A Choice Experiment Study on the Farmers’ Attitudes toward Biogas and Waste Reuse in a Nitrates Vulnerable Zone

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Introduction

• The dairy sector in the period 2011-2013 has represented 15% of the total EU agricultural output (55 billion EUR)

• In 2013, dairy sector accounts for 10% of the Italian agriculture production. Cattle accounts for more than 90% of milk production

• In Sardinia, cattle milk accounts for 45% of total milk production. The cooperative 3A, which manages more than 90% of cattle farms, is the 18th firm for gross income (0.04% of total gross income generated in Sardinia, including the oil sector) and the second in the food sector
Environmental impact of cattle farming

Cattle farming generates large amounts of animal manure and slurry, which represent a serious risk of pollution if not managed optimally on:

- **Air** (greenhouse gases emission, odor emissions)
- **Water** (nitrates water pollution ...)
- **Soil** (soil degradation...)
- **Biodiversity** (compromising habitats where plants and other animals live)
Water pollution

Animal manure and slurry emissions have the most serious impact on the quality of water and groundwater due to the

Excess of Nitrates

Causes: application on soil of raw manure and slurries and use of nitrogen fertilisers

Consequences: eutrofication, damages for ecosystems, low quality of water bodies, dangerous impacts on human and animal health
Legislation addressed to the protection of waters against pollution caused by nitrates from agricultural sources: **The Nitrates Directive** (91/676/CEE)

The European Union has tackled the issue with the Nitrates Directive (1991). The Directive has the objective of:

- reducing water pollution caused or induced by nitrates from agricultural sources and preventing further such pollution (Art.1).

**Key points:**
- standards on concentration of nitrogen from livestock in soil;
- mandatory rules for the application of nitrogen fertilizers, including organic materials: for example, limitation of fertilizer application and a minimum storage capacity for livestock manure;
- identification of polluted or at risk of pollution water bodies;
- designation of **Nitrates Vulnerable Zone (NVZ)** areas (where concentration of nitrates in water is >50 mg/l);
- Action Plans to reduce pollution from nitrates in NVZ.
Main consequences on farm routines due to the Nitrates Directive

• Farmers within NVZs must control the application of nitrogen fertilizers

• They are allowed to apply manure to soil only in given periods so they have to install storage structures to collect manure

• Storage capacity investments are perceived by farmers as pure internalization costs

• BUT manure and slurry can be an added value if they are used as a feedstock for anaerobic digestion.
The Anaerobic Digestion: a useful tool to manage livestock wastes

It is a biochemical process that transform organic material in:

**BIOGAS**

It is a combustible gas, largely composed by methane (~60%) and carbon dioxide. It is a renewable resource that could be adopted to produce electricity and heat (cogeneration technology). With an upgrading process, it could be transformed in **BIOMETHANE**, a biofuel.

**DIGESTATE**

It is a biofertiliser providing the same nutrients as raw manure and slurry. After further processing, could be transformed in solid and liquid fertilizers that can be marketed.
The Anaerobic Digestion Process

Fonte: http://www.planet-biogas.it/
The role of biogas plant in farms

• The biogas obtained by manure and slurries can be used to produce **electricity and heat** (self consumption or market) or upgraded to obtain **biomethane** (used as fuel).

• Anaerobic digestion from agricultural waste has many advantages (the transformation of manure into digestate, reduction of emission, circular economy etc.)

• However, hinders to the diffusion are related to unclear regulation and financial-technical requirements
• Digestate is better than raw material
  – The principal advantages are:
    • reduced bacterial and pathogens load, and therefore reduced health risks to humans and animals;
    • reduction of GHG emissions (CO2, CH4; N2O);
    • reduction of odor emissions;
    • increase in fertilizing properties.
• but is not a solution for the nitrate leaching problem
The Nitrates Directive in Sardinia

The Italian Government implemented the Nitrates Directive with the D.Lgs 152/99, assigning the Regional Governments the task to identify the Nitrates Vulnerable Zones (NVZ) and adopt the related Action Plans.

The Sardinia Regional Government implemented it in 2005, identifying only one NVZ in the area of the Municipality of Arborea. The area is 55 squared kilometres.

Fonte: Provincia di Oristano
**NVZ of Arborea**

- Highly intensive cow farming and the uncontrolled agronomic use of livestock manure and slurry have caused severe environmental consequences.
- The water ecosystem in the Arborea district is classified as extremely vulnerable and after the implementation of Nitrate Directive the situation is improved.

- The handling of such large amount of organic material poses serious management problems to the farmers.
- The anaerobic digestion technology may be useful to convert costs related to storage of farm wastes into a value.
Dairy sector in Arborea

• More than 150 livestock farms are settled in Arborea and produce for the diary sector.

• They are managed by 3A Cooperative, the fourth cow’s milk producer in Italy, with an annual volume of more than 191 million liters.

• On average each farm have 200 cows.

• Annual average of slurries and manure production is 8,700 cubic meter per farm.
The Arborea Case Study

- **OBJECTIVE** The present research aims at analyzing the attitudes of dairy farmers with respect to the adoption of the Biogas technology as a means to turn a cost into earnings.

- A Choice Experiment was designed in order to understand which are the Arborea farmers’ preferences over:
  - different biogas technologies,
  - different treatments of the digestate,
  - different scales of biogas production,
  - identify the factors that influence these choices.
Review of literature

• Few studies on this specific topic
• Bishop et al. (2010) have examined hindners and drivers toward adoption of the anaerobic digestion technology
  – The results show the importance of the attitude toward innovation and economic motivations (financial costs and benefits).
  – However the behavioral intention was better explained by the interaction of private motives with “social” motivations, related to pro-social and pro-environmental attitudes.
  – Other variables such as human capital, financial capacity, or opportunity costs did not prove to significantly affect the attitude toward adoption.
Survey design

• The questionnaire is split up into various section:
  – A first section focused on the collection of farm data (plot size, herd size, production, costs, etc.) and on the adoption of new technologies (both energy and farm technologies)
  – The second section contains questions on the production and management of manure and slurries;
  – The third section is devoted to issues related to market strategies after change in CAP milk policies and an analysis of risk perception (based on Schaper et al., 2010)
  – Section with a series of questions investigates on the farmer’s attitudes toward the Biogas technology
  – Finally, a choice experiment exercise was proposed
The Choice Experiment Design

- The scenario consisted in 5 attributes (the structure of the exercise is very simplistic -> not a real investment situation):

  - A **technological** attribute – 2 levels indicating 2 biogas plants: a **cogeneration** plant or a biogas plant + upgrading for **biomethane** production
  - An **agronomic** attribute – 3 levels indicating different uses of digestate: **raw**, without any other process; after a **separation** procedure, creating a solid and a liquor part; after major processing, transformed in **marketable fertilizers**
  - Biogas plant size – 2 levels: a small plant sized on a **single farm** or a larger plant sized at a **consortium level**
  - Payback period – 3 levels: 5 years, 7 years, 10 years
  - Farm income increase – 4 levels: 3%, 6%, 12%, 18%
## Scenario sheets - Example

### Biogas plants:

**Cogeneration plant for electricity and heat**

### Agronomic use:

**Production of marketable fertilisers**

### Biogas plant size:

**Larger plant sized at a consortium level**

### Payback period:

**7 years**

### Farm income increase:

**18%**

### SCENARIO A

### Biogas plants:

**Biomethane production**

### Agronomic use:

**Raw digestate**

### Biogas plant size:

**Small plant sized on a single farm**

### Payback period:

**7 years**

### Farm income increase:

**6%**

### SCENARIO B
The survey administration

• The whole sample was made of 97 farmers: 92 farmers in Arborea, who account for 60% of the Arborea dairy farmers population; plus 5 farmers outside the ZVN area.

• Each respondent faced 6 choice exercises, where it was possible to select either an Investment Scenario A or an Investment Scenario B, or to choose the Status Quo (No investment) option.
The sample

- After removal of observations because of missing or inconsistent responses, we are left with a sample of 77 individuals.
- The panel is unbalanced, with 6 choices for all farmers but one with 5 choices, and two with 4 choices.
## Results - Multinomial Logit model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>P -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomethane</td>
<td>-0.098</td>
<td>0.063</td>
<td>0.120</td>
</tr>
<tr>
<td>BioFertilisers</td>
<td>-0.026</td>
<td>0.052</td>
<td>0.617</td>
</tr>
<tr>
<td>Separation</td>
<td>-0.335**</td>
<td>0.158</td>
<td>0.034</td>
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<tr>
<td>Size2 (consortium)</td>
<td>0.114**</td>
<td>0.052</td>
<td>0.027</td>
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<tr>
<td>Payback period</td>
<td>-0.052**</td>
<td>0.026</td>
<td>0.045</td>
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<tr>
<td>Income</td>
<td>0.056***</td>
<td>0.009</td>
<td>0.000</td>
</tr>
</tbody>
</table>

N= 457, K=6  
Log likelihood =-288.724  
R2=0.051

- We first check whether, on average, the signs of the Payback period and Income coefficients are consistent with the expectations.
- Both coefficients are significant, and the negative sign indicates that longer periods for the return of the investment are less preferred, while the positive sign indicates that higher increases in income are preferred.
Results - Multinomial Logit model

- The coefficient of the dummy Size2 (plant at consortium level) is significant and positive, indicating that on average the farmers would prefer not to manage a biogas plant on their own;

- The proposed technologies for the treatment of the digestate are not attractive for the farmers: the attribute Separation has a coefficient significant and negative and the coefficient of the attribute BioFertilizers, i.e. the treatment of the digestate to produce marketable fertilizers, is not significant.

- The coefficient on the attribute Biomethane is negative, but not significant: yet, the P-value is close to the 10% level, and it will be seen that different model specifications provide more significant estimates for this attribute.
### Latent Class Logit Model

<table>
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<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Utility parameters in latent class - 1</strong></td>
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<tr>
<td>Biomethane</td>
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<td>BioFertilisers</td>
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<tr>
<td>Separation</td>
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<td>0.561</td>
<td>0.012</td>
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<tr>
<td>Size2 (consortium)</td>
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<tr>
<td>Payback period</td>
<td>-0.075**</td>
<td>0.031</td>
<td>0.016</td>
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<tr>
<td>Income</td>
<td>0.077***</td>
<td>0.012</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Utility parameters in latent class – 2</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Biomethane</td>
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<tr>
<td>BioFertilisers</td>
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<td>0.568</td>
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<tr>
<td>Separation</td>
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<tr>
<td>Size2 (consortium)</td>
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<td>0.003</td>
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<tr>
<td>Payback period</td>
<td>-0.075**</td>
<td>0.031</td>
<td>0.016</td>
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| **Class probability model 1**  |             |                |         |
| Environmental risk prob        | -1.378***   | 0.535          | 0.010   |
| Energy_att                     | -1.317***   | 0.477          | 0.006   |
| Constant                       | 1.222*      | 0.705          | 0.083   |

| **Average Class Probabilities**|             |                |         |
| Class 1 = 0.258                |             |                |         |
| Class 2 = 0.742                |             |                |         |

| N = 457, K=12; Ind=77          | Log likelihood =-254.127 | Adj. R2= 0.176 |
Results – The Latent Class ML model

- The data supports a two-class specification.
  - Farmers in the first class (26%) have strong preferences for a consortium plant, do not care whether it produces Biomethane or Electricity cogeneration and not accept the digestate.
  - The second class is made of farmers (75%) who are interested in investing in their own Biogas plant, and are more interested in the cogeneration technology. They do not express any preference over different treatments of the digestate.
Results – The Latent Class ML model

• The Class probability model gives some insights on the characteristics of the farmers pertaining to either class

• Farmers characterized by:
  – the attitudinal component Energy_attitudes (i.e. people interested in self-consumption of energy, in CO2 reductions, in imitating other farmers who have installed biogas plants)
  – perception of Environmental risks, like climate change and increased risks to animal health

are more probably located in Class 2
Conclusions

• The preliminary results of our study show that dairy farmers are interested in the Biogas technology; in particular we identify a class of farmers who could be potential adopters of the technology, if the financial investment is advantageous.

• The good properties of the digestate, and its transformations, for agronomic use seem still overlooked by the farmers.

• The results of our study will be useful to provide indications to policy makers to support diffusion of Biogas technologies that recycle agricultural waste, and improve the regulation regarding the agronomic use of digestate and biofertilizers.
References


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Photos by Maria Bonaria Lai and Vania Statzu