Regulating agriculture under asymmetric information: an empirical evaluation of the efficiency of subsidies to new farmers

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Abstract

This paper uses contract theory to empirically evaluate an example of a contractual arrangement between government and farmers, namely, the case of subsidies granted to young farmers who set-up in agriculture in France. Using a simple model of regulation where the regulator minimises policy costs for some given objective, we use data from the French Farm Business Survey to estimate the distribution of the private information parameter and determine a preliminary estimate of the cost of the 'optimal' policy under alternative assumptions.

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Introduction

The use of contractual policies in agriculture has become increasingly important in the European Union in recent years. Within the Common Agricultural Policy there has been a significant shift from market support to contractual payments to farmers, e.g. payments for farmers who agree to set-aside land aside from production. Also, in agri-environmental policy, voluntary agreements with farmers who farm in an 'environmentally sensitive' way in return for subsidies have become common. Finally, such policies have also been long used as instrument to aid agricultural restructuring. For example, in a number of member states subsidies - conditional on the individual agreeing to certain conditions - are available to retiring farmers and/or to young farmers setting up in agriculture.

Heterogeneity among farmers in terms of preferences, productivities etc means that asymmetric information is clearly endemic within all such contractual arrangements and should be – in theory – allowed for in the design of the contract between the state and the individual farmer. While the applicability of the theory of contracts to such arrangements in agriculture has been recognised in a number of theoretical papers (Bourgeon, Jayet and Picard, 1995; Wu and Babcock 1996, Richard and Trometter, 1996), few studies consider the empirical usefulness of contract theory in practice (Smith 1995). Indeed, Salanié (1998) argues this reflects a more general imbalance between the vast theoretical literature on regulation and contract design (for surveys see Caillaud, Guesnerie, Rey and Tirole 1988; Laffont, 1994), contrasting with the limited empirical applications of the theory (see for example Thomas, 1994, 1995; Dalen, and Gomez-Lobo; 1997).

The aim of this paper is to use contract theory to empirically evaluate an example of one such contractual arrangement between government and farmers, namely, the case of subsidies granted to young farmers who set-up in agriculture in France. Using a simple model of regulation where the regulator minimises policy costs for some given objective, we use data from the French Farm Business Survey to estimate the distribution of the private information parameter and determine an initial estimate of the cost of the 'optimal' policy. The paper adds to the existing literature in a number of ways. As empirical applications of structural contracting models are limited, it provides further evidence on the relevance of the theory in

practice. Further, the available data and the specifics of the policy examined means that we can avoid the selection problems which are endemic in the estimation of such models (Thomas, 1994, 1995). Finally, it also provides specific information on the effectiveness of subsidizing young farmers to set-up in agriculture in ensuring agricultural continuity.

The structure of the paper is as follows. In the next section, we discuss the background and the current implementation to the policy of granting subsidies to young farmers in France. In section 3 we introduce and briefly analyse a model (related to the generic Laffont and Tirole (1994) model of regulation) to determine what the idealised contract between the state and farmers might be. In Section 4, the available data from the French Farm Business survey is briefly described and the estimation approach is discussed. The estimation results are used for a simulation of the optimal policy costs. Section 5 concludes with a discussion of future extensions to this work.

Farm set-up policy in France

Background

Most typically, exits from farming take place when a farmer retires but the farm is not transferred to the next generation. In recent years the rate of replacement of farms in France has fallen to 35%, so that approximately for every three farmers who retire only one holding is carried on by a new generation of farmers (Allaire, 1998; Agreste, 1996). Since the early sixties, this accelerating decline in the number of farms in France has been viewed with disquiet by successive governments. As a result French policy has attempted to increase the rate at which new farmers enter agriculture through various subsidy schemes. Formally this policy falls under European regulations defined in 1985 which set the framework under which national policies must operate (defining age of subsidised farmers, minimum farm labour requirement, education, etc). At the European level the development of this type of policy can be viewed as part of the move towards supporting farmers on the basis of their management of the countryside. However, in France this policy has been viewed as an important plank of agricultural policy for many decades and arose more out of particular historical concerns about rural depopulation and the maintenance of economic activity in rural areas. As a consequence relative to other member states policy in France is particularly well developed and – arguably – the subsidies on offer are the most generous in the European Union.

Current Policy

The principal stated objective of the policy is to encourage the greatest possible number of young potential farmers to take over a 'viable' farm (Ministère de l'Agriculture de la Pêche et de l'Alimentation, 1999). More concretely, the specific objective of the current set of regulations passed in 1995 (La Charte pour l'installation) was to achieve one farm set up or farm installation for every farm exit by the year 2000. Operationally, this was to be achieved by a series of aids to young farmers including direct payments, interest rate subsidies, tax breaks etc. The single most important element in these measures is the direct payment made to young farmers known as the 'dotation d'installation aux jeunes agriculteurs' or DJA. Although, the total subsidy received by young farmers may be much greater than the DJA payments, this measure is central to the policy as it sets out the conditions under which young farmers are entitled to receive all types of set-up/installation aids. Hence, these conditions form the basis of the contract between the French State and the potential new farmers setting up in agriculture.

In brief, the principal requirements to receive installation aids are that: new farmers must be normally aged between 18 and 35; hold at least an agricultural diploma or equivalent; commit themselves to obtain at least 50% of their earnings from agriculture for at least 10 years; and ensure that after three years in agriculture their agricultural earnings are above some minimum level and below some maximum. Although farmers setting up on farms that generate income above the earnings threshold can benefit from some subsidies, the policy is principally aimed at successors to smaller farms that are viewed as potentially economically 'viable'. This viability condition is seen as crucial and the DJA payments are made in two stages to ensure that recipients meet the income requirement.

The actual DJA payments vary by region, form of business (e.g. partnership, single proprietorship) and time committed to agricultural activities. Table 1 shows the average DJA payments by region. As noted above other types of subsidies are also available. Table 1 also gives an indication of subsidy element of the most important of these, i.e. aids given in the form of the subsidized loans available to farmers satisfying the DJA conditions. Although the overall size of the total amounts vary, calculations from the late 1980's suggest that these payments form a significant part of the financing required by young farmers to take-over existing farm businesses (Cavailhes, 1990).

Table 1: Average subsidies by region

Francs (1998 values per farmer)	Zone 1 (mountainous zone)	Zone 2 (Less favoured zone not mountainous)	Zone 3 (remainder of country)
Average DJA	171 700	106 800	82 700
Equivalent subsidy for subsidized loan of 500 000 Francs for 9 years	138 407	138 407	104 525
Total	310 107	245 207	187 225

Source : Sénat, 1997

Despite the subsidies available, the policy has not reversed the falling trend in the number of set-ups in farm agriculture. Indeed, increasing proportions of new farm-sets ups are now occurring without subsidy. Thus the efficiency of the policy is in question.

Modelling the farm set-up contract

Basic assumptions

We consider a simplified version of the actual scheme where all the different types of subsidy payments are collapsed into an equivalent direct payment. Hence, any behavioral effects of other subsidy elements, e.g. interest rate and tax relief, are ignored. While these assumptions are strong they permit the use of models from the existing literature on the theory of regulation and contracts. In particular, the model presented below is closely related to the standard models of regulation when costs are not observed (Laffont 1994; Laffont and Tirole, 1993; Baron and Myerson, 1982).

Asymmetric information arises because of assumed productivity differences among potential new farmers which are known to the individuals, while the government (regulator) knows only their distribution in the population. The productivity differences assumed might arise from differences in managerial capacity but the main source is assumed to be heterogeneity in land productivity. We assume the productivity of potential new farmers can be characterized by a cost function $c(\beta, q)$ where β is the productivity parameter and q is output level. The parameter β is distributed in the population with cumulative density function $G(\beta)$ over the interval $\left[\underline{\beta}, \overline{\beta}\right]$. The cost function is assumed increasing in β so that $\underline{\beta}$ and $\overline{\beta}$ represent the most and least efficient types respectively.

From this potential population of new farmers only a given proportion will actually set-up in agriculture. In terms of the interval $\left[\underline{\beta}, \overline{\beta}\right]$ this proportion defines a 'cut-off' value $\tilde{\beta}$ as follows

$$n = Pr(\beta < \tilde{\beta})r = G(\tilde{\beta})r \qquad [1]$$

where r the number of potential new farmers and n the number of set-ups.

The definition of social welfare arising from farm set-ups presents a fundamental difficulty. Implicitly, the existence of the set-up policy means that the government believes that the 'market' rate of farm set-up (or equivalent market $\tilde{\beta}$) is too low and that there are social welfare gains to increasing the set-up rate. Hence, in principal, by calculating the benefit associated with a greater number of farm set-ups the government should be able to determine the social optimal value of $\tilde{\beta}$. However, in practice the exact nature of the externality associated with new farmer set-ups is unclear. While it may arise from farmer's contribution to rural economic and social sustainability and/or from farmers' role as 'stewards' of the countryside, such effects are difficult to define adequately. Moreover, any such welfare effects would have to take into account the impact of existing farmers plus any effects the policy might on the structure of agricultural production.

Given these difficulties, we do not attempt to determine the correct form of this externality. Rather we concentrate on whether – for given objectives in terms of number of set-ups - the policy is efficient. This is easy to justify given that the policy exists and uses significant resources. For the modelling this means that we consider the 'cut-off' value $\tilde{\beta}$ as given. By varying this value we can therefore consider the potential effects of changing the government's objectives.

Model

First define profits of potential farmers from agriculture as

$$\pi = pq - c(\beta, q) + t \qquad [2]$$

where p is the output price and t is the level of the transfer received as part of the farm sets up scheme. When transfers are zero the agricultural profit values will be less than the non-agricultural reservation values for a greater proportion of farms than is desirable (from the government's perspective) and hence the rate of farm set-up will be too low. Therefore we

assume the government/regulator wishes to efficiently give transfers to farmers so as to achieve a higher rate of farm set-up.

Given the informational asymmetry and the rate of set-up objective (value of $\tilde{\beta}$) the regulator must choose a menu of contracts (a mechanism), in terms of transfer and output to be produced, i.e. $(t(\beta), q(\beta))_{\beta \in [\underline{\beta}, \tilde{\beta}]}$ so as to minimize

$$\int_{\underline{\beta}}^{\tilde{\beta}} t(\beta) g(\beta) d\beta \qquad [3]$$

while ensuring that transfers are such that all potential farmers of type β in the interval $[\underline{\beta}, \tilde{\beta}]$ set-up in agriculture. As type β producers may misrepresent themselves, they announce their type $\hat{\beta}$ so as to maximize their profits, i.e.

$$\max_{\hat{\beta}} \pi(\beta, \hat{\beta}) = \max_{\hat{\beta}} pq(\hat{\beta}) - c(\beta, q(\hat{\beta})) + t(\hat{\beta}) \qquad [4]$$

where we assume that the cost function $c(\beta, q)$ increases in output and in the efficiency parameter and that costs increase in all 'directions', i.e.

$$\frac{\partial c}{\partial \beta} > 0, \frac{\partial c}{\partial q} > 0 \quad \frac{\partial^2 c}{\partial \beta^2} > 0 \frac{\partial^2 c}{\partial q^2} > 0, \frac{\partial^2 c}{\partial q \partial \beta} > 0 \qquad [5]$$

(These inequalities correspond to the Spence-Mirrlees Conditions)

Type β producers will announce their true type, i.e. truth-telling, if

$$\pi(\beta, \beta) = \max_{\hat{\beta}} \pi(\beta, \hat{\beta}) \qquad [6]$$

Let $\underline{\pi}(\beta) = \pi(\beta, \beta)$ then necessary and sufficient conditions can be shown to be

$$\frac{\partial \underline{\pi}}{\partial \beta} = -\frac{\partial c}{\partial \beta} \qquad [7]$$

and $\dfrac{\partial q(\beta)}{\partial \beta} \leq 0$ \qquad [8]

(see appendix)

That is, [7] and [8] are the incentive compatibility (IC) constraints.

We assume that non-agricultural reservation values are independent of the parameter β to derive the individual rationality (IR) constraints. That is, the values obtained if the potential farmer does not set up in agriculture. Hence, for those types (including the cut–off type) who would not set-up in agriculture without transfers the reservation profits are assumed to be a constant π_o. We ensure conditions on agricultural technology so that for those farmers who would have set up without the policy reservation profit increases 'slowly' with β (see Laffont and Tirole (1994) for a discussion). Hence, for incentive compatibility only the constraint for the 'cut-off' type need to be considered, i.e. $\underline{\pi}(\tilde{\beta}) \geq \pi_o$.

From the equation [2], the transfer received by type β is given by

$$t = \pi - pq + c(\beta, q) \qquad\qquad [9]$$

Substituting for t in [3] gives the regulator's objective in terms of profit and output levels. In summary then the regulator's optimization problem can be written as

$$\max_{q,\pi} \int_{\underline{\beta}}^{\tilde{\beta}} [pq - c(\beta, q) - \pi] g(\beta) d\beta \qquad\qquad [10]$$

subject to different constraints

$$\underline{\pi}(\tilde{\beta}) \geq \pi_o \qquad\qquad \text{(a)}$$

$$\frac{\partial q(\beta)}{\partial \beta} \leq 0 \qquad\qquad \text{(b)}$$

$$\frac{\partial \underline{\pi}}{\partial \beta} = -\frac{\partial c}{\partial \beta} \qquad\qquad \text{(c)}$$

Given that the objective function [10] is decreasing in profit levels, it follows that the first constraint (a) will always be satisfied as an equality at the optimum solution.

We do not consider the second constraint (b) for the moment since we will prove that this constraint is satisfied at the optimal solution (under auxiliary assumptions).

The third constraint (c) can be incorporated in the objective function as follows. By definition,

$$\underline{\pi}(\beta) = -\int_{\beta}^{\tilde{\beta}} \frac{d\underline{\pi}(x)}{dx} dx + \underline{\pi}(\tilde{\beta}) \qquad\qquad [11]$$

8

For the constraint (a) satisfied as an equality and truth telling then the equation [11] can be rewritten as

$$\underline{\pi}(\beta) = \int_{\beta}^{\tilde{\beta}} \frac{\partial c(x,q)}{\partial x} dx + \pi_o \qquad [12]$$

Substituting [12] for profit in the objective function (expression [10]), the regulator's problem can now be formally stated as

$$\max_{q} \int_{\underline{\beta}}^{\tilde{\beta}} \left[pq - c(\beta,q) - \left(\int_{\beta}^{\tilde{\beta}} \frac{\partial c(x,q)}{\partial x} dx + \pi_o \right) \right] g(\beta) d\beta \qquad [13]$$

Integrating by parts (see appendix) [13] becomes

$$\max_{q} \int_{\underline{\beta}}^{\tilde{\beta}} \left[pq - c(\beta,q) + \frac{\partial c(\beta,q)}{\partial \beta} \frac{G(\beta)}{g(\beta)} + \pi_o \right] g(\beta) d\beta \qquad [14]$$

Maximizing with respect to q the latest expression gives the quantities in the optimal contract, i.e.

$$p = \frac{\partial c(\beta,q(\beta))}{\partial q} - \frac{\partial^2 c(\beta,q(\beta))}{\partial \beta \partial q} \frac{G(\beta)}{g(\beta)} \qquad [15]$$

Equation [15] has a standard interpretation.

For any β such as $\underline{\beta} \le \beta \le \tilde{\beta}$, except for the most efficient type ($\beta = \underline{\beta}$) the solution is distorted away from the perfect information solution (i.e marginal cost equals price). Indeed, in the asymmetric case quantities are above their perfect information counterparts.

We can prove that the constraint (b) is always satisfied at the solution of the equation [15] given the cost function properties (conditions [5]) and if it is also assumed that

$$\frac{\partial^3 c}{\partial q \partial \beta^2} \le 0, \frac{\partial^3 c}{\partial q^2 \partial \beta} \le 0, \frac{\partial}{\partial \beta} \left[\frac{G(\beta)}{g(\beta)} \right] < 0 \qquad [16]$$

(The latter assumption is the standard one on the hazard function).

Using [12] with the definition of transfers from [2], optimal transfers may be defined as

$$t(\beta) = \pi_o - \left(pq(\beta) - c(\tilde{\beta}, q(\tilde{\beta})) \right) \tag{17}$$

This again has a standard interpretation, namely, transfers increase with β and equal π_o for the cut-off type $\tilde{\beta}$.

Empirical analysis

The aim of the empirical analysis is to calculate optimal transfers according to different regulator's objectives. The data is taken from the French farm business surveys for the years 1995-1996. From the dataset we construct a balanced panel of 853 farms where the farm operator is older than 55 in 1995. By drawing a sample of farms where the farm operator is above 55 we have sample of farms where over the next few years the farm businesses will either be taken over by a new farmer or will represent a farm exit. Hence we calculate the levels of transfer payments for different values of rates of replacement.

Empirical implementation and parameterisation

We simulate the optimal policy under a set of simple assumptions reported below. Assume Cobb-Douglas technology $q(l,k) = (1/\beta) l^a k^b$ where l represents all other inputs, k the capital a and b the parameters to be estimated. The short run cost function $c(\beta, q, k)$ is given by (Varian 1992, p.66)

$$c(\beta, q, k) = w_1 \beta^{1/a} q^{1/a} k^{-b/a}$$

where w_1 is the price of all other inputs relative to the price of capital.

We assume that β follows a simple uniform distribution over the interval $[\underline{\beta}, \overline{\beta}]$. Furthermore, without loss of generality we normalise so that $\underline{\beta} = 1$, implying a hazard rate $\frac{G(\beta)}{g(\beta)} = \beta - 1$.

From (15), the optimal second best level of production can be calculated

$$q^* = (\beta^{(1-a/a)} w_1 / a k^{b/a} p)^{a/a-1} \tag{18}$$

The values of the optimal transfer for each farm can then be calculated using equation [17] for a given cut-off type $\tilde{\beta}$ and associated reservation profit level π_o.

Estimation of distribution of β

We assume that differences in the β's arise primarily from differences in land productivity, the distribution of β in our sample is not truncated and therefore can be estimated relatively simply.

The basic β value for each is captured as a fixed effect within a simple Cobb-Douglas production function. That is, we estimate the following fixed effect model in first differences

$$\log(q_{it}) = \log(1/\beta_i) + a\log(l_{it}) + b\log(k_{it}) \qquad [19]$$

(see appendix for results). Then the fixed effects values from this regression are estimated. If the distribution of values of β arose only from differences in land productivities then these values could be applied immediately. However, as it is recognised these are not the only source of productivity differences across farms, we make an ad-hoc adjustment to allow factors such as education and experience to play a role. This is done by regressing the estimated values of β against age, general education level and region. Then a set of predicted values can be constructed for the sample farms, under the assumption that all farms may be taken over by potential new farmers who satisfy the required criteria for DJA payments in terms of age and education level.

Simulation

Firstly, the parameter estimates from the Cobb-Douglas production function estimation are used to construct a short-run cost function of the following form.

$$c(\beta, q, k, w_1) = w_1\beta^{1/a}q^{1/a}k^{-b/a} \qquad [20]$$

As costs increase with β then this is consistent with the above theoretical discussion.

Table 2 reports the results from this initial simulation for three values of $\tilde{\beta}$, consistent with the regulator's objective being a rate of replacement of 50, 75 and 100% respectively. For example, if the regulator sets the target rate of replacement to be 50%, the average payment per farmer would be 617 thousand francs and the total cost of transfers would be 262 million francs. Although the assumptions used to generate these values and their preliminary nature

mean that these results should be treated with caution, they nevertheless provide some measure of the trade-off between the rate of replacement objective and the costs of the policy. For example, somewhat surprisingly the total cost of the policy increases by only 33% as the regulator's rate of replacement objective increases from 50 to 100 percent. Further, although such comparisons are more problematic, it is notable that the average payments in Table 2 are well above the estimates of subsidies received in practice reported in Table 1.

Table 2: Optimal transfers

$\dfrac{\tilde{\beta}-\underline{\beta}}{\bar{\beta}-\underline{\beta}}$	50%	75%	100%
Average transfer (000 Francs)	617	468	409
Total of transfers (Million Francs)	262	298	349

Summary and Conclusions

This paper has used contract theory to empirically evaluate an example of a contractual arrangement between government and farmers, namely, the case of subsidies granted to young farmers who set-up in agriculture in France. Using a simple model of regulation where the regulator minimises policy costs for some given objective, we used data from the French Farm Business Survey to estimate the distribution of the private information parameter and determine an initial estimate of cost of the 'optimal' policy under various values of the target rate of replacement.

Although the preliminary nature of these results means they should be treated with caution, they provide some measure of the trade-off between the rate of replacement objective and the costs of the policy. For example, it is shown that the total cost of the policy increases by only 33% as the regulator's rate of replacement objective increases from 50 to 100 percent.

The sensitivity of such results to the assumptions is one area where further work is required. For example, in the initial simulation the distributional assumption used to generate the hazard rate are strong and not data based. Ideally, the hazard rate should modelled using

one of the available non-parametric approaches. Further, the optimal policy generated should be compared with the current policy. The available data would allow this to be undertaken in two ways. Firstly, a representation of the current policy could be applied to the sample of farms used currently but secondly, a sample of young farmer who currently receive DJA payments could be constructed and actual payments compared with possible payments under the optimal policy.

Finally, in terms of the theoretical model applied a number of extensions might be considered. For example, the young farmer –government contract, could be developed to take account of the subsidies that affect farmer behaviour, e.g. interest rate and tax relief. Also, the contract has been modeled as if it takes place in a single period whereas in reality it has a number of multi-period elements that should allow (ultimately) for non-commitment by farmers. Despite these limitations, the initial results show that the theory can be applied empirically and will be useful in giving indications as to the potential trade-off in contracts between desired outcomes and cost.

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Appendix Derivation of the equations

Derivation of equation [7]

Consider type β's profit maximisation problem

$$\max_{\hat{\beta}} \pi(\beta, \hat{\beta}) = \max_{\hat{\beta}} pq(\hat{\beta}) - c(\beta, q(\hat{\beta})) + t(\hat{\beta})$$

For truth telling the optimal solution must be $\hat{\beta} = \beta$. Hence,

$$\underline{\pi}(\beta) = \pi(\beta, \beta) = pq(\beta) - c(\beta, q(\beta)) + t(\beta)$$

Equation [7] follows by applying the envelope theorem to this expression, i.e.

$$\frac{\partial \underline{\pi}}{\partial \beta} = -\frac{\partial c}{\partial \beta}$$

Derivation of equation [8]

The optimal solution to previous problem must satisfy the following first and second order conditions.

$$\frac{\partial \pi(\beta, \hat{\beta})}{\partial \hat{\beta}} = p \frac{\partial q(\hat{\beta})}{\partial \hat{\beta}} - \frac{\partial c(\beta, q(\hat{\beta}))}{\partial q} \frac{\partial q(\hat{\beta})}{\partial \hat{\beta}} + \frac{\partial t(\hat{\beta})}{\partial \hat{\beta}} = 0 \qquad [\text{A.1}]$$

$$\frac{\partial \pi^2(\beta, \hat{\beta})}{\partial \hat{\beta}^2} = \left[p - \frac{\partial c(\beta, q(\hat{\beta}))}{\partial q} \right] \frac{\partial q^2(\hat{\beta})}{\partial \hat{\beta}^2} - \frac{\partial^2 c(\beta, q(\hat{\beta}))}{\partial q^2} \left[\frac{\partial q(\hat{\beta})}{\partial \hat{\beta}} \right]^2 + \frac{\partial^2 t(\hat{\beta})}{\partial \hat{\beta}^2} \leq 0 \qquad [\text{A.2}]$$

Hence for $\hat{\beta} = \beta$ to be the optimal solution we must have

$$\frac{\partial \pi(\beta, \beta)}{\partial \hat{\beta}} = 0, \qquad [\text{A.3}]$$

and

$$\frac{\partial^2 \pi(\beta, \beta)}{\partial \hat{\beta}^2} \leq 0 \qquad [\text{A.4}]$$

Differentiating [A.3] with respect to β

$$\frac{\partial \pi^2(\beta,\beta)}{\partial \hat{\beta}^2} = \left[p - \frac{\partial c(\beta, q(\beta))}{\partial q}\right]\frac{\partial q^2(\beta)}{\partial \hat{\beta}^2} - \frac{\partial^2 c(\beta, q(\beta))}{\partial q \partial \beta}\frac{\partial q(\beta)}{\partial \hat{\beta}} - \frac{\partial^2 c(\beta, q(\beta))}{\partial q^2}\left[\frac{\partial q(\beta)}{\partial \hat{\beta}}\right]^2 + \frac{\partial^2 t(\beta)}{\partial \hat{\beta}^2} = 0$$

[A.5]

Subtracting [A.5] from [A.4] gives

$$\frac{\partial^2 c(\beta, q(\beta))}{\partial q \partial \beta}\frac{\partial q(\beta)}{\partial \hat{\beta}} \le 0$$

Given the assumption [5] concerning the cost function, it follows that $\dfrac{\partial q(\beta)}{\partial \beta} \le 0$ is required

for truth telling.

Derivation of equation [14]

$$\int_{\underline{\beta}}^{\tilde{\beta}}\left[\int_{\beta}^{\tilde{\beta}}\frac{\partial c(x,q)}{\partial x}dx\right]g(\beta)d\beta = \left[G(\beta)\int_{\beta}^{\tilde{\beta}}\frac{\partial c(x,q)}{\partial x}dx\right]_{\underline{\beta}}^{\tilde{\beta}} - \int_{\underline{\beta}}^{\tilde{\beta}}\frac{\partial c(\beta,q)}{\partial \beta}G(\beta)d\beta$$

$$= \left[G(\beta)\big(h(\tilde{\beta}) - h(\beta)\big)\right]_{\underline{\beta}}^{\tilde{\beta}} - \int_{\underline{\beta}}^{\tilde{\beta}}\frac{\partial c(\beta,q)}{\partial \beta}G(\beta)d\beta$$

$$= \left[G(\tilde{\beta})\big(h(\tilde{\beta}) - h(\tilde{\beta})\big)\right] - \left[G(\underline{\beta})\big(h(\tilde{\beta}) - h(\underline{\beta})\big)\right] - \int_{\underline{\beta}}^{\tilde{\beta}}\frac{\partial c(\beta,q)}{\partial \beta}G(\beta)d\beta$$

$$= -\int_{\underline{\beta}}^{\tilde{\beta}}\frac{\partial c(\beta,q)}{\partial \beta}\frac{G(\beta)}{g(\beta)}g(\beta)d\beta$$

[14] follows

Appendix: Estimations Results

Table A1 : Production Function estimation

Explanatory Variables	Estimates
$\Delta \log(l_{it})$	0.169
	(8.84)
$\Delta \log(k_{it})$	0.698
	(17.59)

The t statistics are reported under the coefficients in parentheses.

Table A2: Adjustment of the β parameter

Intercept	$0.789.10^{-3}$
	(4.21)
Age	$-0.296.10^{-5}$
	(0.96)
general education	$-0.713.10^{-4}$
	(-5.50)
area	0.171
	(3.79)

The t statistics are reported under the coefficients in parentheses.