Extreme Weather, Adaptation Strategies and Resilience in Swedish Dairy Production

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Introduction

- Extreme weather and climate change has adverse impacts on agricultural productivity (Burke, Hsiang and Miguel 2015; Roberts, Schlenker and Eyer 2013; Ortiz-Bobea et al. 2021).
- Extreme weather has negative impacts on dairy productivity and animal health (Blanco-Penedo et al. 2020; Finger et al. 2018)
- However, the relationship between extreme weather and dairy productivity, breed-level diversification, and resilience is unknown.

Research Objectives

- To estimate the relationship between temperature and milk production.
- To estimate the farm-level loss due to extreme summer of 2018.
- To estimate the impact of heatwaves on different dairy breeds.
- To estimate the trade-off between genetic milk production potential and resilience to heatwaves.

Data

- Weather data (from 2016 – 2019) from 887 weather stations throughout Sweden.
- Monthly milk record data from 2016 - 2019, at farm and cow-level, from Swedish Milk and Disease Recording System (SMDRS).
- Data merged using the ‘meteoland’ package in R to account for spatial correlations between neighboring weather stations.
- Heatwave defined as 5 consecutive days above 25 degrees Celsius (SMHI definition).

Herd-Level Summary Statistics

	Mean	SD	Min	Max
Milk per cow (kg)	26.5	4.1	5.62	42.6
ECM per cow	31.9	4.2	12.0	47.0
BMSCC	247.7	109.7	11.3	1274.0
Heatwave	0.02	-	0	1
Temperature	10.9	8.6	-17.7	30.6
Humidity	94.2	6.2	61.8	100.0
Precipitation	1.72	1.6	0	11.8
Herd Size	104.6	80.1	16	1155

Cow-level Summary Statistics

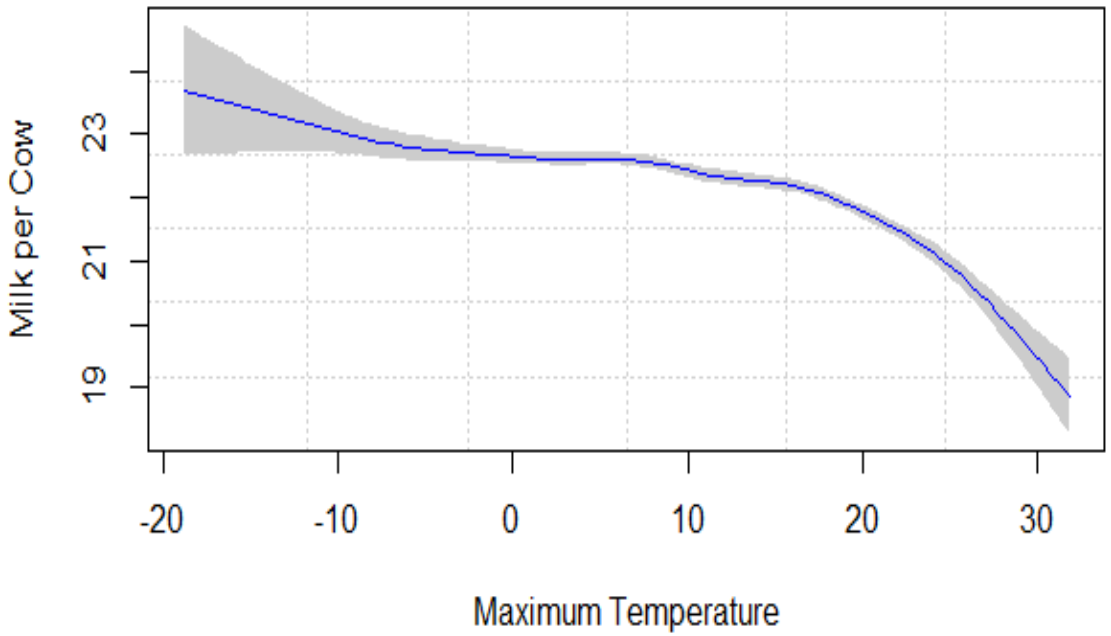
	Mean	SD	Min	Max
Milk per cow (kg)	31.5	9.75	0	99.7
Lactation Number	2.21	1.33	1	16
Days in Milk	196.7	131.4	1	1455
Swedish Holstein	0.52	-	0	1
Swedish Red	0.23	-	0	1
Red/Holstein	0.07	-	0	1
Other	0.18	-	0	1
Milk Index	0.987	0.059	0.495	1.285

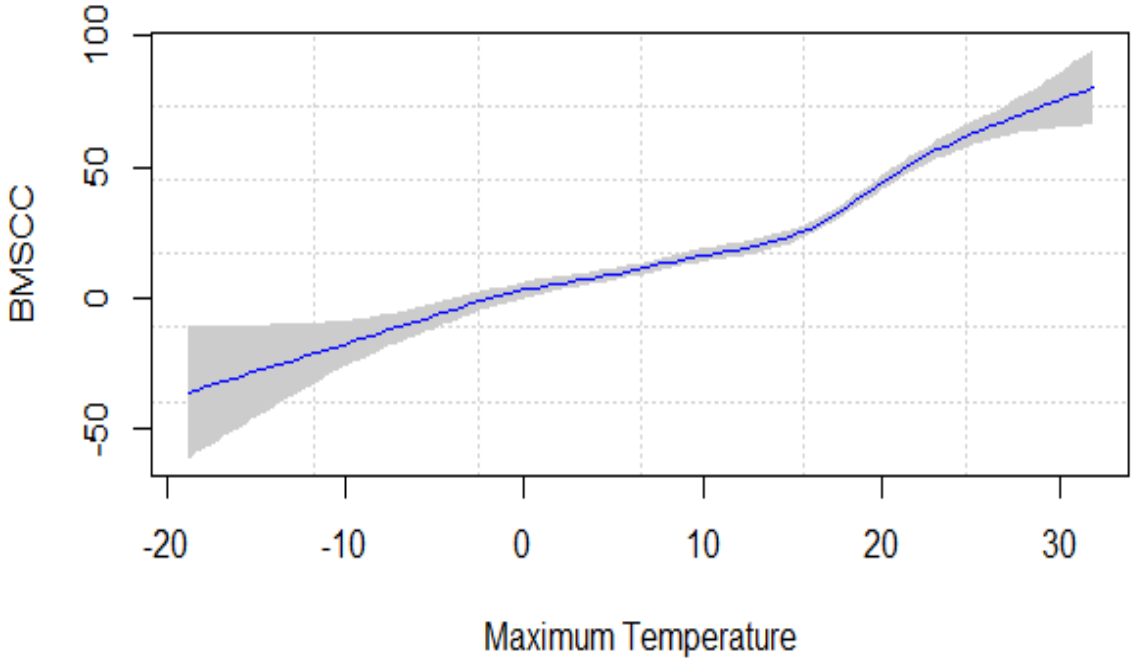
Methods: Relationship between temperature and Milk Production

- We use Generalized Addition Models (GAMs) with farm-by-season fixed effects.

$$Milk_{ist} = \beta_0 + \sum_{j=1}^{p} f_j[(Temp_{ist})] + \gamma X_{ist} + \mu_{is} + e_{ist}$$

Results from GAMs





Temperature Bin Approach to Estimate Losses

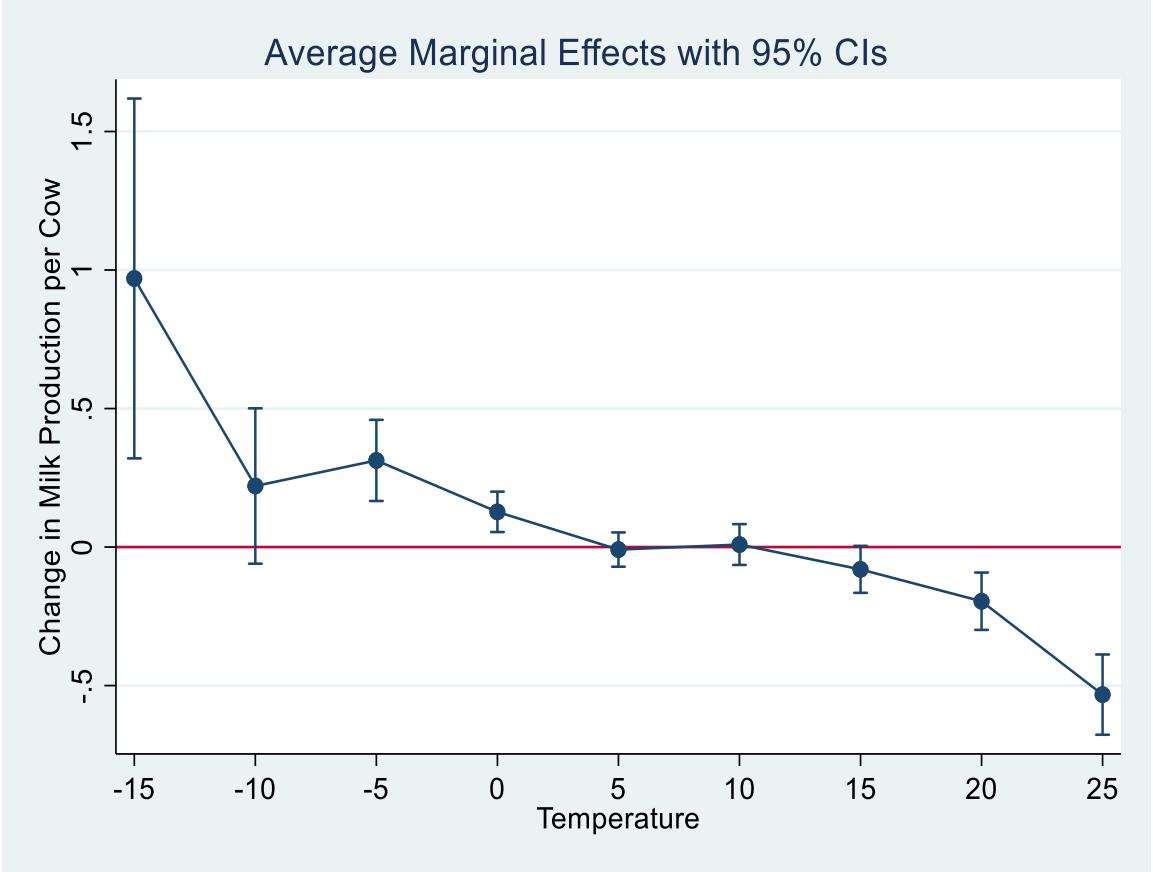
$$Milk_{ist} = \beta_0 + \beta_m \sum_m Tbin_{ist}^m + \gamma X_{ist} + \mu_{is} + e_{ist}$$

With coefficients plotted in the figure.

$$Loss_{it} = (\sum_m \beta_m * No.of\ Days_{it}) * IOFC * Herd\ Size_i$$

We estimate losses of about ~700 EUR for an average farm (SD of 5980) in 2018.

Lower-bound of the actual loss



Impact of Breed Diversification

$$Milk_{ijst} = \alpha_0 + \varphi Heatwave_{jst} + \sum_{m=1}^{M} \alpha_m Breed_{mi} + \sum_{m=1}^{M} \delta_m Breed_{mi} * Heatwave_{jst} + \rho X_{ijst} + \theta_{js} + e_{ijst}$$

δ_m is a vector of coefficients that captures the differential effects of heatwaves on different cow breeds. Any $\delta_m \neq 0$ would provide evidence of differences in the effect of heatwaves on different cow breeds and thus would provide evidence of whether diversification in breeds can work as an adaptation strategy in the Swedish context.

Results: We do not find differential impacts of heatwaves on different breeds.

Genetic Milk Production Potential and Resilience

$$Milk_{ijst} = \beta + \mu Heatwave_{jst} + \varphi MilkIndex_i + \gamma MilkIndex_i * Heatwave_{jst} + \tau X_{ijst} + \theta_{js} + e_{ijst}$$

MilkIndex is genetic milk production potential.

The coefficient on the interaction term, $MilkIndex_i * Heatwave_{jst}$, determines whether there is a trade-off between genetic potential and resilience to climate shocks.

$\gamma < 0$ would indicate that as the genetic milk production potential of a cow increases, its performance under a heatwave goes down.

Resilience: Results

A 10% increase in genetic milk production potential (milk index) related to 27% increase in the impact of heatwave on milk loss.

Policy Implications and Conclusions

- As extreme weather events becomes more likely, dairy industry will face increased losses.
- Diversification in breeds doesn’t seem to blunt climate shocks.
- Will need to change breeding strategies such that the trade-off between milk production potential and climate resilience is minimized.