Resource use in efficiency in livestock farming, how to measure improvements?

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FAO Workshop: Closing livestock’s natural resource use efficiency gap
Rome, April 2nd – 4th 2012
• Livestock is using resources in an inefficient way
⇒ potential for improvements

• Various ways to measure (in)efficiency
⇒ attention for definition and techniques to allow for the right improvements
Measuring resource use inefficiency

**OUTLINE**

- The efficiency notion & frontier techniques
- Some essential adjustments, e.g. the materials-balance-based methods
- A glance on ongoing and future research:
  - Diagnosis and advisory
  - Footprints efficiency
  - Sustainable value
  - Integrative frameworks
The efficiency notion

- Kg roughage/ litre milk
- Kg concentrates/ kg meat
- Kg concentrates/ egg

Is B better than A, C, etc?
The efficiency notion

$A$ frontier of efficient points

$X_1/Y$ $X_2/Y$
The efficiency notion

- TE, technical efficiency = \( \frac{0Q}{0P} \)

<table>
<thead>
<tr>
<th>firm</th>
<th>TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.86</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>0.69</td>
</tr>
</tbody>
</table>

=> the method: DEA, data envelopment analysis
The efficiency notion

EE, economic efficiency
EE = TE * AE (allocative efficiency)

=> various DEA models to combine TE and EE
The efficiency notion

DEA (AND SFA) LITERATURE

• Dairy:
  – Amara & Romain (1990). Dairy sector Québec
  – Balcombe et al. (2006). Australian dairy farms
  – Bravo-Ureta & Reiger (1991)
  – D’Haese et al. (2009) milk production on Reunion Island
  – Fraser & Cordina (1999). Irrigated dairy farms
  – Hailu et al. (2005). Alberta and Onatario dairy farms
  – Jong Moo Kim. Korean dairy farms
  – Kumbhakar et al. (1991) US dairy farms
  – Lapar et al. (2005). Smallholder dairy
The efficiency notion

DEA (AND SFA) LITERATURE

• Dairy:
  – Mbaga et al. (2003).Québec dairy farms
  – Stokes et al. (2007)
  – Weersink et al (1990) Ontario dairy farm

• Pigs:
  – Asmild & Hougaard (2006). Danish pig farms
  – Oude Lansink & Reinhard (2004); Dutch pig farms
  – Sharma et al. (1997, 1999). Hawaian Swine industry
  – Van Meensel et al. (2010). Pigs, Belgium
Resource use & environmental efficiency

INCORPORATION IN THE FRONTIER FRAMEWORK

- DMU’s still related to the multidimensional production frontier
- Specific inputs or outputs from the production process can be considered
- Subvector efficiencies allow for studying the resource use efficiency or environmental impacts
- This approach is interesting for scarce inputs (water, land, energy, …) or undesirable outputs (pollutants)
Inefficient use of a specific resource

**SUBVECTOR EFFICIENCY**

Subvector efficiency for input $x_1$ is determined parallel to the axe for $x_1$: $0^\prime A^\prime / 0^\prime A$
Study on dairy sector on Reunion island (D’Haese et al., 2009)

Critical factor for increasing the local milk production is the limited availability of arable land because of the small size and the volcanic nature of the island.

Results indicate that subvector efficiencies for land use are lower than overall technical efficiency.

Inefficient farms are smaller on average and appear to have too many animals per ha, also investing too little to attain high milk production.
### Efficiency In Milk Production On Reunion Island: Dealing With Land Scarcity

<table>
<thead>
<tr>
<th>Item</th>
<th>Efficient Farms</th>
<th>Less Efficient Farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk production, liter</td>
<td>233,938</td>
<td>132,499</td>
</tr>
<tr>
<td>Milk production per cow</td>
<td>5445</td>
<td>4099</td>
</tr>
<tr>
<td>Number of cows</td>
<td>42</td>
<td>31</td>
</tr>
<tr>
<td>Ha of land</td>
<td>20.7</td>
<td>13.4</td>
</tr>
<tr>
<td>Labor, FTE</td>
<td>2.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Costs for livestock, euros</td>
<td>61,751</td>
<td>38,766</td>
</tr>
<tr>
<td>Operational costs, euros</td>
<td>18,446</td>
<td>12,393</td>
</tr>
</tbody>
</table>

Can be incorporated in the model as detrimental inputs

Study on dairy sector in Netherlands (Reinhard et al., 2000): context: environmental problems caused by agriculture (nitrogen and phosphate surplus and energy)

It is investigated to which extent it is possible to reduce these undesirable outputs (nitrogen/phosphate) and the energy use.
Some examples

ENVIRONMENTAL IMPACTS (UNDESIRABLE OUTPUTS)

– Can be looked at together (all bads) or separately

Table 6
DEA Technical and environmental efficiency scores

<table>
<thead>
<tr>
<th></th>
<th>Technical (%)</th>
<th>Environmental (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output</td>
<td>Input</td>
</tr>
<tr>
<td>Overall mean</td>
<td>78.37</td>
<td>81.10</td>
</tr>
<tr>
<td>Lower quartile</td>
<td>70.10</td>
<td>73.74</td>
</tr>
<tr>
<td>Median</td>
<td>77.54</td>
<td>80.00</td>
</tr>
<tr>
<td>Upper quartile</td>
<td>86.35</td>
<td>88.15</td>
</tr>
<tr>
<td>Mean 1991</td>
<td>78.54</td>
<td>81.27</td>
</tr>
<tr>
<td>1992</td>
<td>78.21</td>
<td>80.91</td>
</tr>
<tr>
<td>1993</td>
<td>77.64</td>
<td>80.44</td>
</tr>
<tr>
<td>1994</td>
<td>79.12</td>
<td>81.84</td>
</tr>
</tbody>
</table>

Resource use and pollution inefficiency

LITERATURE

Some fundamental drawbacks

- Relative figures are context specific
- Subvector efficiency in conflict with allocative thinking
- When environmental outcome is function of inputs and outputs, considering it as an input is redundant
MBB adjustments of the efficiency

**PRINCIPLES**

- MBB, materials-balance-based: what goes in must go out
- Exploits nutrient contents in X and Y similar to price information
- Measures an ecological outcome
- Allows for deriving trade-offs between economic (efficiency) and emission (efficiency)
Various allocative optima
Positive and negative trade-offs
A glance on ongoing research

**DIAGNOSIS AND OPTIMISATION**

- *Is low input farming input efficient?*
  SOLID project (EU FP7)
- *Does stocking density influence rabbit performance?*
  (national), IWT
- *Is this improved diagnosis applicable in current advisory?*
  Pigs2win (national, IWT)
- *Helminths infections and efficiency: cause-effects relationship?*
  ECOWORM (national)
- *Helminths infections and efficiency: farm-specific advisory?*
  ECOWORM (national)

For more information: contact the authors (ludwig.lauwers@ilvo.vlaanderen.be)
Low input dairy farming
Clusters of low-input dairy
1, where are we?
2, how to improve?
3, novel strategies
The MBB adjusted method

LITERATURE

• Method elaboration, with pig production as illustrative case:
  – Coelli et al. (2007). The DEA method
  – Lauwers (2009); The principles

• Use in agriculture:
  – Hoang & Rao (2010), Hoang (2011). OECD agriculture
  – Hoang & Coelli (2011). Nutrients balance OECD countries
  – Hoang & Alauddin (2012). OECD agriculture (profit, nutrient, exergy)

• Other use
A glance on further research

FOOTPRINTING AND CONSTANT CAPITAL

• Footprinting efficiency
  – Exergy efficiency
  – LCA

• Sustainable value
  – Added value over resource use
  – Capital preservation
    -> economic capital
    -> environmental capital
    -> social capital

• Integrating various efficiency concepts
# Sustainable Value: a simple calculus

<table>
<thead>
<tr>
<th>Type of capital form</th>
<th>Capital form</th>
<th>Measurement unit (m.u.)</th>
<th>Example farm</th>
<th>Average Productivity (€/m.u.)</th>
<th>Value contribution (€)</th>
<th>Sustainable value (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmenta l</td>
<td>Water</td>
<td>m³</td>
<td>1,770.00</td>
<td>67.15</td>
<td>161.49</td>
<td>-166,981.80</td>
</tr>
<tr>
<td></td>
<td>CO₂- emission</td>
<td>tonne CO₂- eq.</td>
<td>499.21</td>
<td>238.10</td>
<td>255.08</td>
<td>-8,476.59</td>
</tr>
<tr>
<td></td>
<td>N-excretion</td>
<td>kg/ha</td>
<td>121.33</td>
<td>979.64</td>
<td>757.18</td>
<td>26,991.07</td>
</tr>
<tr>
<td></td>
<td>Land</td>
<td>ha</td>
<td>50.36</td>
<td>2,360.21</td>
<td>1,923.33</td>
<td>22,001.28</td>
</tr>
<tr>
<td>Social</td>
<td>Labour</td>
<td>hours</td>
<td>5,074.00</td>
<td>23.43</td>
<td>19.03</td>
<td>22,325.60</td>
</tr>
<tr>
<td>Manufactured</td>
<td>Farm capital</td>
<td>€</td>
<td>21,429.00</td>
<td>5.55</td>
<td>4.77</td>
<td>16,714.62</td>
</tr>
<tr>
<td></td>
<td>Concentrates</td>
<td>tonne</td>
<td>290.94</td>
<td>408.54</td>
<td>479.57</td>
<td>-20,665.47</td>
</tr>
</tbody>
</table>

**ILVO**

**UNIVERSITEIT GENT**

**FACULTEIT BIO-INGENIEURSWETENSCHAPPEN**
Sustainable Value

FURTHER READING

– Figge & Hahn, 2004
– Discussion in Ecological Economics, issue 69
– EUROCHOICE, 2011, 10 (2)
Livestock and resource use efficiency

TAKE-HOME MESSAGE

• Inefficiency can be measured
• Use DEA (or SFA) context-specific
• Relative measures will give an indication of improvement margins but not of absolute resource efficiency
• Need for enlarging towards a system analysis => constant capital stocks of resources
Livestock and resource use efficiency

TAKE-HOME REFERENCES FROM AUTHORS

Thank you for your attention! Questions?