N surplus and GHG emissions in a productivity framework: A case study of Dutch dairy farms

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Motivation

- Dutch dairy farms contribute substantially to N pollution and greenhouse gas (GHG) emissions.
- Should we focus on *production* or *productivity*?
- Here, we focus on productivity.
- Theoretical framework: multi-equation modeling approach of Murty et al. (2012)
- Two studies:
  - Lamkowsky et al. (2021): "Closing productivity gaps among Dutch dairy farms can boost profit and reduce nitrogen pollution" (Environmental Research Letters) $\rightarrow$ nitrogen surplus
  - Ang et al. (2022): "Energy productivity and greenhouse gas emission intensity in Dutch dairy farms: A Hicks–Moorsteen by-production approach under non-convexity and convexity with equivalence results" (Journal of Agricultural Economics) $\rightarrow$ GHG emissions

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What this paper does

- We propose a two-step approach:
  - Quantify possible TFP gains in monetary values using the Bennet-Lowe indicator (Ang, 2019).
  - Quantify possible reduction of N surplus at maximum TFP levels using the by-production approach of Murty et al. (2012).
- Using data envelopment analysis (DEA), we apply the proposed framework to a sample of 341 Dutch dairy farms over the time period 2006 to 2017.
- The results show that the Dutch dairy sector could have simultaneously increased TFP by 34% and reduced N surplus by 50%. While trade-offs exist, farmers are able to do both in 96% of cases.

Data description

- This article uses panel data of Dutch dairy farms covering the period 2006 – 2017.
- Data sources: Farm Accountancy Data Network and EUROSTAT
- We distinguish **four fixed inputs** (land, labor, capital, animals), **eight variable inputs** (seeds and planting materials, purchased feed, pesticides, fertilizers, energy, veterinary costs, contract work and costs of renting machinery) and **two outputs** (sales of dairy products and cattle, and sales of other agricultural outputs including other livestock, crops, fruits and flowers), and the **N surplus**.

Data Envelopment Analysis

Approximating the technology is essential for the identification of maximum TFP and minimum N surplus. Consider a sample of I farms. The farm under evaluation is indexed by k. Assuming that the actual technology set exhibits variable returns to scale (VRS), the conventional technology for farm k in year t is approximated by $\hat{T}_t$:

$$\hat{T}_t = \left\{ (\mathbf{x}_{kt}, \mathbf{y}_{kt}) | \sum_{i=1}^{I} \lambda_{it} \mathbf{x}_{it} \leq \mathbf{x}_{kt}, \sum_{i=1}^{I} \lambda_{it} \mathbf{y}_{it} \geq \mathbf{y}_{kt}, \sum_{i=1}^{I} \lambda_{it} = 1 \right\}. \quad (1)$$

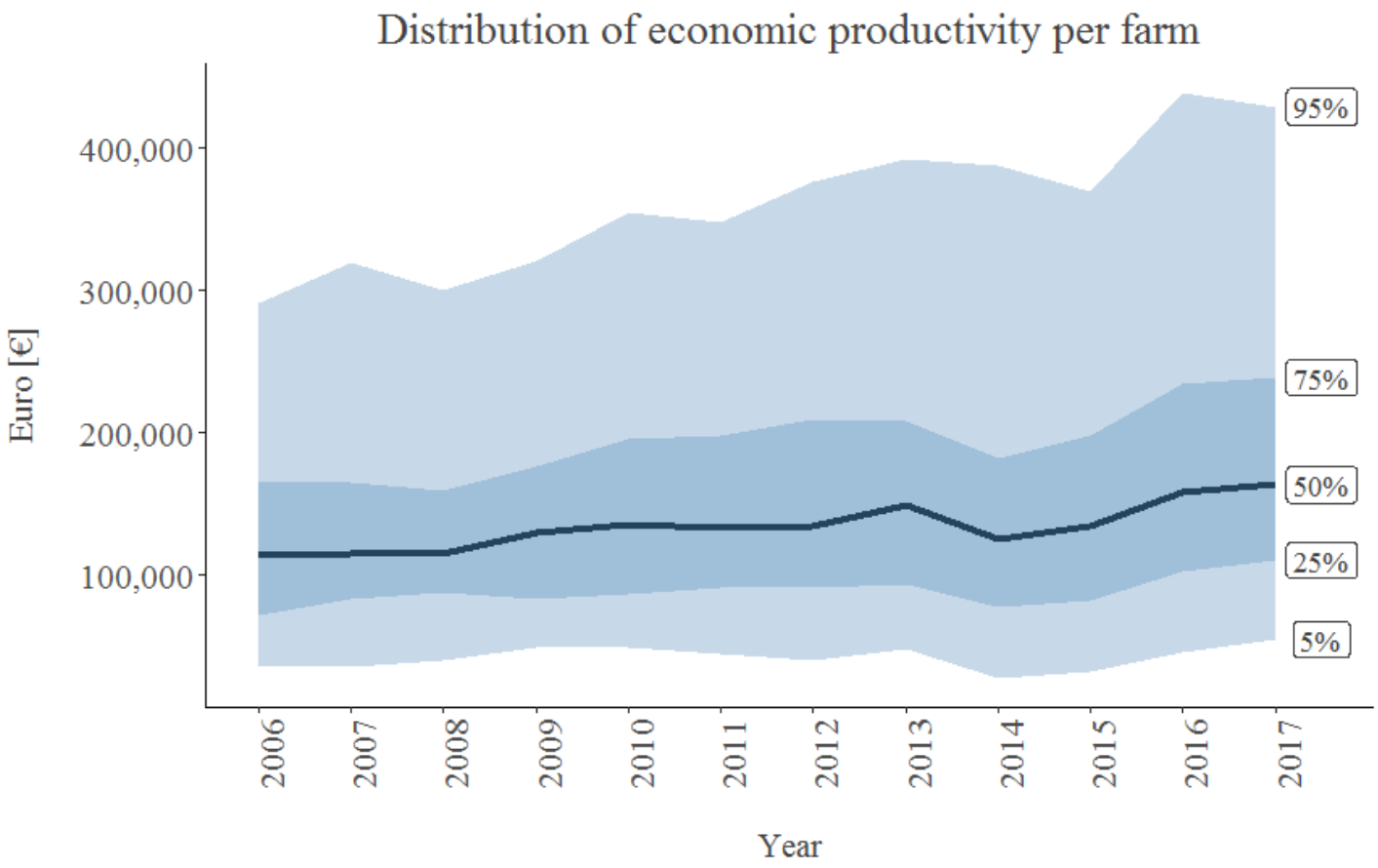
The approximated by-production technology set under VRS is $\hat{H}_t$:

$$\hat{H}_t = \left\{ (\mathbf{z}^*_{kt}, \mathbf{b}_{kt}) | \sum_{i=1}^{I} \mu_{it} \mathbf{b}_{it} \leq \mathbf{b}_{kt}, \sum_{i=1}^{I} \mu_{it} \mathbf{z}_{it} \geq \mathbf{z}^*_{kt}, \sum_{i=1}^{I} \mu_{it} = 1 \right\}, \quad (2)$$

where $\mathbf{z}^*$ indicate the optimal values of the polluting inputs by TFP maximization in the conventional technology.

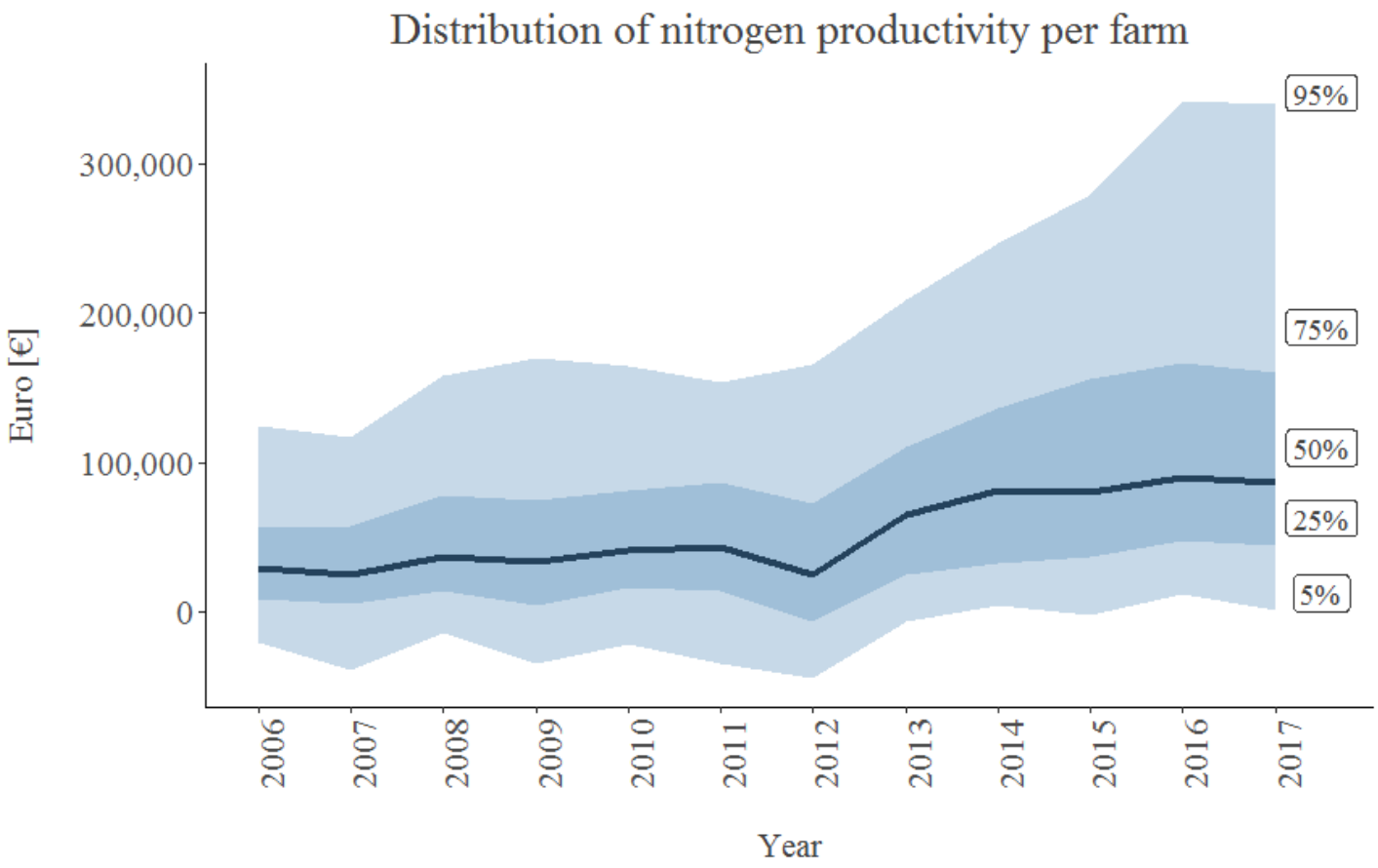
Average Economic TFP, 2006-2017

Over this 12-year period, the average economic productivity per farm increased by 48%.



Average N Productivity, 2006-2017

Over this 12-year period, the average N productivity per farm increased by 192%.

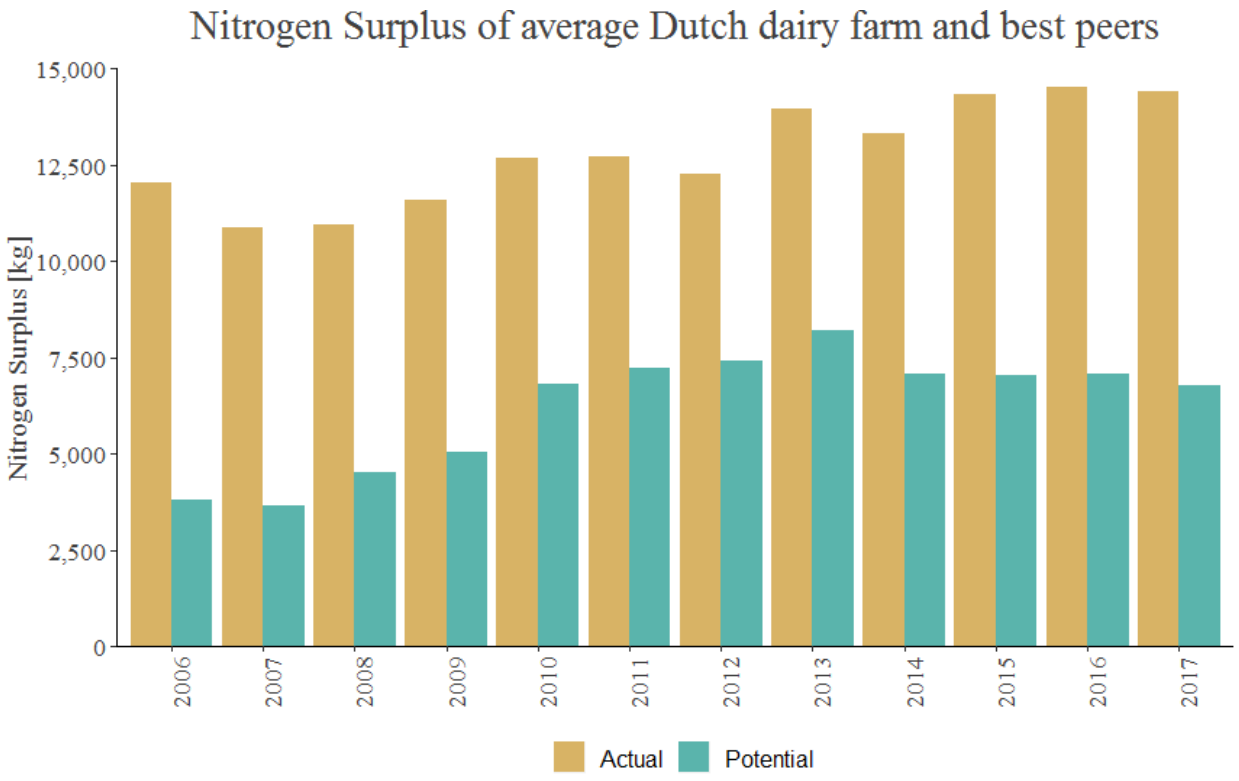


Average gross profit: actual vs. maximum

For the years 2006 to 2017, the annual economic productivity gap between the average Dutch dairy farmer and its best performing peers is 68,292 euro. This means that by closing the productivity **gap** the average farm could increase their **annual gross profit by 34%** and total annual farm income by **68,292 euro**.

Average N surplus: actual vs. minimum

For the years 2006 to 2017 the average annual N productivity gap is 6,563 kg N surplus per farm. This means that by closing the N productivity gap, farmers could on average **reduce the annual N surplus by 50%**. This amounts to an annual reduction of **113 kiloton of N** for the entire Dutch dairy farming sector.



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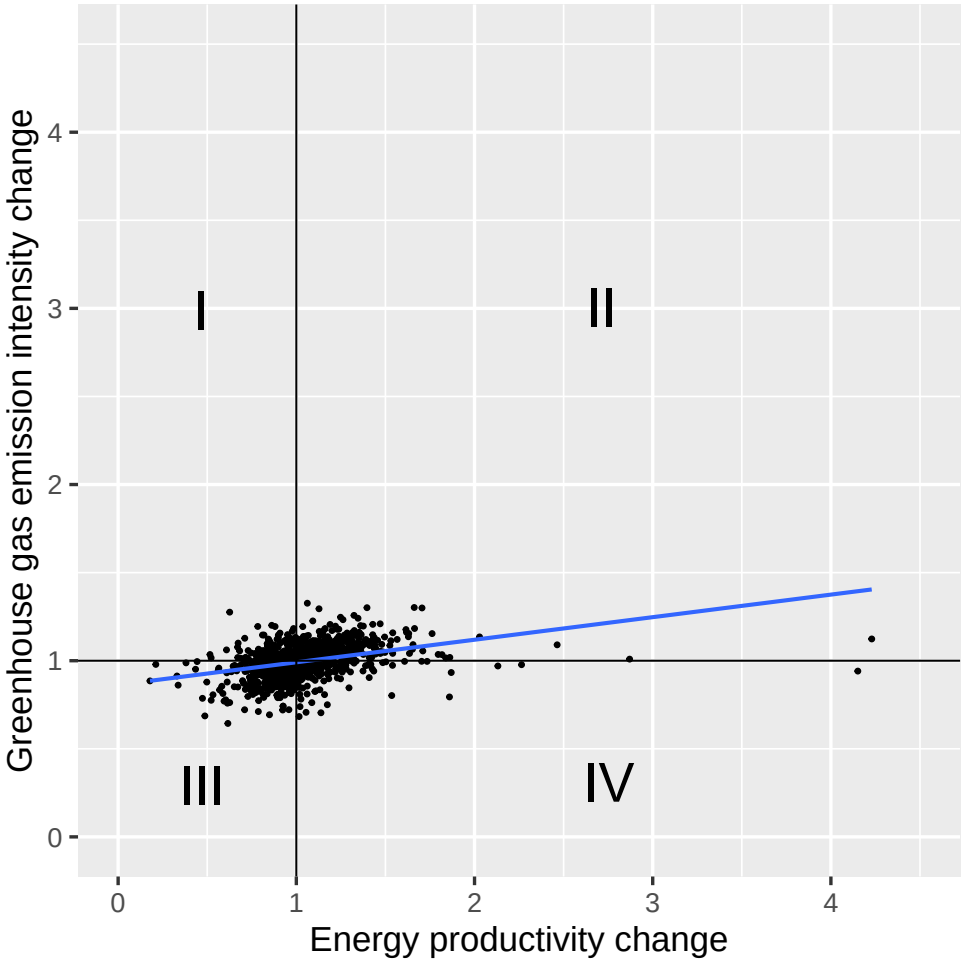
What this paper does

- Analysis of the nexus of energy use, agricultural production and GHG emissions.
- We evaluate performance in (1) the conventional technology and (2) emission-generating technology, using Hicks-Moorsteen formulations (Bjurek, 1996):
  - Energy productivity change: ratio of aggregate output change to energy use change
  - GHG emission intensity change: ratio of GHG emission change to polluting input change
- Using data envelopment analysis (DEA), we apply the proposed framework to 1,510 observations of Dutch dairy farms over the time period 2011 to 2019.
- The results show a positive association between energy productivity change and GHG emission intensity change, which calls into question the potential of on-farm, energy-efficiency-increasing measures to reduce GHG emission intensity.

Energy productivity change vs. GHG emission intensity change



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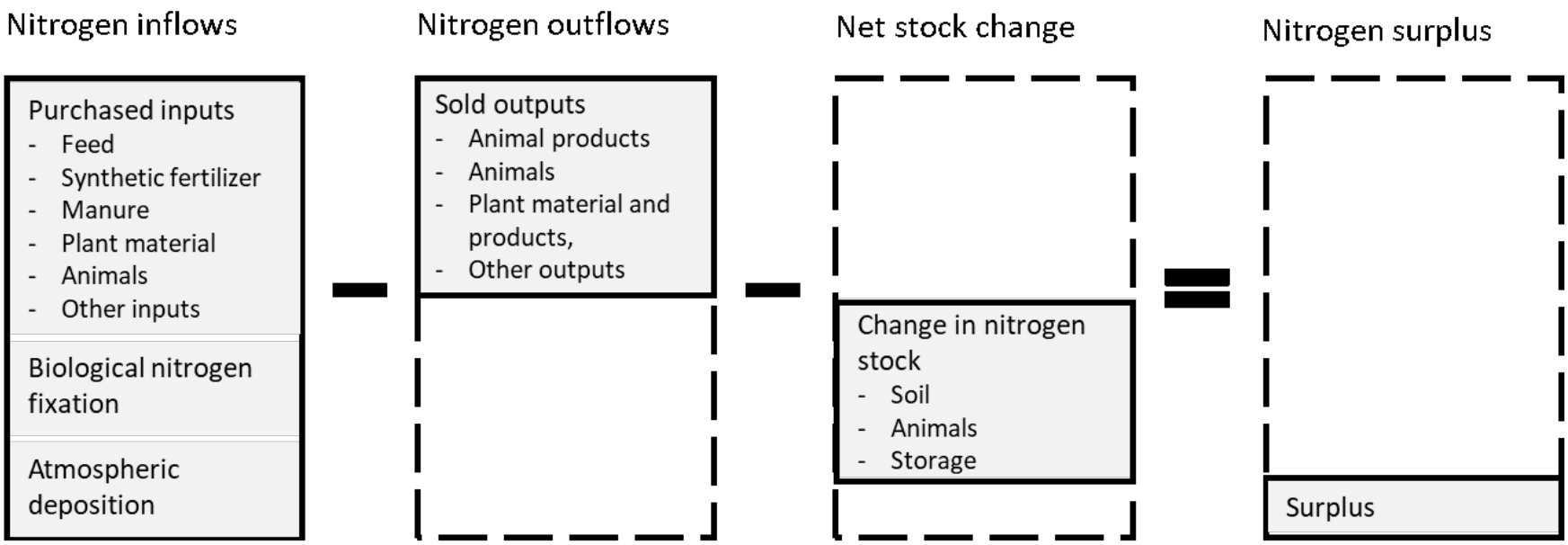
Conclusions

- Multi-equation modeling approach of Murty et al. (2012) is suitable for considering pollutants in a productivity framework.
- Next step: consideration of positive externalities (e.g. soil organic matter, animal welfare).

Descriptive statistics for Dutch dairy farms, 2006-2017

Variable	Dimension	Average	Average annual % growth (price-corrected)
Land	Hectares	50	1.87
Labor	Annual working hours	4,197	1.29
Cows	Number of milking cows	119	3.33
Capital value	Euro	337,735	5.31
Seeds expenditure	Euro	2,723	0.52
Purchased feed expenditure	Euro	52,685	7.63
Pesticides expenditure	Euro	2,241	3.60
Fertilizer expenditure	Euro	5,476	2.11
Energy expenditure	Euro	6,182	4.36
Veterinary costs expenditure	Euro	7,672	4.14
Contract work	Euro	17,580	5.91
Machinery rental	Euro	18,534	5.45
Dairy + cattle income	Euro	240,654	4.97
Other income	Euro	7,565	−1.91
Nitrogen surplus	Kilogram	12,801	1.85

Calculation of N surplus



Ang, F. (2019): "Analyzing Components of Productivity Growth using the Bennet-Lowe Indicator: An Application to Welsh Sheep Farms," *American Journal of Agricultural Economics*, 101, 1262–1276.

Ang, F., K. Kerstens, and J. Sadeghi (2022): "Energy productivity and greenhouse gas emission intensity in Dutch dairy farms: A Hicks–Moorsteen by-production approach under non-convexity and convexity with equivalence results," *Journal of Agricultural Economics*.

Bjurek, H. (1996): "The Malmquist Total Factor Productivity index," *Scandinavian Journal of Economics*, 98, 303–313.

Lamkowsky, M., O. Oenema, M. P. M. Meuwissen, and F. Ang (2021): "Closing Productivity Gaps among Dutch Dairy Farms Can Boost Profit and Reduce Nitrogen Pollution," *Environmental Research Letters*, 16, 124003.

Murty, S., R. R. Russell, and S. B. Levkoff (2012): "On Modeling Pollution-Generating Technologies," *Journal of Environmental Economics and Management*, 64, 117 – 135.