# Theory of Contracts and Agri-Environment Policies: A Budget Restriction Alters Standard Results of Mechanisms Design Theory

Jan Christensen
e-mail: janch@kvl.dk

**Paper prepared for presentation at the X[th] EAAE Congress**
**'Exploring Diversity in the European Agri-Food System',**
**Zaragoza (Spain), 28-31 August 2002**

Paper presented at the Xth EAAE-congress in Zaragoza Spain, August 28-31, 2002.

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Author:

Jan Christensen

Mailing address:

Department of Economics and Natural Resources
The Royal Veterinary and Agricultural University (KVL)
Rolighedsvej 23
1958 Frederiksberg
Denmark
Phone (+45) 35 28 22 68

e-mail: janch@kvl.dk

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Keywords: Agri-environmental schemes, Mechanisms design, Information Economics.

JEL classification: Q28, D82.

## Abstract

Agri-environmental schemes are offered by a regulator to farmers. The farmer is to produce certain environmental goods and gets a pecuniary compensation for doing so. The problem of designing optimal schemes is dealt with using mechanisms design theory. This paper considers the situation where the regulator faces a budget constraint on total payments to farmers. It is shown, that 2 results of standard mechanisms design theory are affected when a budget restriction on total payments is present. 1) The "no distortion at the top rule" does not always hold. 2) It is not always optimal to offer heterogeneous farmers heterogeneous argi-environmental schemes.

## Introduction

In recent decades increasing attention has been devoted to the environmental impact from agriculture. Environmental aspects have been introduced in agricultural policies. The EU recognizes the role of farmers as conservators of the landscape and protectors of natural resources. Recognition of the relation between farming practices and environmental benefits has led to specific policies in the EU. The Environmentally Sensitive Area Agreement and the accompanying measures in the CAP both aim at regulating the farming methods. Regulation 2078/92 allows for the member states to "compensate farmers for any income losses caused by reductions in output and/or increases in costs and for the part they play in improving the environment". Payments based on foregone profits can be justified from a social point of view, since the improvement in social surplus from improved environmental quality is greater than the decrease in producer surplus. Throughout the EU, member states have implemented agri-environmental schemes (AES). Farmers are given incentives to adapt environmentally friendly farming methods by the AES. Agreement proposals are offered by the government to farmers. It specifies what environmentally friendly actions to take and the size of the pecuniary compensation the farmer gets in return for the effort. Examples of environmentally friendly actions are: Refraining from pesticides use, reducing nitrogen fertilizer application and providing public access to the farming areas. Typically, existing AES are homogeneous standards providing homogeneous incentives to heterogeneous farmers (Bonnieux et al., 1998). For instance in the case of reducing nitrogen application farmers are offered only 1 level of reduction and a corresponding payment. According to standard mechanisms design theory, with no budget restriction, it is optimal to discriminate among heterogeneous farmers (Varian, 1992). The single level AES is not optimal. Moxey et al. (1999) show that in a situation with 2 different types of farmers, different with respect to the costs of producing environmental goods, it is optimal to offer a 2 level AES. A high level intended for the low-cost farmers and a low level intended for the high-cost farmers. Denoting the socially optimal level of environmental goods production for the high cost farmers and the low cost farmers $\bar{z}_1$ and $\bar{z}_2$ respectively, an optimal incentive scheme must fulfill: $0 < \bar{z}_1 < \bar{z}_2$. This rule does not always hold, when a budget restriction is present.

Much attention has been devoted to the situation of asymmetric information. For instance Wu and Babcock (1996); Smith (1995) and Slangen (1997) model the purchase of environmental goods from agriculture in various asymmetric information settings. If the type of any particular farmer is common knowledge and the regulator is able to use this information when designing the AES, a situation of perfect information prevails. If, on the contrary, the regulator is prohibited from using this information or the type of any particular farmer is private knowledge, a situation of asymmetric information prevails. The socially optimal levels of environmental goods production for the most efficient farmers in the perfect information case and the asymmetric case are denoted $\bar{z}_2^p$ and $\bar{z}_2^a$ respectively. A result in standard mechanisms design theory is that $\bar{z}_2^p = \bar{z}_2^a$, called the "no distortion at the top" rule, see for example (Salanie, 1997). This rule does not always hold, when a budget restriction is present.

In this paper it is shown that if the regulator faces a limited budget to spend on total payments to farmers, 2 results of general mechanisms design theory no longer hold. 1) The rule that it is optimal to discriminate among heterogeneous farmers and 2) the no distortion at the top rule do not always apply.

The following section introduces the model. An objective function expressing the net social benefit from environmental goods production is presented. The optimal levels of environmental goods production in the perfect information situation and the asymmetric information situation are outlined in sections 2 and 3 respectively. In section 4 it is shown that the no distortion at the top rule does not always hold when a budget restriction is present. In section 5 it is shown that when a budget restriction is present it is not always optimal to offer heterogeneous farmers a heterogeneous AES. In the last section findings are summed up.

# 1 The model

Standard methods of mechanisms design (Salanie, 1997) are used in this section to analyze the 2 results challenged by introducing a budget restriction. A framework with 2 types of farmers is used. Farmers either belong to the high-cost group or the low-cost group. High-cost farmers are denoted $\theta_1$ and the low-cost ones $\theta_2$. Without any loss of generality it is assumed that there are 2 farmers. Each type has 1 farmer belonging to it. The production of environmental goods is expressed by a scalar $z$. Only positive values of $z$ are considered. An AES asking farmers to produce less environmental goods than at present is not feasible. The costs for a $\theta_1$ farmer of producing $z$ are linear, expressed by $c(z|\theta_1) = \alpha_1 z$. For a $\theta_2$ farmer the costs are expressed by $c(z|\theta_2) = \alpha_2 z$. Since by definition $\alpha_1 > \alpha_2$ the costs at any level of $z$ are higher for $\theta_1$ farmers and so are the marginal costs. The net environmental benefit of $z$ is quadratic and independent of which type of farmer is producing it. The environmental benefit from a $\theta_1$ farmer producing $z_1$ is expressed by $b(z_1) = \beta z_1 - \beta_0 z_1^2$. For a $\theta_2$ farmer the social benefit is $b(z_2) = \beta z_2 - \beta_0 z_2^2$. The net social benefit from farmers $\theta_1$ and $\theta_2$ producing $z_1$ and $z_2$ respectively is expressed by $\Omega$:

$$\Omega\left(z_1, z_2\right) = \left(\beta z_1 - \beta_0 z_1^2 - \alpha_1 z_1\right) + \left(\beta z_2 - \beta_0 z_2^2 - \alpha_2 z_2\right) \tag{1}$$

This net social benefit function (1) can be restated as (2):

$$\left(z_1 - \frac{\beta - \alpha_1}{2\beta_0}\right)^2 + \left(z_2 - \frac{\beta - \alpha_2}{2\beta_0}\right)^2 = \left(\frac{\beta - \alpha_1}{2\beta_0}\right)^2 + \left(\frac{\beta - \alpha_2}{2\beta_0}\right)^2 - \frac{\Omega}{\beta_0} \tag{2}$$

From (2) it follows that the social indifference curves are shaped like circles with center $\left(\frac{\beta-\alpha_1}{2\beta_0}, \frac{\beta-\alpha_2}{2\beta_0}\right)$, as illustrated in figure 1. For a given level of net social benefit $\widetilde{\Omega}^p$, (2) constitutes an indifference circle with radius $\sqrt{\left(\frac{\beta-\alpha_1}{2\beta_0}\right)^2 + \left(\frac{\beta-\alpha_2}{2\beta_0}\right)^2 - \frac{\widetilde{\Omega}^p}{\beta_0}}$. This is illustrated as the inner circle of figure 1. The rational part of the indifference circle is continuous. The irrational part is dotted. Higher levels of $\Omega$ corresponds with a shorter radius. The highest level of net social benefit $\Omega = \frac{\alpha_1^2+\alpha_2^2-2\beta(\alpha_1+\alpha_2-\beta)}{4\beta_0}$ is achieved when radius equals 0.

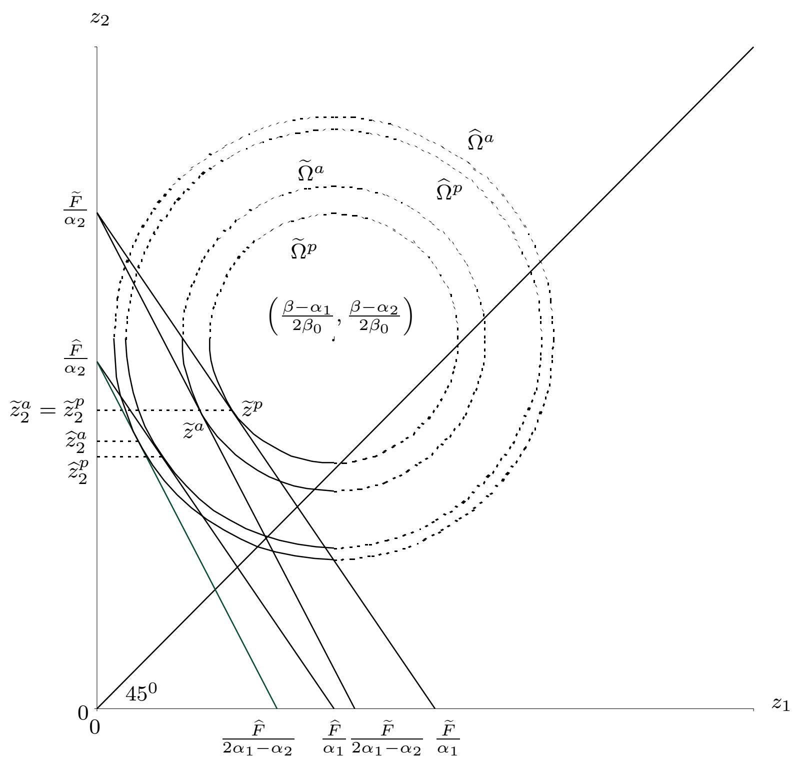


**Figure 1: There is no distortion at the top when the budget equals $\widetilde{F}$. Otherwise, for instance when the budget equals $\widehat{F}$, there is distortion at the top.**

## 2 The perfect information case

If the regulator knows each individual farmers' type and is able to use this information, a situation of perfect information prevails. Providing farmers incentives to enter an agreement proposal from the AES, they are offered compensations $\Gamma$ equal to their cost. The restriction on compensations is called the participation constraint $(PC)$. $\theta_1$ farmers are offered compensation level $\Gamma_1 = \alpha_1 z_1$. The participation constraint for $\theta_1$ farmers is denoted $(PC_1)$. $\theta_2$ farmers are offered compensation level $\Gamma_2 = \alpha_2 z_2$. The participation constraint for $\theta_2$ farmers is denoted $(PC_2)$. The regulator faces a budget $\widetilde{F}$, which is assumed to be binding. The restrictions facing the regulator are $(PC_1)$, $(PC_2)$ and the budget restriction:

$$(PC_1) : \Gamma_1 = \alpha_1 z_1, \quad (PC_2) : \Gamma_2 = \alpha_2 z_2, \quad \widetilde{F} = \Gamma_1 + \Gamma_2$$

Reducing the restrictions on payments for the perfect information case to a 1 line restriction gives a new budget line (3) containing all information about the restrictions on payments:

$$\widetilde{F} = \alpha_1 z_1 + \alpha_2 z_2 \tag{3}$$

In terms of figure 1 the restriction (3) represents a negatively sloped straight line. For a given budget $\widetilde{F}$ the budget line intersects the axes at $\widetilde{F}/\alpha_1$ and $\widetilde{F}/\alpha_2$ respectively, as illustrated in figure 1.

Maximizing net social benefit $\Omega$ with respect to restriction (3) gives optimal levels of the $z$'s, expressed by (4) and (5):

$$\widetilde{z}_1^p = \frac{\alpha_2^2\beta - \alpha_1\alpha_2\beta + 2\beta_0\widetilde{F}\alpha_1}{2\beta_0(\alpha_1^2 + \alpha_2^2)} \tag{4}$$

$$\widetilde{z}_2^p = \frac{\alpha_1^2\beta - \alpha_1\alpha_2\beta + 2\beta_0\widetilde{F}\alpha_2}{2\beta_0(\alpha_1^2 + \alpha_2^2)} \tag{5}$$

In figure 1 optimal levels of environmental goods production are illustrated, given budget level $\widetilde{F}$. The maximum social benefit (the tangency point with the smallest feasible circle) is $\widetilde{\Omega}^p$ at point $\widetilde{z}^p = (\widetilde{z}_1^p, \widetilde{z}_2^p)$.

## 3 The asymmetric information case

When the regulator does not have perfect information about the types of the farmers or has the information but is unable to use it, a situation of asymmetric information prevails. The farmers are able to pick any element from the AES. He can pick the element intended for his own type, or he can pick the one intended for the other type. To achieve the socially optimal level of environmental goods production the regulator must take this into account. The farmers are given incentives to pick the element intended for their own type. As in the perfect information case in the previous section, farmers are offered compensation that at least covers their costs $(PC_1): \ \Gamma_1 \geq \alpha_1 z_1, (PC_2): \ \Gamma_2 \geq \alpha_2 z_2$. To ensure that each farmer has incentive to choose the element intended for his own type, further restrictions are put on the compensations. Choosing the element intended for the other type of farmer should make no farmer any better off than if he chooses the element intended for his own type. These restrictions are called incentive compatibility constraints ($IC$). If a $\theta_2$ farmer picks the element intended for $\theta_1$ farmers, he is to produce $z_1$. The costs of doing so are $c(z_1|\theta_2) = \alpha_2 z_1$. If he was to receive compensation covering the costs of a low-cost farmer $\big(c(z_1|\theta_1) = \alpha_1 z_1\big)$, he would encounter a strictly positive profit $c(z_1|\theta_1) - c(z_1|\theta_2) = \alpha_1 z_1 - \alpha_2 z_1$. To give him incentives to refrain from doing so, $\theta_2$ farmers are overcompensated. The overcompensation must be sufficiently large to ensure that he has incentives to pick the element intended for his own type. The incentive compatibility constraint for the low cost farmers is $(IC_2): \ \Gamma_2 \geq \alpha_2 z_2 + \alpha_1 z_1 - \alpha_2 z_1$. The overcompensation is called the informational rent, because it is the rent that is paid to the low-cost farmers for revealing information about his type. The incentive compatibility constraint for $\theta_1$ farmers is derived in a similar fashion $(IC_1): \ \Gamma_1 \geq \alpha_1 z_1 + \alpha_2 z_2 - \alpha_1 z_2$. The participation constraints and incentive compatibility constraints are summed up in equations (6)-(9):

$$
\begin{aligned}
(PC_1) &\ : \ \Gamma_1 \geq \alpha_1 z_1, && (6)\\
(PC_2) &\ : \ \Gamma_2 \geq \alpha_2 z_2, && (7)\\
(IC_1) &\ : \ \Gamma_1 \geq \alpha_1 z_1 + \alpha_2 z_2 - \alpha_1 z_2, && (8)\\
(IC_2) &\ : \ \Gamma_2 \geq \alpha_2 z_2 + \alpha_1 z_1 - \alpha_2 z_1 && (9)
\end{aligned}
$$

Not all restrictions (6)-(9) are binding. Restrictions $PC_1$ and $IC_1$ regard $\theta_1$ farmers. Since $\alpha_2 z_2 - \alpha_1 z_2$ is strictly negative, the right hand side of $(IC_1)$ is smaller than the right hand side of $(PC_1)$. Therefore, $IC_1$ is not binding. Compensations to $\theta_1$ farmers is then determined solely by $PC_1$. Restrictions $PC_2$ and $IC_2$ have to do with $\theta_2$ farmers. Since $\alpha_1 z_1 - \alpha_2 z_1$ is strictly positive $PC_2$ is not binding. The compensation to $\theta_2$ farmers is then determined solely by $IC_2$. Restrictions $PC_1$, $IC_2$ and the budget restriction are the only binding restrictions. Binding restrictions on payments in the asymmetric information case are:

$$(PC_1): \Gamma_1 = \alpha_1 z_1, \quad (IC_2): \Gamma_2 = \alpha_2 z_2 + \alpha_1 z_1 - \alpha_2 z_1, \quad \widetilde{F} = \Gamma_1 + \Gamma_2$$

Reducing these restrictions to a 1 line restriction gives a new budget restriction containing all relevant information about the restrictions on payments (10):

$$\widetilde{F} = (2\alpha_1 - \alpha_2) z_1 + \alpha_2 z_2 \tag{10}$$

In terms of figure 1 the budget line (10) intersects the axes at $\widetilde{F}/(2\alpha_1 - \alpha_2)$ and $\widetilde{F}/\alpha_2$ respectively, for a given budget $\widetilde{F}$.

Maximum net social benefit $\Omega$ from the AES in the asymmetric information case is found by maximizing the objective function (1) with respect to restriction (10). The optimal solution to the optimization problem is expressed by (11) and (12):

$$z_1^a = \frac{-\alpha_2^3 + 2\alpha_2^2\beta + \alpha_1\alpha_2^2 - 2\alpha_2\beta_0 F - 2\alpha_1\beta\alpha_2 + 4\alpha_1\beta_0 F}{4\beta_0\left(\alpha_2^2 + 2\alpha_1^2 - 2\alpha_1\alpha_2\right)} \tag{11}$$

$$z_2^a = \frac{-6\alpha_1\beta\alpha_2 + 2\alpha_2^2\beta + 2\alpha_2\beta_0 F - 2\alpha_2\alpha_1^2 + 3\alpha_1\alpha_2^2 + 4\alpha_1^2\beta - \alpha_2^3}{4\beta_0\left(\alpha_2^2 + 2\alpha_1^2 - 2\alpha_1\alpha_2\right)} \tag{12}$$

It is illustrated in figure 1, that given budget level $\widetilde{F}$, the maximum net social benefit in the asymmetric information case is $\widetilde{\Omega}^a$ at point $\widetilde{z}^a = (\widetilde{z}_1^a, \widetilde{z}_2^a)$. It is clear from the figure that $\widetilde{\Omega}^p > \widetilde{\Omega}^a$. The net social benefit from the AES is smaller in the asymmetric case because of the informational rent to $\theta_2$ farmers.

# 4 Distortion at the top

The no distortion at the top rule states, that the low-cost farmers are to produce environmental goods in the asymmetric information case to the same extend as in the perfect information case. If the no distortion at the top rule is to be fulfilled, it must hold that the optimal level of environmental goods production in the perfect information case equals the optimal level in the asymmetric case, i.e. $z_2^p = z_2^a$. From equations expressing the optimal levels of environmental goods production for $\theta_2$ farmers, equations (5) and (12) respectively, it follows that this equality is only fulfilled when the budget equals $\widetilde{F}$:

$$\widetilde{F} \quad = \quad -\frac{2\alpha_1^3-\alpha_2\alpha_1^2-2\alpha_1^2\beta+2\alpha_1\alpha_2^2-2\alpha_1\beta\alpha_2+2\alpha_2^2\beta-\alpha_2^3}{2(3\alpha_1-\alpha_2)\beta_0} \tag{13}$$

Figure 1 illustrates, that with a given budget $\widetilde{F}$, the no distortion at the top rule holds, i.e. $\widetilde{z}_2^p = \widetilde{z}_2^a$. If the budget is different from $\widetilde{F}$, the no distortion at the top rule does no longer hold. If the budget is $\widehat{F}\left(< \widetilde{F}\right)$, it is illustrated in figure 1 that the optimal level of environmental goods production for the low-cost farmers in the case of perfect information is $\widehat{z}_2^p$. In the asymmetric case it is $\widehat{z}_2^a$. It follows from the figure that $\widehat{z}_2^p \neq \widehat{z}_2^a$. Therefore, in this case, the no distortion at the top rule does not hold. The rule does not in general apply when a budget restriction on total payments is present. In fact, the no distortion at the top rule only holds when the size of the budget equals $\widetilde{F}$.

# 5 No discrimination

In this section only the perfect information case is considered. However, the results would remain the same had the asymmetric case been considered. A standard result of mechanisms design theory is that it is optimal to offer heterogeneous AES to heterogeneous farmers. In this section it is shown, that when a budget restriction on total payments on compensations to farmers is present, the result does not always hold. Figure 2 illustrates why this is true. Figure 2 illustrates 4 indifference circles, representing net social benefit levels $\Omega^1 \dots \Omega^4$ with common center $\left(\frac{\beta-\alpha_1}{2\beta_0}, \frac{\beta-\alpha_2}{2\beta_0}\right)$. Budget constraints are also drawn, illustrating different levels funding available to spend on compensations to farmers.

Figure 2 illustrates that with a budget $F^4$, the optimal levels of environmental goods production are at point $z^4 = (z_1^4, z_2^4)$, achieving net social benefit $\Omega^4$. Considering the lower budget $F^3 (< F^4)$, the figure illustrates that the optimal levels are $z^3 = (z_1^3, z_2^3)$, achieving the lower net social benefit level $\Omega^3$. If the budget is as low as $F^1$ reaching net social benefit level $\Omega^1$ at point $z^1 = (z_1^1, z_2^1)$. It follows from the figure that if the budget is $F^1$ the optimal level of environmental goods production for $\theta^1$ farmers is $z_1^1 = 0$. In this case it is optimal to offer a single-level AES. From the equation expressing the optimal level of environmental goods production for $\theta_1$ farmers (4) it follows that $z_1^1 = 0$ if the budget equals $F^1$:

$$F^1 = \frac{\alpha_1\alpha_2\beta - \alpha_2^2\beta}{2\beta_0\alpha_1} \tag{14}$$

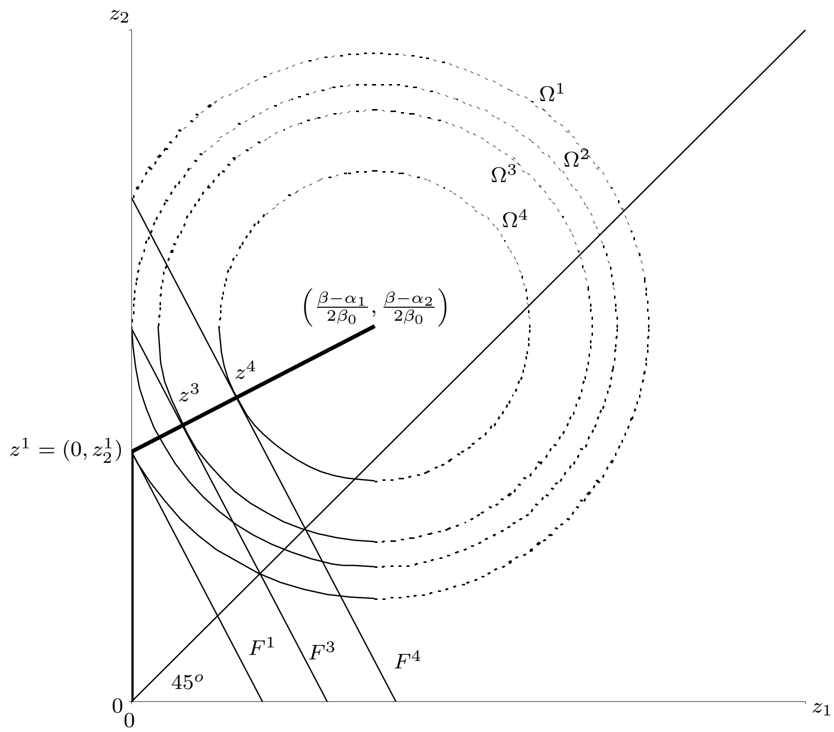


**Figure 2: If the budget is very low ($F \leq F^1$) it is optimal to offer a single level AES to heterogeneous farmers.**

If the budget is less than or equal to $F^1$ it is optimal to offer a single-level AES aiming at the low-cost farmers only. If the budget is larger than $F^1$ it is optimal to offer a 2-level AES.

# Conclusion

This paper shows, that if a regulator offering AES to farmers faces a limited budget to spend on the total payments, 2 results of general mechanisms design theory no longer hold in general. A framework with 2 types of farmers is used, as described in sections 1-5. Using the cost and benefit functions parameters $(\alpha_1, \alpha_2, \beta, \beta_0)$, the 2 results derived in this paper are:

1. The no distortion at the top rule does not always hold when a budget restriction is present. It only holds if the budget equals $\widetilde{F} = -\frac{2\alpha_1^3 - \alpha_2\alpha_1^2 - 2\alpha_1^2\beta + 2\alpha_1\alpha_2^2 - 2\alpha_1\beta\alpha_2 + 2\alpha_2^2\beta - \alpha_2^3}{2(3\alpha_1 - \alpha_2)\beta_0}$, as shown in section 4.

2. The rule that it is optimal to discriminate among heterogeneous farmers does not always hold when a budget restriction is present. For the perfect information case, it only holds when the budget is "large" $\left(F > F^1 = \frac{\alpha_1\alpha_2\beta - \alpha_2^2\beta}{2\beta_0\alpha_1}\right)$, as shown in section 5.

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