Revealing the cost of environmental services in dairy farms

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Motivation

- Increasing awareness of environmental concerns in agriculture
- Possible trade-off between climate change and biodiversity impact
- Important role of the agricultural sector through public policies and private initiatives
- Understanding the real cost of environmental services provided by farms
  - Make improved decisions about agricultural sustainability
  - Encourage to take account of efforts to preserve and protect the environment in trade negotiations

Literature

- Relationship between environmental services and their production costs
  - High production costs for label and organic farms (Uematsu et al; Froehlich et al.)
  - Studies rarely carried out for conventional farms (Rosa-Schleich et al.)

Our aim

- Evaluating the real cost of environmental performance in conventional dairy farms
  - Method 1: Mixed-effects panel model
  - Method 2: Generalized propensity score model
  - GHG emission and crop diversity index
  - Controling for unobserved heterogeneity in production conditions (Wolf et al.)
  - Also consider the effect of structural factors (Jan et al.)

- Individual accounting data for Bretagne

➢ Economic indicator or variable of interest

- **Milk production cost (*€ /1000 liters*)**

➢ Environmental performance indicators

- **Greenhouse gas emissions (*Kg CO2 eq /hectare*)**

$$cctot_i = \sum_j q_j * cc_j + \sum_h q_h * cc_h$$

  - q_j quantity produced per crop
  - cc_j unit emissions indicator per kg of crop produced
  - q_h quantity produced by animal category
  - cc_h unit emissions indicator per kg of animals produced

- **Crop diversity index (Shannon index)**

$$H' = -\Sigma\, pi * log(pi)$$

  - pi the proportion of each crop in the farm's total area

➢ Building environmental performance classes

Farm classification according to GHG emission

Farm number	GHG score	Environmental Performance
1	7	High
2	5	Average
3	9	Very high
4	0	Low
5	3	Very low
...		

Farm classification according to Shannon index

Farm number	Shannon index	Environmental Performance
1	<1	Unfavorable
2	Between 1 and 1.8	Neutral
3	>1.8	Favorable
...		

Data

- Individual accounting data for specialized conventional dairy farms in Bretagne
  - Share of dairy product over total product exceeds 70%

- Unbalanced panel of 1,747 farms over 3 years (2020 - 2022)
  - 2,092 observations (1.2 observations per farm)
  - 697 observations per year

Sample characteristics

Variables	Mean	sd	Min	Max
Total UTH	1.85	0.79	1	6.1
UAA *(ha)*	94	42	25	461
Number of dairy cows	79	34	20	313
% area Corn/ forage area	44	13	0	110
Livestock density (Bovine unit/ha)	1.69	0.40	0.77	7.51
Milk produced *(liters)*	618,600	311,300	113,900	2,409,200
Milk *(liters /dairy cows)*	7,600	1,300	2,900	11,700
GHG emissions *(Kg/ha)*	9,100	2,200	3,100	14,900
GHG emissions *(Kg/liter)*	1.39	0.15	1.07	2.48
Shannon index	1.1	0.5	0.0	2.7
Production cost *(€/1000l)*	502	82	308	1,121

Milk production costs by emission (GHG) class

	Very low	Low	Average	Strong	Very strong
Production cost (€/1000l)	466	480	491	511	560
Feeding	112	108	106	107	100
Workshop management	52	52	53	55	54
Mechanization	73	75	80	81	93
Building	65	66	62	63	63
Miscellaneous management expenses	25	27	28	30	36
Land	18	20	21	23	30
Working capital	13	13	13	13	14
Labor	109	118	128	137	169
Productivity (litres/Total labour)	411,300	375,100	346,100	325,900	271,900

Milk production costs by Shannon class

	Unfavorable	Neutral	Favorable
Production cost (€/1000l)	504	501	497
Feeding	108	106	108
Workshop management	53	54	54
Mechanization	81	80	78
Building	66	63	62
Miscellaneous management expenses	29	30	29
Land	22	23	22
Working capital	14	13	12
Labor	131	133	132
Productivity (liters/Total labour)	350,700	344,400	335,200

Identification strategy

Method 1: Mixed-effects model

$$y_{it} = \alpha_0 + Z'_{it}\alpha + \gamma_t + \mu_i + \varepsilon_{it}$$

- y_t production cost in year t for individual i
- γ_t temporal effects
- μ random individual effects
- Z'_t explanatory variables vector
- ε_t residual

Method 2: Generalized propensity score model

$$y_i = \beta_0 + \sum_{c=2}^{5} \beta_c T_{c,i} + \varepsilon_i$$

- y production cost
- T_c environmental performance class
- β_c effect of environmental performance compared with the reference class
- ε residual

The effect of GHG emission/ha on production costs

- 77% of production cost variability is due to inter-farm variability
- Higher environmental performance significantly increases costs
- The service cost curve has a quadratic shape
- Same trend with the two methods (form of validation and robustness of results)

	Mixed effects model		IPTW method	
	Coefficients	Standard errors	Coefficients	Standard errors
Constant	460.85	(4.17)***	515.67	(9.8)***
Performance_ghgLow	18.60	(5.69)***	14.27	(4.68)***
Performance_ghgAverage	33.35	(5.59)***	26.46	(5.17)***
Performance_ghgHigh	58.96	(5.50)***	50.21	(5.73)***
Performance_ghgVery high	40.25	(5.15)***	89.76	(6.56)***
Number of observations		2,092		2,092
R2		35%		10%

*** *1%*

The effect of Shannon index on production costs

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- Higher environmental performance significantly decreases costs
- The service cost curve has a quadratic shape
- Same trend with the two methods (form of validation and robustness of results)

	IPTW* method		Mixed effects model	
	Coefficients	Standard errors	Coefficients	Standard errors
Constant	508.51	(3.11)***	495.80	(10.71)***
Performance_shannonNeutral	-8.34	(4.44)***	-7.75	(3.10)**
Performance_shannonFavorable	-15.41	(4.42)***	-11.98	(6.53)*

*** 1%

Conclusion

- Existing environmental efforts in conventional dairy farms with large individual heterogenity
- The mixed effects model fits better than propensity score method (individual effects)
- Milk marginal production cost
  - increases with GHG/ha performance class (+58.96 €/1000l from very low to high)
  - Decreases with Shannon index performance class (-8.34 €/1000l from unfavorable to neutral)
- Possible trade-off between GHG/ha perfomance and biodiversity performance at farm scale
- Choice of indicators and ranking method debatable

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Thanks for your attention!

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