Contracts Between Small Scale Soybean Farmers and the Biodiesel Industry in Brazil: An Application of Principal-Agent Model

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Abstract

A contract is considered incomplete when the optimal solution for a contractual problem requires some information from the parts which is not observable by one or both parts. This problem is found in the biodiesel production chain among small scale farmers and biodiesel companies in Brazil, which is regulated by a certification called Social Fuel Seal under the framework of the PNPB (Brazilian Program for Production and Use of Biodiesel). In order to minimize this hindrance, an incentive structure was elaborated utilizing the nonlinear programming. The Principal-Agent approach was used to verify if these new incentives allow for the small scale soybean farmer to put great effort level in the agricultural production. When the incentive structure is evaluated through the model proposed, the result indicates that both the farmer and the biodiesel company will have their profits maximized if the producer puts on great effort. Thus, it is clear the importance to include this mechanism of stimulation to productivity increase into the PNPB framework in order to contribute to the competitiveness of the Biodiesel chain in Brazil.

Keywords: *Contracts Farms, Biofuel, Principal-Agent Model*

1 Introduction

In developing countries, the agricultural contracts emerged after World War II for two main reasons. First, agribusiness corporations were forced to give up their land rights as a result of pressure from nationalists (WATTS, 1992), and second, farmers signed agreements through contracts with the promise of agricultural credit and modernization (CLAPP, 1988).
However, contract in agriculture are generally incomplete and characterized by asymmetric information, which occurs when one party has privileged information (moral hazard). One way to minimize this problem in agricultural contracts and make the farmer (agent) act according to the objective of the employer (principal) is offering incentives.
In the Brazilian agribusiness there are examples of chain organized under contract, e.g poultry, pig, orange, sugar-cane and tobacco production chain. In the recently developed Brazilian biodiesel chain, negotiations between small scale farmers and biodiesel producers are defined by the Social Fuel Seal of the National Program for Production and Use of Biodiesel (PNPB).
The Social Fuel Seal is a certificate granted by the Ministry of Agrarian Development to biodiesel producers who have spent from 15 to 30 percent of its total expenditure on the purchase of oilseed from small scale farmers or on the supply of input or service to these farmers through legally binding agreement. The contract has to be monitored by a recognized small scale farmer organizations and it has to safeguard the rural income and provide technical training and assistance to the farmers (Silva, 2012).
By signing contracts with small scale soybean farmers, biodiesel companies establish various rules and regulations, such as quality and delivery scheme, but none relates to the provision

of incentives for the agents. This lack of incentive mechanism enables opportunistic action by the agent and brings inefficiency to the system. Due to differences in productivity among soybean producers, a good system of agricultural incentives to minimize the moral hazard problem would be paying the small farmer according to productivity, encouraging him to perform an "extra effort" in soybean production. From this system of incentives, farmers can increase productivity (effort) to receive this incentive. “Effort” indicates that the farmer will probably deliver a greater quantity of soybeans for biodiesel companies, getting the price stated in the contract plus an incentives. On the other hand, no effort means the delivery of a smaller quantity of soybean, with the farmer receiving only the price agreed in the contract.

Considering the structure of the Brazilian biodiesel production chain, the aim of this paper is to analyze the contractual relations between farmers and biodiesel companies under the National Program for Production and Use of Biodiesel. Specifically, it aims at: i) propose a system of incentives in contract farming that stimulates increased productivity of small scale soybean farms, ii) analyze the proposed new incentives for contracts between companies of biodiesel and soybean producers using the Principal-Agent approach to Moral Hazard, and iii) verify that the proposed new contracts encourage smallholders to implement high effort in soybean production under PNPB.

2 Theoretical Framework

The Principal-Agent model is used in relationships where there is asymmetric information and the relationship between the economic agents is characterized by a Principal inducing (through a contract) an agent to perform certain actions. The Principal sets in the contract a "pay-off" to encourage the agent to act in the best possible way (MAS-COLELL, 1995).

The Principal chooses a function y (.) that maximize their utility, subject to the restrictions imposed by the optimizing behavior of the agent, which are basically two: i) participation restriction (PR), and ii) Incentive Compatibility (RCI) (Sampaio, 2007).

The general formulation of the Principal-Agent problem, based on Laffont (2002), for two players, consider A = set of actions the agent, S = set of possible outcomes. The agent takes actions belonging to the set, A = {a1, a2, ..., an} that produce a result "s" of the set S = {s1, s2, ..., sm} and occur with certain probability:

$\pi_{n1}, \pi_{n2}, ..., \pi_{nm}$, such that $\sum_{m=1}^{M} \pi_{nm} = 1$.

Thus, for each action "a" belongs to the set A, there is a probability distribution in S (ΠA). If W is the amount paid for the service, it is assumed that the contract offered is a function W: S → R. That is, if "s" is observed, the principal pays W (s) to the agent, ie. the agent's remuneration is determined by the result of their actions.

For the principal, a couple of "a" and "s" results in income B (a, s) and hence the profits of the principal are given by: B (a, s) - W (s). Thus, the expected profits of the principal can be written as:

$$Expected\ profits = \sum_{m=1}^{M} \pi_{nm}(B(a_n, s_m) - W(s_m)) \quad (1)$$

To agent, it is assumed a von Neumann-Morgenstern utility function, u (W,). Since each agent has other alternatives that brings him a reserve utility, $\overline{u}$,, he accepts a contract proposed by the principal if the inequality (2) holds:

$$Max\ expected\ utility\ = \sum_{m=1}^{M} \pi_{nm} u(w(s_m), a_n) \geq \overline{u} \qquad (2)$$

That is, participation restriction (PR) is satisfied when his expected utility of the chosen action (n) is greater than or equal to the expected utility of other actions available. Furthermore, the agent is induced to take the main action that maximizes their expected profits, satisfying the incentive compatibility constraint (RCI). For the chosen action a_n:

$$\sum_{m=1}^{M} \pi_{nm} u(W(s_m) - d(a_n) \geq \sum_{m=1}^{M} \pi_{n'm} u\big(W(s_m)\big) - d(a_{n'}) \qquad (3)$$

Where in
n' = 1...N

d is the "disutility" resulting from the execution of an action.

Thus, for each W and each action a_n, has a payoff (pair of results to the principal and agent, respectively):

$$\sum_{m=1}^{M} \pi_{nm} (B(a_n, s_m) - W(s_m))\,;\ \sum_{m=1}^{M} \pi_{nm} u(W(s_m), a_n) \geq \overline{u} \qquad (4)$$

Figure 1 shows how to obtain the solution of this game using the Nash Equilibrium in perfect subset. In the last stage, an agent chooses its action in order to comply with RCI, then observe whether their utility is greater than their expected utility.

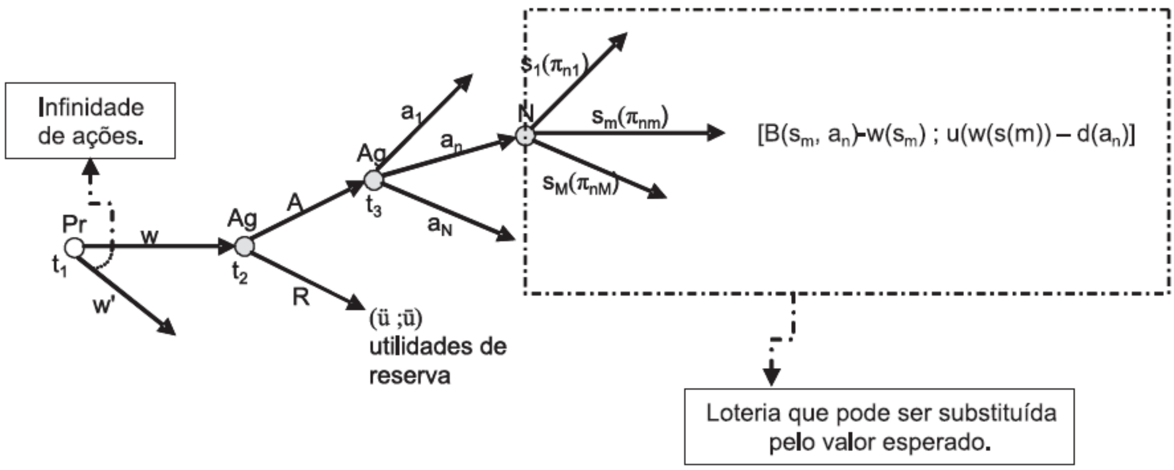

Figure 1. Principal-Agent game form
Source: SAMPAIO (2007).

The incentives to agents may be of several types, for example, higher rates of pay or bonuses, that depending on the type of activity and the established contract.
Given the incentives, agents can spend a specific level of effort, low or high, and this decision will reflect in the result of its action. Furthermore, the agent is still subject to random factors that can positively influence (lucky) or negatively (unlucky) his result.

3 Analytical Framework

3.1 Mathematical Model

Aiming to offer an incentive structure for agricultural contracts between small scale soybean farmers and the biodiesel industry under the PNPB framework, a mathematical model was developed using a nonlinear programming technique.
The objective function could be defined in several ways; maximizing the revenue of the firm, maximizing revenue of the farmer with fixed productivity or maximizing the farmer revenue with varied productivity. Following the proposal of Gibbons (1998) concerning the relationship between incentives and performance, it was chosen to maximize the farmer revenue with varied productivity. Thus, to run the model, the following input data were considered:

Farmer revenue

Total revenue (TR) per hectare of the small scale soybean farmer, considering the price of the soybean within a range of productivity (soybean per hectare).

$$RT = \sum_{k=1}^{4} (PS_k \; x \; PROD_k) \qquad (6)$$

wherein PS_k is the price of soybean at the level of productivity *k* and $PROD_k$ is the quantity of soybean per hectare, according to the level k of productivity.

Price restriction

For the price restriction it was considered the average price of soybean pays to small scale farmer under the PNPB framework as the minimum amount to be paid in each of the *k* levels of productivity per hectare. Moreover, the price paid must increase considering the increased productivity in order to make the model establishes a direct relationship between price and yield (similar to Gibbons (1998), incentive and performance).

$$PS_k = average \; price \; when \; k = 0 \qquad (7)$$
$$PS_k > average \; price \; when \; k = 1 \qquad (8)$$
$$PS_4 > PS_3 > PS_2 > PS_1 \qquad (9)$$

Productivity restriction

We considered five levels of productivity per hectare being,

$$PROD_k \leq n_0 \; kilogram \; for \; k = 0 \qquad (10)$$
$$PROD_k \leq n_1 \; kilogram \; for \; k = 1 \qquad (11)$$
$$PROD_k \leq n_2 \; kilogram \; for \; k = 2 \qquad (12)$$
$$PROD_k \leq n_3 \; kilogram \; for \; k = 3 \qquad (13)$$
$$PROD_k > n_4 \; kilogram \; for \; k = 4 \qquad (14)$$
$$n_4 > n_3 > n_2 > n_1 > n_0 \qquad (15)$$

wherein n_k is the amount (kg) of soy produced per hectare.

Total cost of production

Defined as,

$$CT = \sum_{k=1}^{4} (CS_k \ x \ PROD_k) \leq Cmin \qquad (14)$$

where, CS_k is the total cost of production per bag, $PROD_k$ the level of productivity per hectare, and $Cmin$ the minimum average cost of small producers of soybeans.

Model structure

Therefore, we define the model used to generate optimal incentive structure for agricultural contracts. Structuring it in the conventional manner, we have

Maximize

$$RT = \sum_{k=1}^{4} (PS_k \ x \ PROD_k)$$

Subject to

$$PS_0 = average\ price$$
$$PS_1 > average\ price$$
$$PS_4 > PS_3 > PS_2 > PS_1$$
$$PROD_0 \leq n_0$$
$$PROD_1 \leq n_1$$
$$PROD_2 \leq n_2$$
$$PROD_3 \leq n_3$$
$$PROD_4 > n_4$$
$$CT = \sum_{k=1}^{4} (CS_k \ x \ PROD_k) \leq Cmin$$

3.2 Modeling of agricultural contracts

In the contracts of purchase soybeans to produce biodiesel, the small scale farmer is seen as hired (agent) by the producers of biodiesel (principal) and must deliver all production to the biodiesel company. This situation can be considered a Principal-Agent problem with hidden action. This hypothesis is supported by the fact that the contracts involve the supply of inputs and technical assistance, as well as monitoring of the production process by the company.

Considering different goals within the principal-agent approach, the problem is restricted to the reward structure that the company will propose to the producer. In Biodiesel Company, the principal wants to maximize it profits depend on the efforts applied by the farmers in the production, as well depending on random factors (states of nature) as rainfall, pest control, etc. Even monitoring the production, the company does not have complete information about the farmer and their effort levels. Therefore, the results (higher productivity per hectare) depend on the effort that held the producer and the states of nature.

Considering the state of nature there are situations in which the producer is "lucky" or "unlucky" in a given season, with its respective probabilities.

Thus, we can consider that the timing of the game is the following: a biodiesel company offers farmers a contract characterized by the level of effort and conditional payments to states of nature observed. Further, each agent performs the effort level chosen by the principal, considering the contract, and delivers the raw material produced to the company. Finally, the state of nature is observed by all and payments are made.

The following table indicates the main data used in the model.

Table 1. Main Data

Average soybean production cost	R$[1] 1.200/ha
Quantity of oil extract per ton of soybean	190 kg
Quantity of meal obtained per ton of soybean	760 kg
Quantity of biodiesel produced (m3) per ton of soybean oil	1,0 m3
Average price of meal per ton	R$ 734,17
Industrial cost to extract the oil per ton of soybean	R$ 63,30
Average price of biodiesel	R$ 2,43/l

[1] R$ 1,00 around U$S 2,09
Source: Projeto BiodieselUFV

4 Results and Discussion

4.1 Optimized incentive

The non-linear programming was used to propose an optimal incentive structure that maximizes the revenue of the family farmer soybean producer. Table 2 shows the results of the model.

Table 2. Optimal incentive structure for the soybean contract

Incentive	Productivity
R$ 0,000/bag	below de 1600 kg/ha
R$ 0,598/bag	from 1600 to 2280 kg/ha
R$ 0,603/bag	from 2281 to 2340 kg/ha
R$ 0,605/bag	from 2341 to 2400 kg/ha
R$ 0,608/bag	More than 2401 kg/ha

Source: Results.

The new incentive structure has increasing values, according to the performance of the small scale farmer. It is noteworthy that the purpose of this incentive is not to punish the producer less productive, but encourage him to seek technical assistance and follow the guidelines in order to achieve higher levels of productivity. Note that, as the difference in the amount paid by each stimulus level is small, the difference between the levels of productivity also shows modest, so that with small interventions in the form of production without major structural modifications costs, small farmers can now achieve a higher level and receive a greater benefit by bags produced.

4.2 Contract modelling

The problem for the contractual scheme is restricted to the new system of incentives that the company will propose to the small scale farmers, since both have different objectives within the principal-agent system. The company in this case has interested that the yield obtained in each hectare planted by farmers is as high as possible, in order to maximize their profits, since a greater amount of vegetable oil can be processed into biodiesel and sold to ANP (Brazilian Agency for Petroleum, Natural Gas and Biofuels) in the “biodiesel social seal” auctions, plus ensure the use of social label that gives also tax benefits.

However, for this to be possible, it is necessary that the farmer (agent) performs efforts in the production process and get "lucky", ie, depends on both the commitment applied by farmers as the random factors (states of nature).

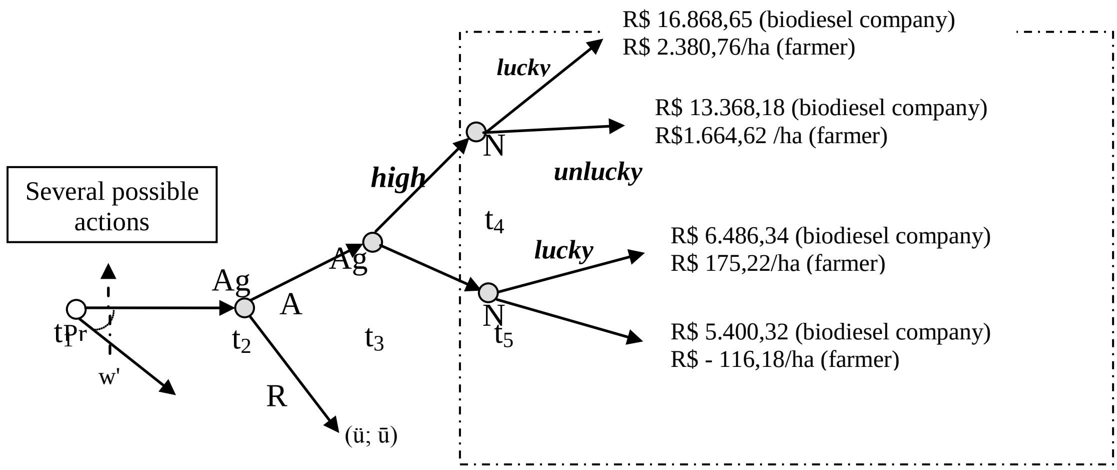

Figure 2. Principal-Agent game with incentive
Source: Results.

The solution to the game can be found using the reverse induction. Substituting the last lottery of Figure 2, corresponding to the possible states of nature, by their expected values, passes to the node t3, the agent will decide between two possible actions to be performed: high or low effort. At this point, the agent compares the expected utilities for the two cases, analyzing the difference in gain of the two alternatives, and thus decides what level of effort

w

low

unlucky

will employ, which maximize its utility. The small scale farmer actually will compare the

ū = small scale farmes reserve utility is R$ 520,00/ha

utility of two possible actions, given its expected revenue according to the states of nature, and their efforts, ie, it compares the utility of applying high effort, $u(p(s) * 2.380,76 + p(a) * 1.664,62, a_1)$,with the utility to implement low effort, $u(p(s) * 175,22 + p(a) - 116,18, a_2)$.

The expected profits, in turn, depends directly on the probability for each state of nature. In this case, in the worst case, ie, when a farmer family has bad luck (unlucky) with a 100% chance (p (a) = 1), the difference between high and low effort applied is R$ 1,780.80 / ha (R$

1,664.62 – (R$ -116.18), which represents a very significant for small scale soybean farmers. So the choice for the implementation of high effort becomes justifiable because the farmer receives a "prize" of R$ 1,780.80 / ha for the effort.

After deciding for high effort, the agent passes to node t2, in which he will decide whether to accept or reject the contract offered by the company. He will accept it only if the expected utility of the chosen action is greater than or equal to the expected utility of other possible options, i.e., the level of utility allows the farmer's family, respecting the Participation Restriction. Small scale soybean farmers receive an average of R $ 520.00 / ha when selling to middlemen, who do not offer any bonuses or incentives. With this income (see t2) following the theoretical model, the agent will accept the proposed contract, since, at worst, the amount that will be received with the contract, to state the nature of chance, is $ 1,664.62 / ha, which is higher than the value of the utility reserves, according to the values stated in this paper.

In t1, the principal chooses how much to pay for the family farmer, given the choices of the agent in t2 and t3, such that the payoff (expected profit) of principal is maximized. The question is whether the contract with incentives, he offered, is appropriate for each type of family farmers. For both, there are differences in company's earnings for each state of nature. If the status is "lucky", the company has a profit exceeding R$ 10,382.31 (R$ 16,868.65 - R$ 6,486.34) if the family farmers apply high effort. If the state of nature is "unlucky", the company wins R$ 7, 967.86 more if the farmer opts for high effort. These values correspond to how the company could pay more for the effort of the family farmer.

The new incentive structure proposed by the principal encourages the agent to implement high effort. Its decision to accept or reject the company's contract depended solely on the expected profits, levels of effort, its reserve utility and the state of nature. It is an advantage for the small scale farmer to enter into contract with the biodiesel company.

5 Conclusion

The National Program for Production and Use of Biodiesel (PNPB) is a biofuel program from the Brazilian government which has a social objective, ie, the inclusion of small scale farmers.

Considering the usually contracts scheme for trading soybeans, it is noticed the absence of an incentive structure that encourages small scale farmers to achieve high effort. In order to minimize this obstacle, an incentive was proposed using the logic of non-linear programming in order to maximize the soybean farmers revenue.

Using the principal agent model approach, the payoffs of the game indicate that both the farmer and the biodiesel company will maximized their profits with the action of high effort implemented by the farmer. A second game, considering no incentive, was run and showed that, although the contract without incentives and subsidies stimulate higher effort, the acceptance of contact proposed by the company is subject to the state of nature, which would make the negotiation unstable in the long run. Therefore, a contract with incentives is an important tool to induce farmers to produce with effort. But even knowing that this is the best way to be followed by the farmer, it can in fact be affected by some reasons that deserve attention.

First, the gain that can be achieved when the farmer put high level of effort and has a 100% of “not lucky” is the limit that the farmer would be willing to participate in the contract.

Another point to be noted is the small scale farmers low level of formal education, which can compromise the use of the full technical instructions. It is especially important when

considering other oleaginous production chain in Brazil (e.g Castor seed). This may imply that even if the farmer effort, he is not able to apply the recommended production techniques and get low-productivity.
Furthermore, considering the importance of incentives for effective insertion of the small scale farmers in the biodiesel cahin, it is clear that the public agency responsible for the contract management of agricultural PNPB need to insert this mechanism in the PNPB social seal framework.

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