Influence of heat and drought stress on economic efficiency and resilience of EU dairy farms

Sylvain Quiédeville (sylvain.quiedeville@fibl.org)

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Introduction

- Increasing challenges at farm level in the context of climate change
- Heat and drought stress are two key climate related challenges at farm level, often impacting the production and economic performance
- Limited evidence on the association of climate challenges and dairy farm performance
- Economic efficiency and resilience are relevant indicators of performance

What is the influence of heat and drought stress on economic efficiency and resilience on EU dairy farms?

In the frame of the H2020 project Gentore (GENomic management Tools to Optimize Resilience and Efficiency) (2017-2022)
Data

- FADN database from 2007 to 2013
- Panel data of 4,669 individual farms in 24 EU countries
- Performance measurement: technical efficiency and economic resilience
- Output expressed in milk yield per dairy cow
- Inputs expressed in constant monetary values (2013)
- Climate indicators: regional heat and drought stress (derived from the Agri4cast database)
Steps

- Use of a Latent Class model (Orea and Kumbhakar, 2004) to assign NUTS2 regions to climatic classes that represent similar production environments

- Estimation of technical efficiency and economic resilience by class using a panel stochastic frontier model (Battese and Coelli, 1995) and a downside risk parameter (Chavas, 2008), respectively

- Evaluation of the influence of heat and drought stress on efficiency and resilience using regression models

(Unit of analysis: dairy cow)
**Efficiency methodology (1)**

- Cobb-Douglas functional form: underlying assumption of constant returns to scale tested (Abdulai and Huffman, 2000)
- Time-varying model with true fixed-effects (Greene, 2005)
- Half-normal distribution for the inefficiency term (Kumbhakar et al. 2015).
- Input variables:
  - Feed
  - Forage
  - Machinery
  - Labour
  - Others
Efficiency methodology (2)

- In the frame of the SF panel model, the effect of climatic stress on the inefficiency term is investigated (combined estimation process)

- Climatic regressors:
  - number of periods of at least 40 consecutive dry days (<3mm/day)
  - the same variable but with a lagged effect (previous year)
  - the number of periods of at least 3, 10, or 20 consecutive days, depending on the class characteristics, with a Temperature Humidity Index (THI) strictly above 60

\[
THI = (1.8T_{db} + 32) - [(0.55 - 0.0055R_H) \times (1.8 + T_{db} - 26.0)] \quad (NRC, 1971)
\]

- Additional regressors
  - farm size (UAA)
  - stocking density
  - dairy specialisation rate
  - price of milk (/dt)
Economic resilience methodology

- Downside risk calculated on an annual basis for each farm
  
  = actual gross margin – average gross margin over 2007-2013

- Tobit panel data model (dependent variable right censored at the 0 value) (Tobin, 1958)

- Same climatic and additional regressors as in efficiency analysis
### Class splitting

<table>
<thead>
<tr>
<th>ZONE</th>
<th>North Atlantic (NA)</th>
<th>West Atlantic (WA)</th>
<th>Boreal (BOR)</th>
<th>Continental (CON)</th>
<th>Southern (SOU)</th>
<th>Mountain / Upland (UPL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Cool and wet, with little temperature variation</td>
<td>Moderate temperature, with warmer summers, cooler winters</td>
<td>Very cold winters, moderate summer, dry</td>
<td>Warm summers, cold winters</td>
<td>Hot summers, cool winters</td>
<td>Relatively warm summers and cool winters, variable rainfall</td>
</tr>
<tr>
<td>Production (kg/cow)</td>
<td>5,842</td>
<td>7,259</td>
<td>8,624</td>
<td>5,981</td>
<td>6,818</td>
<td>6,366</td>
</tr>
<tr>
<td>Farm size (ha)</td>
<td>77</td>
<td>76</td>
<td>71</td>
<td>65</td>
<td>49</td>
<td>47</td>
</tr>
</tbody>
</table>
Technical efficiency score (0;1)

- High average efficiency scores: from 0.88 in class SOU and UPL to 0.95 in class NA and CON
- Flatter efficiency distribution in class SOU and UPL
## Influence of drought and heat stress on inefficiency (0;1)

<table>
<thead>
<tr>
<th>Class</th>
<th>NA</th>
<th>WA</th>
<th>BOR</th>
<th>CON</th>
<th>SOU</th>
<th>UPL</th>
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<tbody>
<tr>
<td>Observations</td>
<td>2,366</td>
<td>9,611</td>
<td>1,596</td>
<td>13,174</td>
<td>2,135</td>
<td>3,801</td>
</tr>
<tr>
<td>Individual farms</td>
<td>338</td>
<td>1,373</td>
<td>228</td>
<td>1,882</td>
<td>305</td>
<td>543</td>
</tr>
<tr>
<td>Periods ≥ 40 consecutive dry days</td>
<td>-0.072</td>
<td><strong>0.448</strong>*</td>
<td>0.389</td>
<td>-0.111</td>
<td>0.322</td>
<td><strong>0.691</strong>*</td>
</tr>
<tr>
<td>Lagged periods ≥ 40 consecutive dry days</td>
<td><strong>4.471</strong>*</td>
<td>0.327</td>
<td>-0.349</td>
<td>0.205</td>
<td><strong>0.662</strong>*</td>
<td></td>
</tr>
<tr>
<td>Periods ≥ 3 consecutive hot days</td>
<td><strong>0.811</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periods ≥ 10 consecutive hot days</td>
<td></td>
<td><strong>0.495</strong>*</td>
<td><strong>0.368</strong>*</td>
<td>-0.02</td>
<td></td>
<td><strong>-0.182</strong>*</td>
</tr>
</tbody>
</table>
| Periods ≥ 20 consecutive hot days | | | | | | **0.858**
| Farm size              | -0.015 | **-0.010*** | **-0.013*** | -0.02 | -0.001 | -0.001 |
| Stocking density       | **-0.273*** | **0.222*** | **-0.187*** | -0.119 | **0.080*** | 0.092 |
| Specialisation         | **-0.062*** | **-0.040*** | **-0.055*** | **-0.070*** | **-0.046*** | **-0.030*** |
| Milk price             | 0.007 | **0.084*** | **0.171*** | **0.074*** | **0.067*** | **0.034*** |
| Constant               | -1.229 | **-5.584*** | **-7.613*** | -2.408 | **-5.042*** | **-2.851*** |
Resilience outcome

- Similar trends across all classes apart from class BOR
Influence of drought and heat stress on economic resilience (€/cow)

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<td>543</td>
</tr>
<tr>
<td>Periods ≥ 40 consecutive dry days</td>
<td><strong>191.138</strong>*</td>
<td><strong>93.092</strong>*</td>
<td><strong>-95.305</strong>*</td>
<td><strong>-70.072</strong>*</td>
<td><strong>-112.083</strong>*</td>
<td><strong>-74.846</strong>*</td>
</tr>
<tr>
<td>Lagged periods ≥ 40 consecutive dry days</td>
<td><strong>-227.229</strong>*</td>
<td><strong>-107.284</strong>*</td>
<td><strong>-112.079</strong>*</td>
<td><strong>-0.649</strong></td>
<td><strong>-61.779</strong>*</td>
<td></td>
</tr>
<tr>
<td>Periods ≥ 3 consecutive hot days</td>
<td><strong>-98.508</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periods ≥ 10 consecutive hot days</td>
<td></td>
<td><strong>-11.277</strong>*</td>
<td><strong>-23.034</strong>*</td>
<td><strong>30.204</strong>*</td>
<td><strong>29.761</strong>*</td>
<td></td>
</tr>
<tr>
<td>Periods ≥ 20 consecutive hot days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>-169.897</strong>*</td>
</tr>
<tr>
<td>Farm size</td>
<td>-0.553***</td>
<td>0.233***</td>
<td><strong>-0.216</strong>*</td>
<td><strong>-0.516</strong>*</td>
<td>0.065***</td>
<td>0.051***</td>
</tr>
<tr>
<td>Stocking density</td>
<td>7.944***</td>
<td>-6.289***</td>
<td><strong>44.136</strong>*</td>
<td><strong>-16.735</strong>*</td>
<td>-4.926***</td>
<td><strong>-19.858</strong>*</td>
</tr>
<tr>
<td>Specialisation</td>
<td>0.846***</td>
<td>-0.962***</td>
<td><strong>17.617</strong>*</td>
<td><strong>0.170</strong>*</td>
<td><strong>6.108</strong>*</td>
<td><strong>2.511</strong>*</td>
</tr>
<tr>
<td>Milk price</td>
<td>38.243***</td>
<td>40.286***</td>
<td><strong>2.198</strong>*</td>
<td><strong>13.228</strong>*</td>
<td><strong>4.857</strong>*</td>
<td><strong>11.465</strong>*</td>
</tr>
<tr>
<td>Constant</td>
<td><strong>-1,123.333</strong>*</td>
<td><strong>-1,331.317</strong>*</td>
<td><strong>-1,447.720</strong>*</td>
<td><strong>-395.127</strong>*</td>
<td><strong>-273.006</strong>*</td>
<td><strong>-588.608</strong>*</td>
</tr>
</tbody>
</table>
Conclusions

- Technical efficiency:
  - High technical efficiency of farms in the EU dairy sector
  - Little influence of drought
  - Significant negative influence of the heat across all classes apart from class UPL
  - Little scope for efficiency improvement, but heat stress adaptation strategies need to be further considered

- Economic resilience:
  - Significant negative influence of the drought across all classes, but less clear in class NA and WA
  - Significant negative influence of the heat across all classes apart from class CON and UPL
  - Clear threats to economic resilience, requiring adaptation strategies
References


Thanks for your attention!

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