Planning feedstock supply for a new territorial biorefinery

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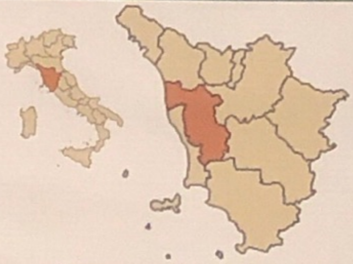
Statement of the problem

- The investment in a biorefinery is irreversible, with high start-up and management costs
- Biomass supply has to be guaranteed for a long enough period to cover investment costs, secure continuous operations, create stable relations and ensure against exogenous risk
- Having farmers interested in subscribing a production contract is crucial for locating the biorefinery

Case study



Industrial hemp in Tuscany (Province of Pisa, NUTS 3)

Aim

Use contract theory to identify the optimal set of farmers to create a biomass supply area for a territorial biorefinery

The principal-agent framework

The principal delegates *x* ha biomass cropping (ρ=yield in terms of end-product, *V*=unit price of end-product) to as set of *n* agents (Φ=contract number; *fc*, *vc*=fixed and variable costs; b^*=optimal area-based payment), to satisfy production constraints (*L*=minimum cultivated area), while maximising profit (*Z*)

$$\max\ Z = V\cdot\rho\cdot x_n - (b^*\cdot x_n + fc\cdot\Phi + vc\cdot x_n) \qquad \text{s.t.} \quad \sum_r x_n \ge L$$

Hidden information about transaction-costs (θ) of (3) agents' profiles, $\underline{\theta} > \overline{\theta} > \overline{\overline{\theta}}$, generates adverse selection and information rents by lower-cost agents

Incentive rationality (first best condition) $\quad \underline{U} = \underline{b}^*\cdot\underline{x} - \underline{\theta}\cdot\underline{x} \ge 0 \quad \overline{U} = \overline{b}^*\cdot\overline{x} - \overline{\theta}\cdot\overline{x} \ge 0 \quad \overline{\overline{U}} = \overline{\overline{b}}^*\cdot\overline{\overline{x}} - \overline{\overline{\theta}}\cdot\overline{\overline{x}} \ge 0$

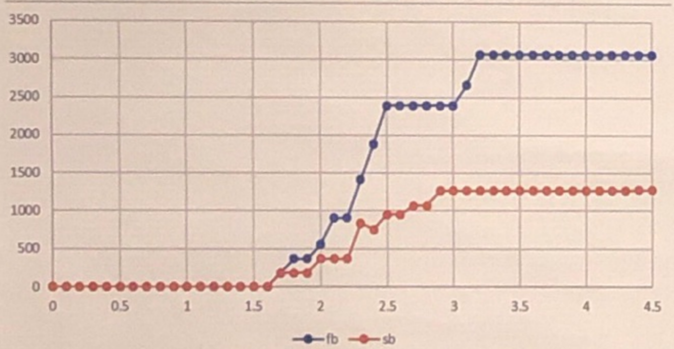
Incentive compatibility (second best condition) $\quad \underline{U} \ge \overline{U} + \underline{\Delta\theta}'(\overline{x}) \quad \overline{U} \ge \overline{\overline{U}} - \Delta\theta'(\overline{\overline{x}}) \quad \underline{b}^*\cdot\underline{x} - \underline{\theta}'\cdot\underline{x} \ge \overline{\overline{b}}^*\cdot\overline{\overline{x}} - \Delta\theta'(\overline{x} + \overline{\overline{x}})$

Research methods

1. Identification of farm types: cluster analysis using Italian census of agriculture (2010)
2. Estimation of production costs and profit maximisation: linear optimisation, using real world data
3. Simulation of the principal-agent model

Results

ha hemp (x) vs. € unit end product (V) (L=0, TC=0)



€ per ha hemp (b)

Farm type	First best condition						Second best condition					
	L ? 500 ha			L ? 1000 ha			L ? 500 ha			L ? 1000 ha		
	noTC	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*
F1	1264.3	980	980	980	980	980	1264.3	1264.3	1264.3	1106.17	1264.3	1106.17
F2	657.7	657.7	657.7	657.7	657.7	657.7	690.3	692.49	690.48	689.66	754.81	689.66
F3	1264.3	974.58	974.58	974.58	974.58	974.58	1264.3	1264.3	1264.3	1068.57	1264.3	1068.57
F4	1264.3	831.1	831.1	831.1	831.1	831.1	892.67	892.66	892.67	1068.57	842.09	1068.57
F5	816.97	816.97	816.97	816.97	816.97	816.97	892.67	892.66	892.67	1068.57	842.09	1068.57
F6	1132.54	994.16	994.16	994.16	994.16	994.16	1264.3	1264.3	1264.3	1106.17	1264.3	1106.17
F7	710.48	710.48	710.48	710.48	710.48	710.48	719.59	723.76	719.94	1068.57	842.09	1068.57
F8	906.33	906.33	906.33	906.33	906.33	906.33	1264.3	1264.3	1264.3	1068.57	925.8	1068.57
F9	1273.3	1211.9	1211.9	1211.9	1211.9	1211.9	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3
F10	925.79	925.79	925.79	925.79	925.79	925.79	1264.3	1264.3	1264.3	1068.57	925.8	1068.57
F11	892.65	892.65	892.65	892.65	892.65	892.65	892.67	892.66	892.67	1068.57	905.5	1068.57
F12	787.81	787.81	787.81	787.81	787.81	787.81	892.67	892.66	892.67	1068.57	842.09	1068.57
F13	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3	1264.3

ha hemp (x) per farm type

Farm type	First best condition						Second best condition					
	L ? 500 ha			L ? 1000 ha			L ? 500 ha			L ? 1000 ha		
	noTC	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*
F1	0	0	0	0	0	0	0	0	0	5	5	0
F2	90	90	90	90	90	90	90	90	90	90	90	90
F3	0	0	0	0	0	0	0	0	0	7	7	0
F4	0	0	0	212	212	212	2.37	3.45	2.46	7	7	7
F5	0	0	0	68	68	68	2.37	3.45	2.46	7	7	7
F6	0	0	0	0	0	0	0	0	0	5	5	0
F7	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.5	47.4	47.4
F8	0	0	0	0	0	0	0	0	0	2.71	2.71	7
F9	0	0	0	0	0	0	0	0	0	2.07	2.07	0
F10	0	0	0	0	0	0	0	0	0	5	8	15
F11	0	0	0	6.6	2.15	6.6	2.37	3.45	2.46	7	7	7
F12	65.2	65.2	65.2	95	95	95	18	24	0	95	95	95
F13	0	0	0	0	0	0	0	0	0	2.07	2.07	0

number of contracts per farm type (Φ)

Farm type	First best condition						Second best condition					
	L ? 500 ha			L ? 1000 ha			? 500 ha			? 1000 ha		
	noTC	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*	*noTC*	*lowTC*	*highTC*
F1	0	0	0	0	0	0	0	0	0	20	20	0
F2	2	2	2	2	2	2	2	2	2	2	2	2
F3	0	0	0	0	0	0	0	0	0	5	5	0
F4	0	0	0	1	1	1	1	0	1	1	1	1
F5	0	0	0	2	2	2	2	2	2	2	2	2
F6	0	0	0	0	0	0	0	0	0	15	15	0
F7	4	4	4	4	4	4	4	4	4	4	4	4
F8	0	0	0	0	0	0	0	0	0	1	1	1
F9	0	0	0	0	0	0	0	0	0	1	1	0
F10	0	0	0	0	0	0	0	0	0	15	15	15
F11	0	0	0	14	14	43	50	34	50	50	50	50
F12	2	2	2	2	2	2	2	2	0	2	2	2
F13	0	0	0	0	0	0	0	0	0	40	40	0

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Piacenza, 15-16 June 2017