MEASURING FARM COSTS OF POLLUTION ABATEMENT

A CASE STUDY OF DUTCH DAIRY FARMING

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Study background

- Most production processes generate in addition to desirable outputs (good outputs) some undesirable non-marketed byproducts (bad outputs)
- Examples in agricultural production: nitrogen and phosphorus leaching, GHG emissions, pesticide pollution etc.
- Recent literature focused on two main problems:
  - How to assess farm environmental performance?
  - How to price bad outputs?
Methods used to model a pollution-generating technology:

- Distance function approach (Shephard, 1970; Chung, Färe and Grosskopf, 1997), assuming weak disposability of by-products – bad outputs cannot be reduced without reducing production of good outputs
- Separate modeling of two technologies: an intended production technology and a by-production technology (Murty, Russell and Levkoff, 2012)
Our approach

• Two functions are used:
  – a transformation function (input distance function)
  – a hedonic aggregate output function

• We formulate a hedonic (output aggregator) function

\[ \eta = h(b, y) \]

• and then incorporate it into the input distance function

\[ D(b, y, x) = D[h(b, y), x] \]

where \( x \) represents a vector of inputs and \( h(b, y) \) is the aggregator function
Data

• Highly specialized Dutch dairy farms (LEI FADN data)
• 1868 observations for 2001-2009
• Sample farm average size (min – max values):
  – 112 cows (18 - 544)
  – 51 ha ag. land (9 - 265)
  – 1.7 workers (0.7 - 8.5)
• Nitrogen surplus:
  • 174 kg per ha of agricultural land
  • 37 kg per 1000 Euro of farm revenue (ca. 59 in 1991-1994)
• Reduction in N surplus over the study period:
  • by 2.2 % p.a. per ha agricultural land
  • by 4.0 % p.a. per Euro of farm revenue
Model variables

• 3 outputs:
  – Good output 1 ($y_1$), revenue from milk and livestock products’ sales plus, Euro
  – Good output 2 ($y_2$), revenue from sales of crop products, Euro
  – Bad output ($b$), nitrogen surplus (the difference between total nitrogen quantity applied on the farm minus total nitrogen content in the production output), kg

• 6 inputs:
  – Total utilized ag. area ($L$), hectares
  – Labor ($W$), annual working units
  – Capital ($K$), farm machinery buildings depreciation value, Euro
  – Materials ($M$), Euro (used for normalization)
  – Livestock ($A$), LSU
  – Purchased feed ($F$), Euro
Model estimates

- Most parameters (87%) obtained significant estimates
- Elasticities are close to those from previous studies (Emvalomatis et al., 2010 and Reinhard et al., 1999)
  - Land 0.07
  - Labor 0.07
  - Capital 0.09
  - Livestock 0.48
  - Feed purch. 0.16
- Technical change rate: 1.0 % p.a.
Technical efficiency estimates

- Average TE score = 0.93, i.e. farms could produce the same amount of output by reducing their input use by 7.2% on average
- No statistically significant time trend in technical efficiency estimates
For most farms shadow prices for N surplus have the expected sign and vary between 5 and 20 Euro/kg.

The average shadow price of 12.4 is substantially higher than ca. 1.96 Euro/kg as found by Reinhard et al (1999) for the period 1991-1994.
## Determinants of shadow prices

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient estimate</th>
<th>t-value</th>
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<tbody>
<tr>
<td>const.</td>
<td>6.03</td>
<td>3.04</td>
</tr>
<tr>
<td>t</td>
<td>0.20</td>
<td>3.16</td>
</tr>
<tr>
<td>oldest shareholder age</td>
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<td>off-farm employment</td>
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<td>own land share</td>
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<td>I/K ratio</td>
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<td>off farm manure displacement</td>
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<td>grazing land per LSU</td>
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<td>input contracting</td>
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<td>on-farm processing</td>
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<tr>
<td>LSU number</td>
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<td>total subsidies</td>
<td>0.00006</td>
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</table>

*Log likelihood*

5967.65
Conclusions

• A high variation in the N surplus shadow price signal highly heterogeneous costs of pollution reduction ... can be an impediment for developing environmental cross-compliance instruments.

• An increase of the N surplus shadow price over time suggests that pollution abatement has become more costly.

• Policies aimed at compensation of farm costs related to pollution abatement might be rather costly.

• Are there options to use public funds more effectively?
Fair Oaks Farms in Indiana

- With 36,000 cows on 11 farms covering 35,000 acres, it is one of America’s biggest dairy operations
- “Three times a day the manure is vacuumed from the cows’ barns while they are being milked. It then sits for 21 days in a methane digester, while anaerobic bacteria get to work producing gas that is used to generate electricity or as fuel.”
- “Once the manure comes out of the methane digester it runs through sieves to capture the long fibres, which are used to fertilise the farms’ soil.”
- “The remaining water is sent through a nutrient-recovery system, which removes 80% of the phosphorous and 75% of the organic nitrogen, compressed into dry matter and reused on the farms.”

Source: The Economist, September 5th 2015
Open questions

• Might there be scale effects for pollution-abating technologies in dairy farming? or

• *Do dairy farms have to become that big to benefit from clean technologies?*

• May large-scale dairy farming have a comparative advantage also in terms of animal welfare?
Aggregator function estimates

- 7 of 9 parameters were statistically significant
- Elasticities of the distance function with respect to three outputs
  - Milk and livestock \((y1)\) - 0.80
  - Crop products \((y2)\) - 0.02
  - N surplus \((b)\) - 0.10
- Returns to scale: 1.23 (1.09 if the bad output is considered)
Aggregator function properties

- Differences in the curvature of the aggregator function with respect to single outputs
- In particular, in the case of bad output (red line) a completely different pattern was captured