $(H2)$, *and* $(H3)$, *the individual private rent is higher with the quota contract than with the set-aside contract when* λ *is close to* 0.

Corollary 1 *When* λ *is close to* 0, *the global rent in the quota contract is higher than the global rent in the set-aside contract.*

The differences in rents do not affect welfare; this paradox is due to the fact that transfers are not costly ($\lambda = 0$). Note that the rent curves intersect in figure 2B. Such intersection reflects the regulator's opportunity to limit the number of agents eligible to contract — following for instance Bourgeon et al. A high rent in the quota contract — higher than the rent in the set aside contract — allows the principal to decrease the farm's pivot performance, which discriminates the farmers "in" and "out of" the contract.

Let us now study the difference in welfare that both programs imply. Assume that all farms contract: in other words, $\eta_s = \eta_q = \overline{\theta}$. Starting from previous expression of welfare, we can write the difference:

$$W_s - W_q = -\lambda(R_s(\theta) - R_q(\theta)) + \int_{\Theta} \int_{\overline{u}(\theta)}^{\overline{v}(\theta)} k(x,\theta)h(x,\theta)dxf(\theta)d\theta$$

Proposition 4 implies that when the required assumptions are satisfied, the set-aside contract dominates the quota contract.

Proposition 4 *Assuming* $(H1)$ *and* $(H2)$*, the net social welfare is the same in both contracts when* $\lambda = 0$*. Assuming* $(H3)$*, the net social welfare is higher with the set-aside contracts than with the quota contracts when* λ *is positively close to* 0*.*

Our result should hold true even when input and output regulations, related to two different goods, are more complex. Our environmental good is exactly equivalent to the input of the agricultural good. Furthermore, our result holds true even if there is no collective value given to this input ($m = 0$). Theoretical results often depend strongly on technologies and the agents' and principals' roles but in our setting the costs associated with public funding ($\lambda > 0$) drive the result.

To some extent, the analysis of our agro-environmental problem indicates dominance of input monitoring when accounting for increasing shadow cost of public funds, which reflects alternative re-allocation for other public purposes. But our assumptions could lead to ambiguous hierarchy between the two contracts. Consider first the case of low — but positive — shadow cost of public funds. We can expect input monitoring to yield a higher social welfare, in the case of pure environmental regulation. But our results still favor input monitoring when a pure agricultural regulation is considered, although the agricultural policy regulates the output. Finally, in figure 2, contracts hierarchy is exactly the opposite to rents hierarchy. When the cost of public funds increases above a threshold, the hierarchy of individual rents becomes heterogeneous. Meanwhile, the number of agents eligible to the contracts becomes different. The cumulative rents imply more complex results, which strengthens the role of the shadow cost of public funds in the analysis.

Conclusions

Compared to the existing regulations, individual contracts improve efficiency. When there is asymmetric information, informational rents limit these improvements as soon as they impose an additional social cost. This is why we introduce positive costs associated with public funding. Informational rents imply that some agents can gain individual advantages from accepting the contract, whereas other can't; they also limit the social welfare gains expected from the regulation. This is the price one must pay to improve the acceptance of the regulation.

Assuming that individual contracts are preferable, the regulator can still choose among several type of individual contracts. We consider that the regulator offers only one of the two types of contracts to all agents. Contract choice can be particularly delicate when the regulation has multiple objectives. This article addresses the question of regulation of two social consequences of agricultural production, which are related to the production of marketable agricultural goods and to the production of amenities. The mechanism design related to this kind of twofold regulation is defined when the private good — a cash crop — and the public good — an amenity — compete in the use of land as a production factor. The principal can regulate these productions either through production quotas or through set-aside requirements for production of a specific good. This article focuses on information asymmetry that creates adverse selection when applying certain farm performance indices.

We find that under some assumptions about the plot distribution according to a productivity parameter, the contract's set-aside requirements should always decrease with regards to the farm performance index, while the quotas should increase. Informational rents decrease when performance indices increase; the rents are linked to each contract. The assumptions required are related to the stochastic dominance assumption and the Spence-Mirlees condition, which are both usually encountered in these kinds of adverse-selection problems. The decreasing rent implies that regulators propose the contract to the subset of farms with lowest performance if they want to decrease production of the good related positively to the performance index or if the principal seeks to increase the production of the other good related to production of environmental amenities.

In the special case, when no costs are associated with public funding, we find that both contracts induce equal net social welfare and equivalent private consequences in terms of input consumption and produced quantities. In this case, all agents are eligible to contract and they all accept the contracts. The individual thresholds discriminating land devoted to set-aside and land devoted to the cash crop are identical. Under some additional assumptions, the individual rent of the producers is higher with the quota contracts than with the set-aside contracts. In general, we also find that if the goal of the regulation is to decrease production of the cash crop regulated in the quota contract, then society benefits most from a set-aside contract. In contrast to that, individual farmers tend to prefer the quota mechanism to set aside. This is the case in a program to limit agricultural production and in the contrasted situation, when the principal aims to increase amenities' production.

In each contract, a threshold plot defines a partition between plots used for cash-crop production and plots used for amenity production. This plot is always more productive in the set-aside contract compared to the quota contract. This means that set aside leads to lower traditional agricultural production compared to quotas. A positive burden from public funding implies that the informational rent associated with set aside is larger than the corresponding rent associated with quotas. This holds true only if it is optimal to include all farms in the regulation. For relatively high excess burden, it is socially optimal to propose the contracts to the least productive farms in our model. The threshold farmer's productivity is decreasing in the excess burden and is lower in the quota contract compared to the set aside contract. So even if the informational rent is higher in the set-aside contract for the least performing farms, this may not remain true for the cumulated informational rents paid to all contracting farms.

We show that both monitoring instruments are socially equivalent in the absence of shadow cost of public funds. When the shadow cost increases, we show further that input monitoring dominates. These last results differ from what Maskin and Riley and Bontems and Bourgeon obtained using a class of models more or less close to ours, which are more favorable to the mechanism design based on the output. Their model do not apply to our problem because of our assumptions on technology and on the principal's goal but our results still indicate that accounting for the shadow cost of public funds could strongly modify the social hierarchy between the two incentive schemes in these more general models as well. Considering monitoring costs, which we discard here, would probably favor land control even more — through remote sensing or usual CAP control in the EU. A high shadow cost of public funds could change the results. One of the advantages of this paper is to show how this parameter affects both quantitative and qualitative results in the analysis.

Voluntary incentives may not always be optimal and there are situations in which mandatory regulations would yield a higher social welfare (Bourgeon et al. 1995; Segerson 1998; Segerson and Miceli 1998). But mandatory regulations are not always socially accepted. In fact farmers have used direct actions to turn down many of them in several European countries. Voluntary incentives have the advantage that the regulated farmers are at least never worse off, which should increase their acceptance of the regulation — see the Territorial exploitation contracts (CTE) or the more recent Contracts for a sustainable agriculture (CAD) in France. Voluntary incentives might well be one of the most relevant and socially acceptable way to reform the CAP in Europe, and to increase support for public regulation in any country.

References

Babcock, B. A., P. Lakshminarayan, W. JunJie, and D. Zilberman (1996, November). The economics of a public fund for environmental amenities: A study of CRP contracts. *American Journal of Agricultural Economics 78*(4), 961–971.

Bontems, P. and J.-M. Bourgeon (2000). Creating countervailing incentives through the choice of instruments. *Journal of Public Economics 76*, 181–202.

Bourgeon, J.-M., P.-A. Jayet, and P. Picard (1995). An incentive approach to land set-aside programs. *European Economic Review 39*, 1487–1509.

Crépin, A.-S. (2005). Incentives for wetland creation. *Journal of Environmental Economics and Management*. In Press.

Dasgupta, P. S., P. Hammond, and E. Maskin (1979). The implementation of social choice rules: Some results on incentive compatibility. *Review of Economic Studies 46*, 185–216.

Gren, I.-M. (2004, March). Uniform or discriminating payments for environmental production on arable land under asymmetric information. *European Review of Agricultural Economics 31*(1), 61–76.

Guesnerie, R. and J.-J. Laffont (1984). A complete solution to a class of principal-agent problems with an application to the control of self-managed firm. *Journal of Public Economics 25*(3), 329–369.

Innes, R. (2003, February). Stop and go agricultural policies with a land market. *American Journal of Agricultural Economics 85*(1), 198–215.

Jayet, P.-A. (2001). Évaluation de politiques de retrait des terres pour la régulation d'un marché agricole. *Annales d'Économie et de Statistique 61.*

Kahlil, F. and J. Lawarrée (1995). Input versus output monitoring: Who is the residual claimant? *Journal of Economic Theory 66*, 139–157.

Khanna, M. (2001). Non-mandatory approaches to environmental protection. *Journal of Economic Surveys 15*(3), 291–324.

Laffont, J.-J. and J. Tirole (1993). *A theory of incentives in procurement and regulation*. The MIT Press.

Maskin, E. and J. Riley (1985). Input versus output incentive schemes. *Journal of Public Economics 28*, 1–23.

Myerson, R. (1979). Incentive compatibility and the bargaining problem. *Econometrica 47*, 61–74.

Segerson, K. (1998, December). Voluntary vs. mandatory approaches to nonpoint pollution control:complements or substitutes. *Nota Di Lavoro 98*(92), 1–33. Fondazione Eni Enrico Mattei.

Segerson, K. and T. J. Miceli (1998). Voluntary environmental agreements: Good or bad news for environmental protection? *Journal of Environmental Economic and Management 36*, 109–130.

Smith, R. B. (1995, February). The conservation reserve program as a least-cost land retirement mechanism. *American Journal of Agricultural Economics 77*, 93–105.

Söderqvist, T. (2003). Are farmers prosocial? determinants of the willingness to participate in a Swedish catchment-based wetland creation programme. *Ecological Economics 47*, 107–120.

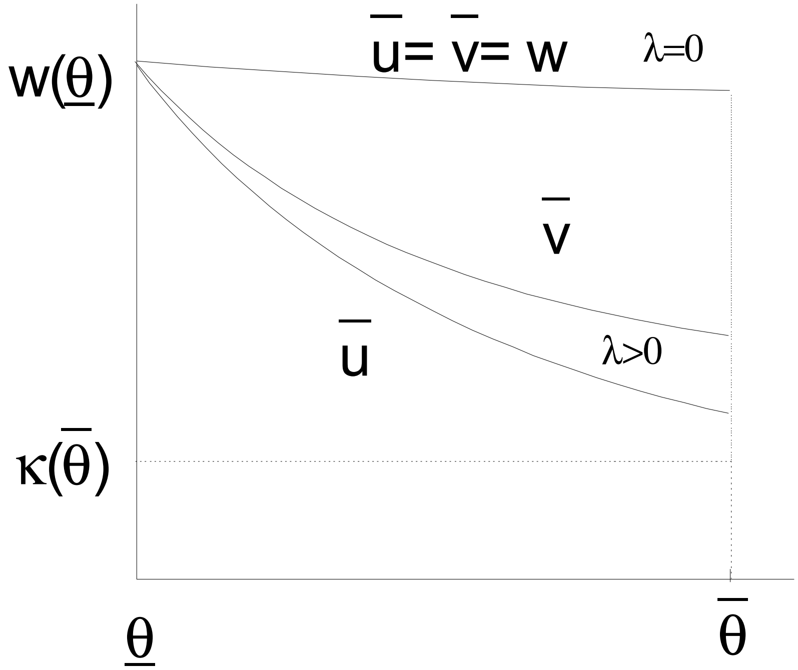
Wu, J. and B. A. Babcock (1996, November). Contract design for the purchase of environmental goods from agriculture. *American Journal of Agricultural Economics 78*, 935–945.

Table 1: Set-aside and Quota Contracts

	set-aside	quota
amenities (q_1) product (q_2) first order IC	$q_1\left(\overline{v}\left(\theta\right),\theta\right)$ $q_2\left(\overline{v}(\theta),\theta\right)$ $\dot{t} = b(\overline{v}-\kappa)\dot{s}$	$q_1\left(\overline{u}(\theta),\theta\right)$ $q_2\left(\overline{u}(\theta),\theta\right)$ $\dot{\tau} = b\left(\frac{\kappa}{\overline{u}}-1\right)\dot{\psi}$
second order IC	$(H3)$ implying $\dot{s} < 0$	$(H4)$ implying $\dot{\psi} > 0$
subset of firms eligible to contract	$[\underline{\theta}, \eta_s]$	$[\underline{\theta}, \eta_q]$

.

A



B

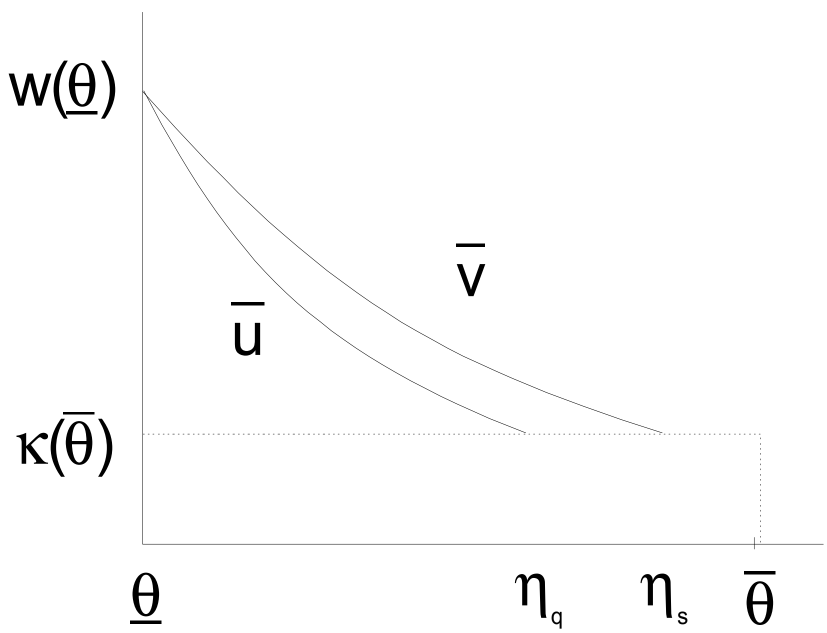


Figure 1: Threshold productivity when all farms are expected to contract for lambda low (A) and when only a subset of farms is expected to contract for lambda high (B).

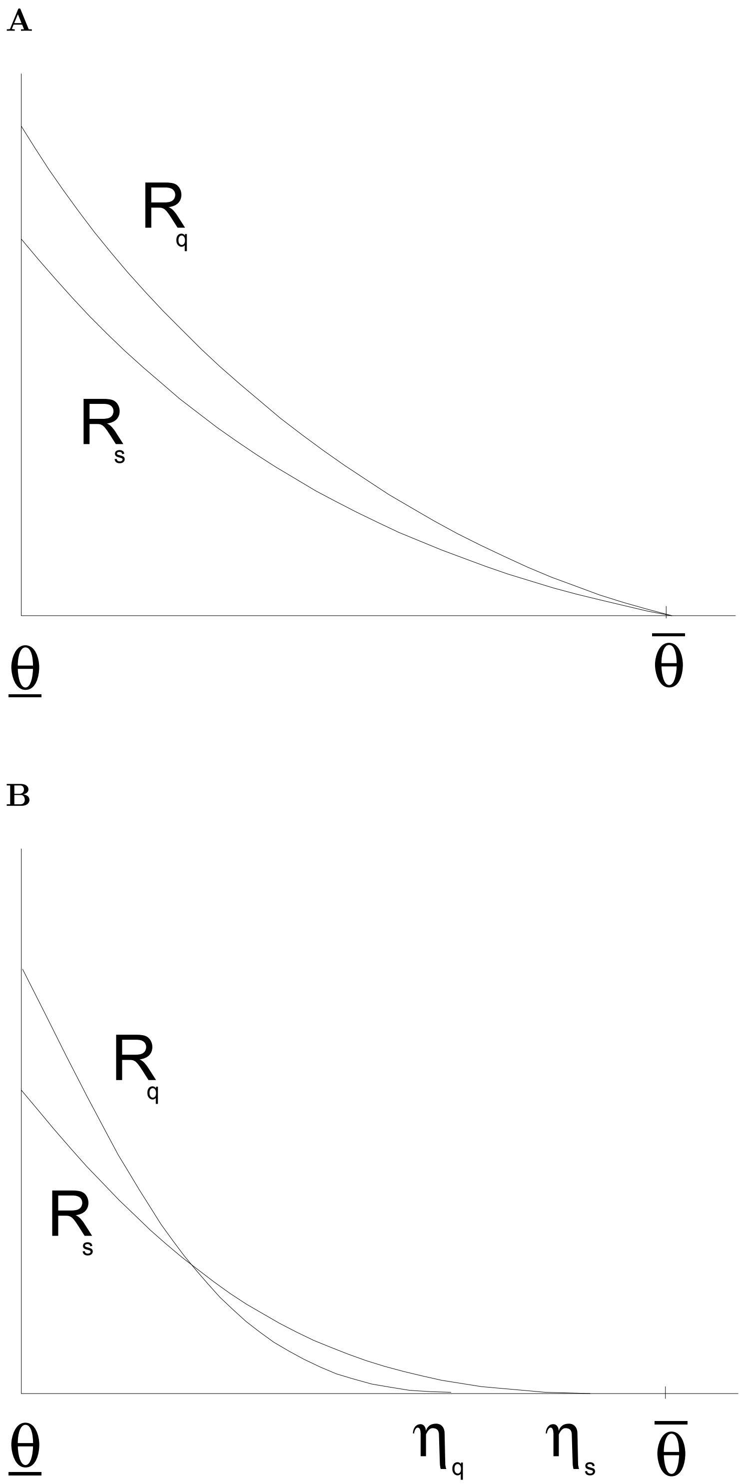


Figure 2: Rents when all farms contract for lambda low (A) and when only a subset of farms is expected to contract for lambda high (B)