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Modeling a Polluting Technology: A Hedonic Approach

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Study background

- Most production processes generate in addition to desirable outputs (good outputs) some undesirable ***non-marketed*** polluting byproducts (bad outputs)
- Recent literature focused on two main issues:
  - evaluating firms' efficiency taking into account their environmental performance
  - pricing of bad outputs

Study background

- Most studies model a pollution-generating technology by using a single transformation function
  - ➢ Distance function (Färe et al., 1985)
  - ➢ Directional distance function (DDF) (Chung, Färe and Grosskopf, 1997)
  - Separate modeling of two technologies: an intended production technology and a by-production technology (Murty, Russell and Levkoff, 2012)
  - Most applications are done by using a data envelopment analysis (DEA)
  - Extensions to a stochastic frontier model seem to be rather problematic

Two functions

- We suggest to describe pollution-generating technology by means of two functions:
  - a transformation function (input distance function)
  - a hedonic aggregate output function
- We formulate a hedonic/aggregator function which explicitly capture the relationship between bad and good outputs $\eta = h(b, y)$
- and then incorporate it into the input distance function

$$D(b, y, x) = D[h(b, y), x] \tag{1}$$

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

Data

- Highly specialized Dutch dairy farms
- 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 (compared to ca. **59 in 1991-1994**)
- Reduction in N surplus over the study period:
  - by 2.2 % p.a. wrt. agricultural land
  - by 4.0 % p.a. wrt. farm revenue

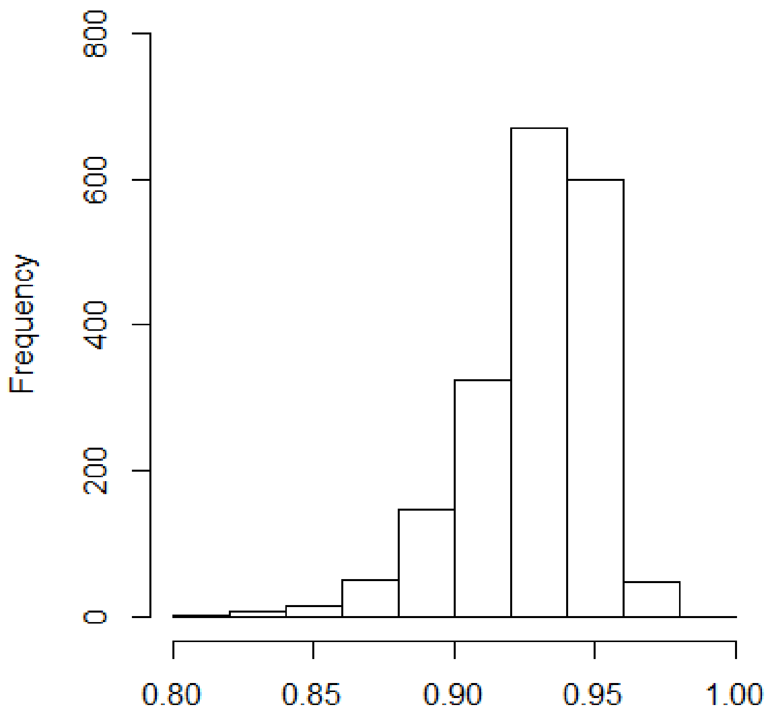
Model variables

- **3 outputs:**
  - Good output 1 (y1), deflated revenue from milk and livestock products' sales plus changes in the valuation of livestock, Euro
  - Good output 2 (y2), deflated revenue from sales of crop products, Euro
  - Bad output (b), nitrogen surplus measured as 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), deflated depreciation value of farm machinery and buildings, Euro
  - Materials (M), deflated value, Euro – **used for normalization**
  - Livestock, (A), livestock standard units
  - Purchased feed (F), deflated value, Euro
- Monetary indicators were adjusted to the 2005 price level

Model estimates

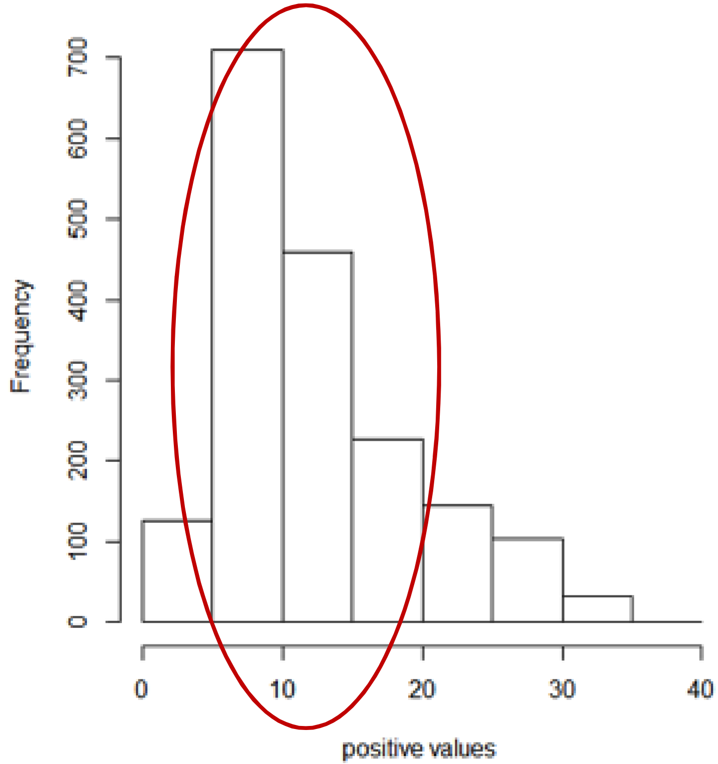
- Most parameters (87%) obtained significant estimates
- Elasticities are close to those from previous studies
  - Land 0.07
  - Labor 0.07
  - Capital 0.09
  - Livestock 0.48
  - Feed purc. 0.16
- Technical change rate: 1.0 % p.a.

Technical efficiency estimates



- 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

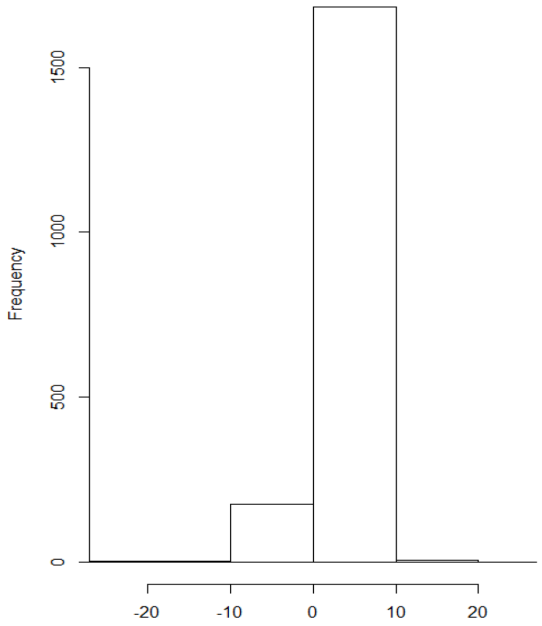
Shadow prices

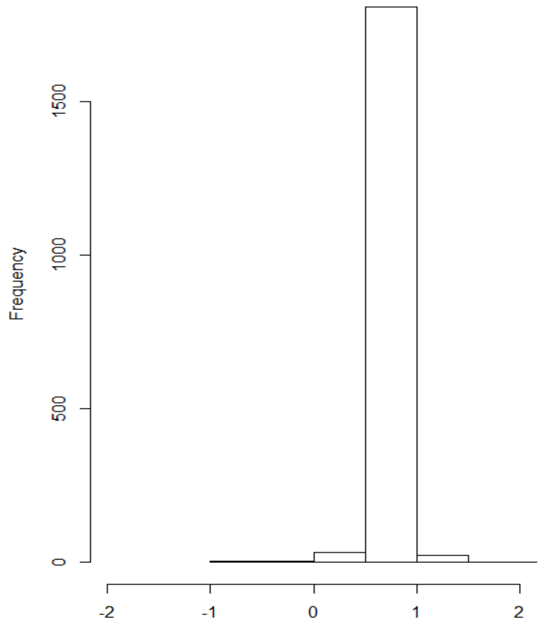


- For most farms shadow prices for N surplus have the expected sign and vary between 5 and 20 Euro/kg
- The average shadow price of 12.4 is substantially higher than ca. 1.96 Euro/kg as found by Reinhard et al (1999) to be in 1991-1994

Morishima elasticities of substitution (MES)

How a given change in pollution intensity influences the (good-bad output) shadow price ratio

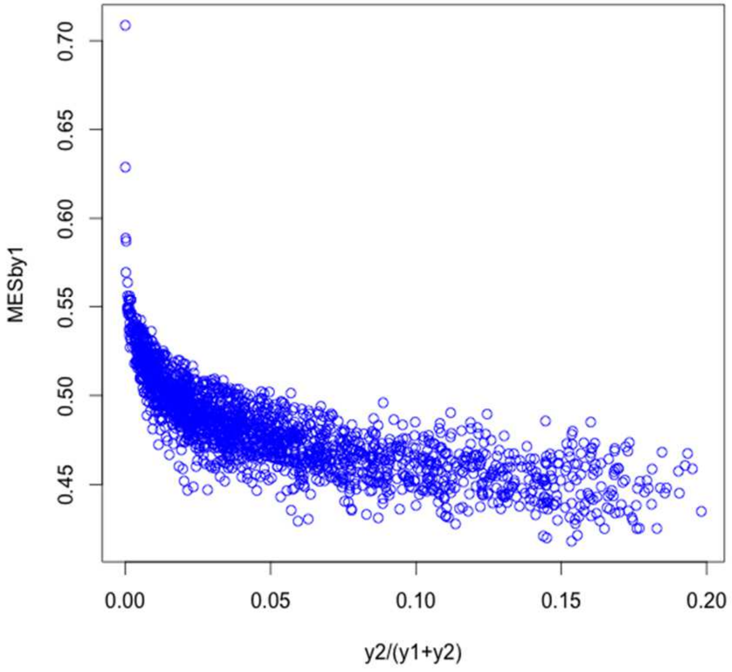


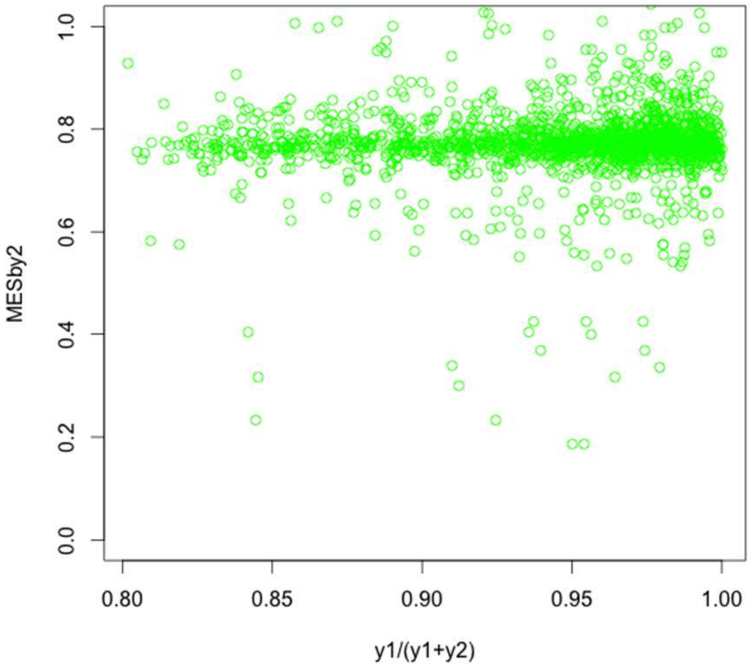


MES_{by1}

MES_{by2}

MES estimates s.t. degree of specialization





Determinants of shadow prices

Variable	Coefficient estimate	t-value
const.	6.03	3.04
t	**0.20**	**3.16**
oldest shareholder age	**0.03**	**1.92**
off-farm employment	-0.01	-0.38
own land share	**2.32**	**4.54**
I/K ratio	**0.33**	**2.94**
off farm manure displacement	**-0.00011**	**-1.81**
grazing land per LSU	**-2.79**	**-1.73**
input contracting	-0.16	-0.12
on-farm processing	0.55	0.58
LSU number	**0.57**	**1.66**
total subsidies	**0.00006**	**4.40**
Log likelihood	5967.65	

Conclusions

- We show how the distance function approach can be augmented to model technological relationships between desirable marketed and undesirable non-marketed outputs
- A high variation in the N surplus shadow price … can impede targeting of environmental cross-complience instruments
- Increase in shadow prices for N surplus over time suggests that pollution abatement has become more costly (another obstacle for developing effective policy instruments?)

Fair Oaks Farms in Indiana

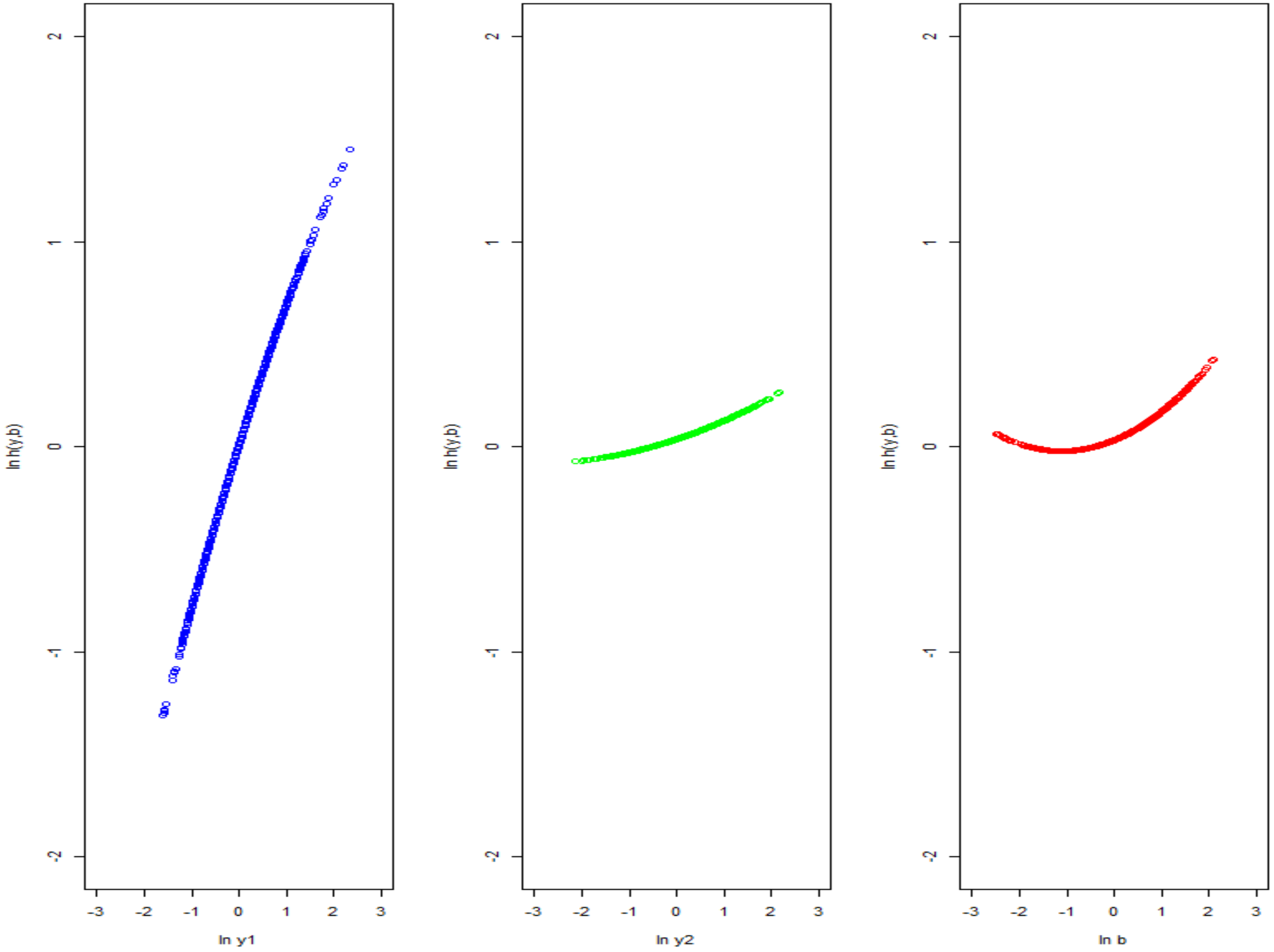
- With 36,000 cows on 11 farms covering 35,000 acres, it is one of America's biggest and most modern dairy operations
- "Fair Oaks Farms reuses everything in sight: Three times a day the manure is vacuumed from the cows' barns while they are being milked. It then sits for 21 days in a methane digester, while anaerobic bacteria get to work producing gas that is used to generate electricity or as fuel. The electricity powers all the farm buildings and machines and the excess is sold into the grid. Any unused gas is compressed and used to power the farms' fleet of 42 lorries…"
- "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. The water that comes out of the recovery system could be used for irrigation.

Source: The Economist, September 5th 2015

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