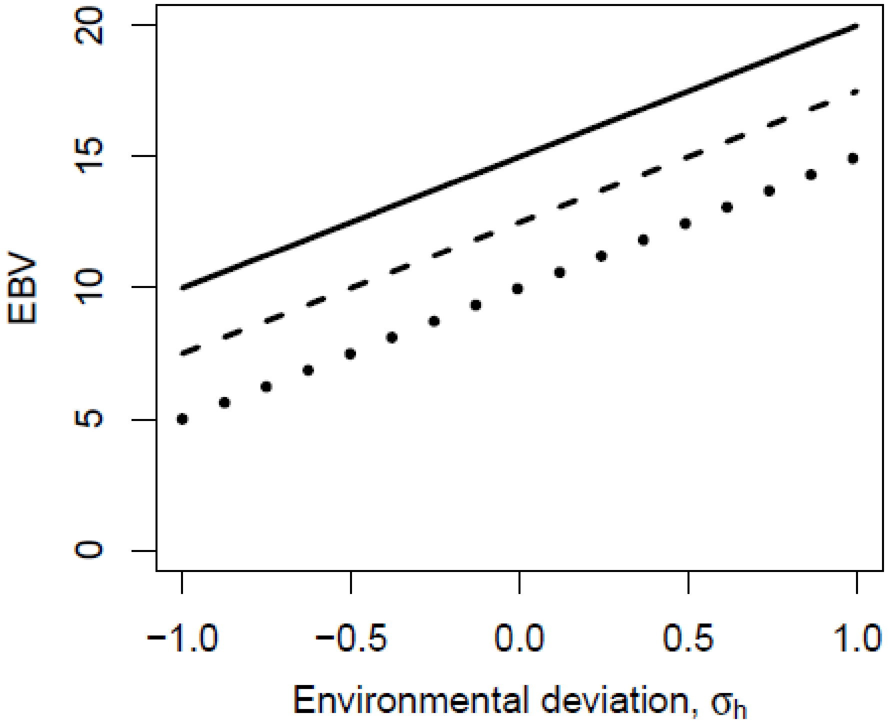
Adjusting for macro-environmental sensitivity in growth rate

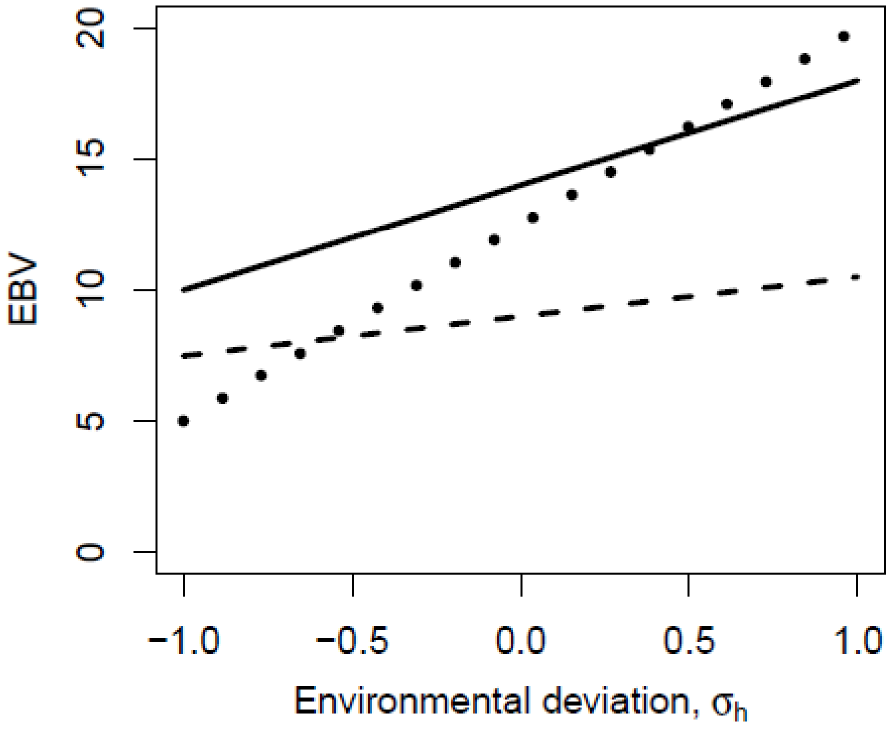


Macro-ES ≠ G×E

- Macro-ES → change in EBV across environments



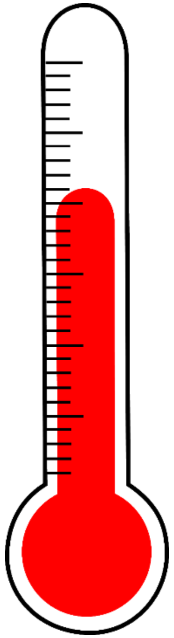
- G×E → differences in change between genotypes

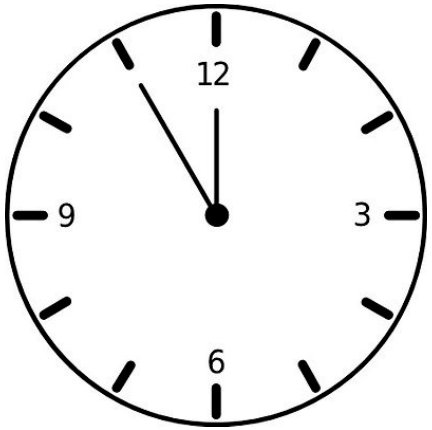


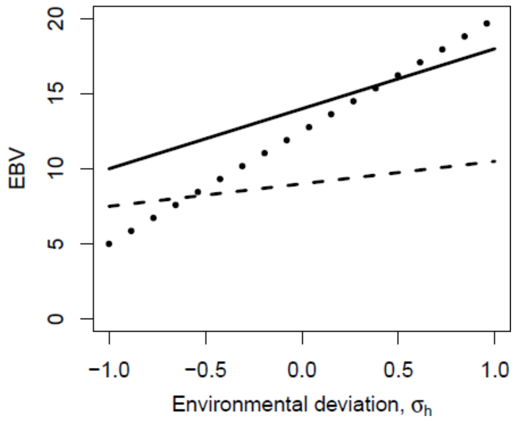
Statistical approaches

- Character state models
  - Discrete environments

- Reaction norm models
  - Continuous environments







The problem of knowing the environment

- Phenotypic means as covariate
- Pre-estimated covariates
- Iteratively updated covariate

Bayesian analysis of the linear reaction norm model with unknown covariates
G. Su, P. Madsen, M. S. Lund, D. Sorensen, I. R. Korsgaard and J. Jensen
2006

CENTER FOR QUANTITATIVE GENETICS AND GENOMICS

Macro-environmental sensitivity for growth rate in Danish Duroc pigs is under genetic control[1]

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2018

GenSAP

DET FRIE FORSKNINGSRÅD
DANISH COUNCIL FOR INDEPENDENT RESEARCH

Miljø- og Fødevareministeriet gudp

Data

SEGES

- Phenotype: ADG (g/day)
  - Sex specific trait, r_g=0.88 (Nielsen et al., 2018)

	Boars	Gilts
#Records	32,297	42,724
Mean (g/day)	1,184	1,117
SD (g/day)	123	108
#Herds	16	19

		Boars			Gilts		
		HYM	Group	Litter	HYM	Group	Litter
#Levels		1212	3398	13802	1280	4200	14973
#Animals per level	Mean (SD)	27 (16)	10 (2)	2 (1)	33 (21)	10 (2)	3 (2)
	Min	2	1	1	3	1	1
	Max	103	15	10	139	15	14

Model

- Univariate reaction norm model

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za_0} + \mathbf{Ha^*} + \mathbf{Wh} + \mathbf{Vp} + \mathbf{Ll} + \mathbf{e}$$

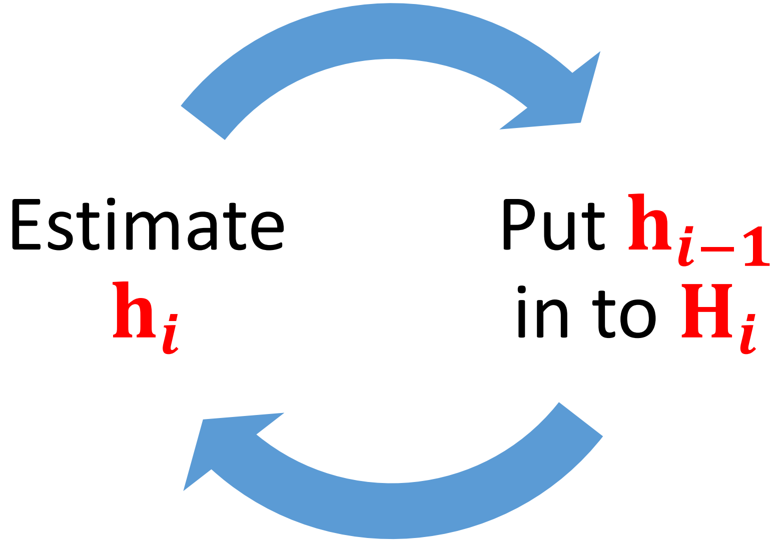
$\mathbf{y}$: Response variable - ADG $\mathbf{b}$: Fixed parameters $\mathbf{a_0}$: Intercept of additive genetic variance $\mathbf{a^*}$: Slope of additive genetic variance $\mathbf{h}$: Herd−Year−Month on test (HYM) $\mathbf{p}$: Group $\mathbf{l}$: Litter $\mathbf{e}$: Residual variance $\mathbf{X}$, $\mathbf{Z}$, $\mathbf{W}$, $\mathbf{V}$ and $\mathbf{L}$: Design matrices $\mathbf{H}$: Design matrix with environmental covariate	$\begin{bmatrix}\mathbf{a_0}\\ \mathbf{a^*}\end{bmatrix} \sim N\left(\mathbf{0}, \mathbf{A} \otimes \begin{bmatrix}\sigma^2_{a_0} & \sigma_{a_0,a^*}\\ \sigma_{a_0,a^*} & \sigma^2_{a^*}\end{bmatrix}\right)$ $\mathbf{h} \sim N(\mathbf{0}, \mathbf{I}\sigma^2_h)$ $\mathbf{p} \sim N(\mathbf{0}, \mathbf{I}\sigma^2_p)$ $\mathbf{l} \sim N(\mathbf{0}, \mathbf{I}\sigma^2_l)$ $\begin{bmatrix}e_1\\ \vdots\\ e_m\end{bmatrix} \sim N\left(\mathbf{0}, \begin{bmatrix}\mathbf{I}\sigma^2_{e_1} & \cdots & 0\\ \vdots & \ddots & \vdots\\ 0 & \cdots & \mathbf{I}\sigma^2_{e_m}\end{bmatrix}\right)$

Approach

- $\mathbf{y} = \mathbf{Xb} + \mathbf{Za}_0 + \mathbf{Ha}^* + \mathbf{Wh} + \mathbf{Vp} + \mathbf{Ll} + \mathbf{e}$

- Covariate ($\mathbf{H}$) updated in each iteration based on the HYM effect ($\mathbf{h}$)

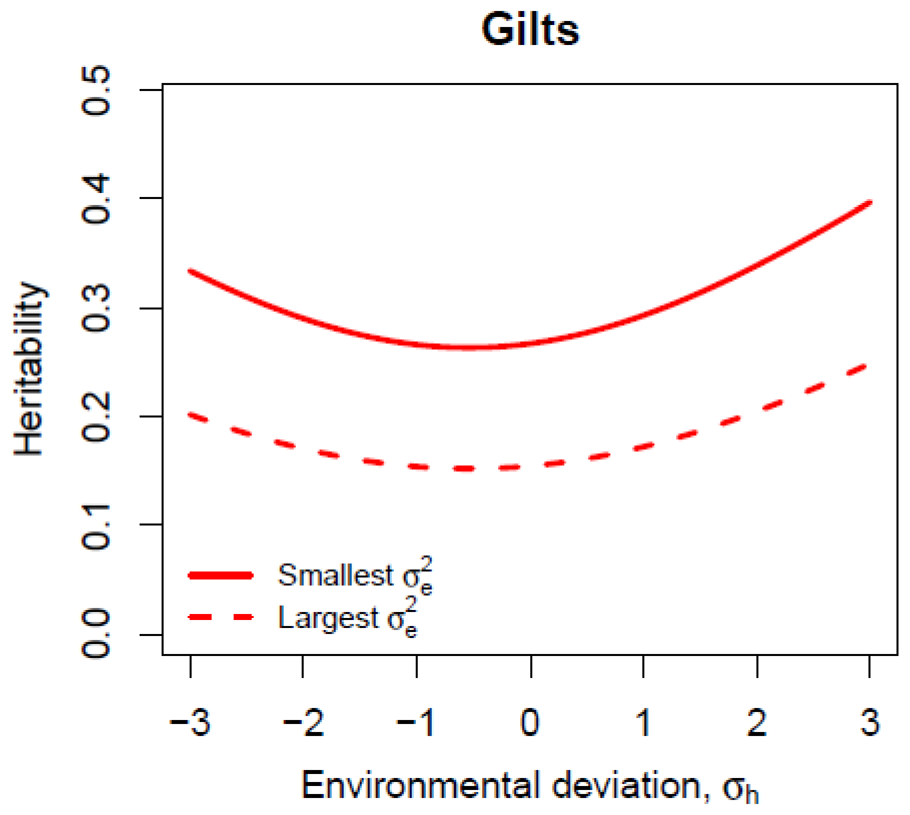
- RJMC module in DMU (Madsen and Jensen, 2013)
- Bayesian setting (Gibbs sampling)
  - 2.5 M rounds
  - 500k burn-in
  - 200 interleave



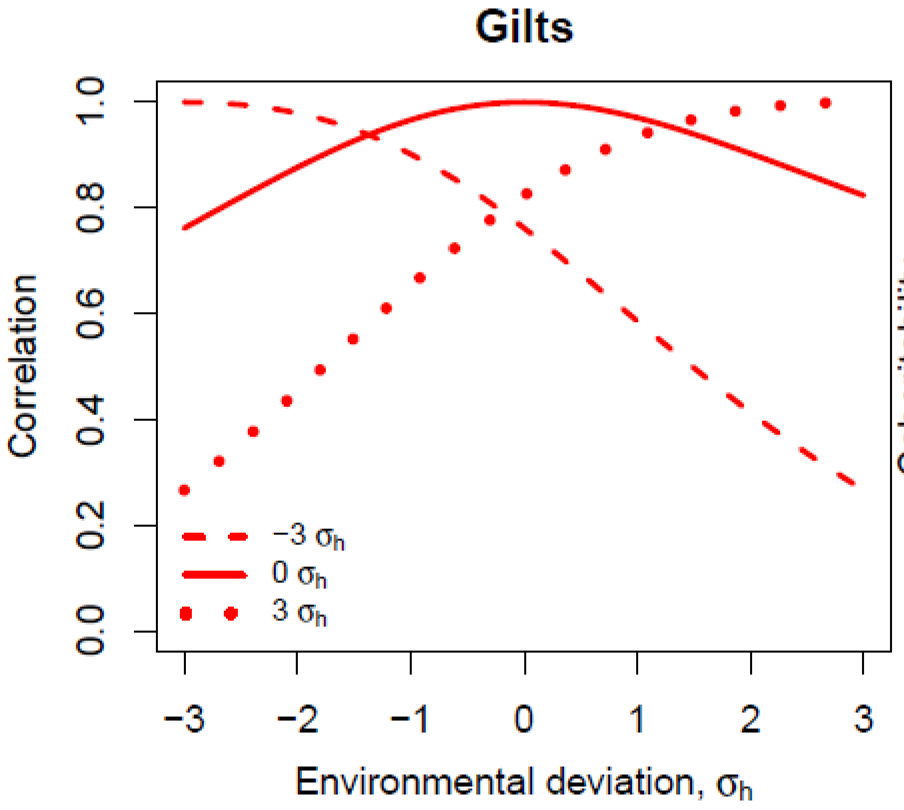
σ_a^2 and h^2

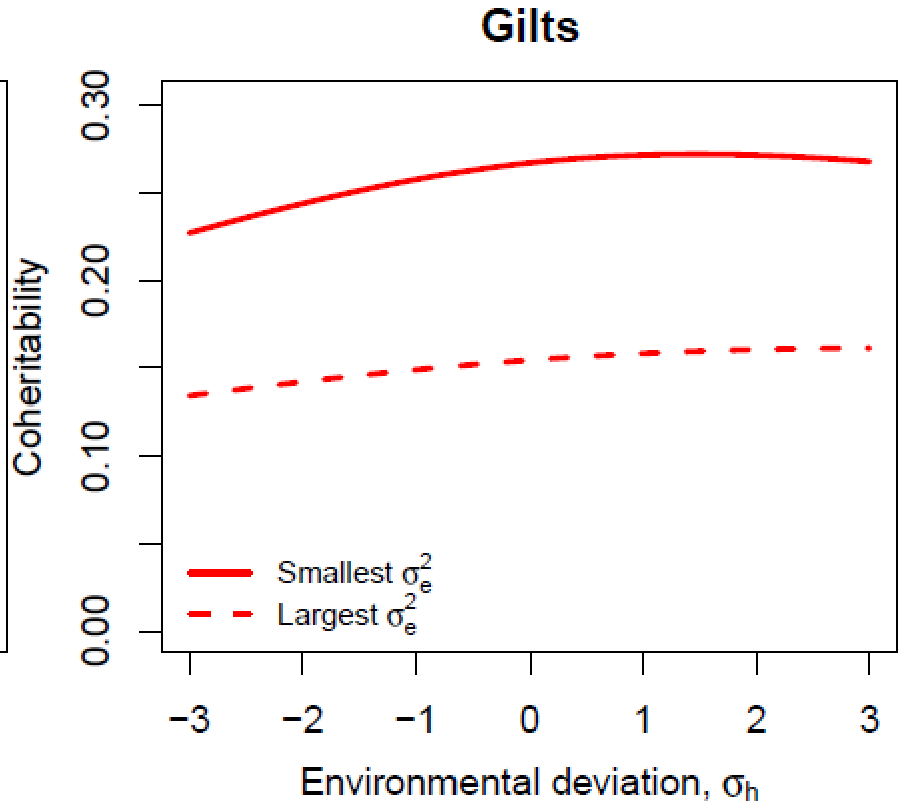
	Boars	Gilts
$\sigma_{a_0}^2$	1385[a]	1333[a]
$\sigma_{a^*}^2$	0.014[a]	0.024[a]
r_{a_0,a^*}	-0.227	0.144
σ_h^2	5076[a]	3755[a]

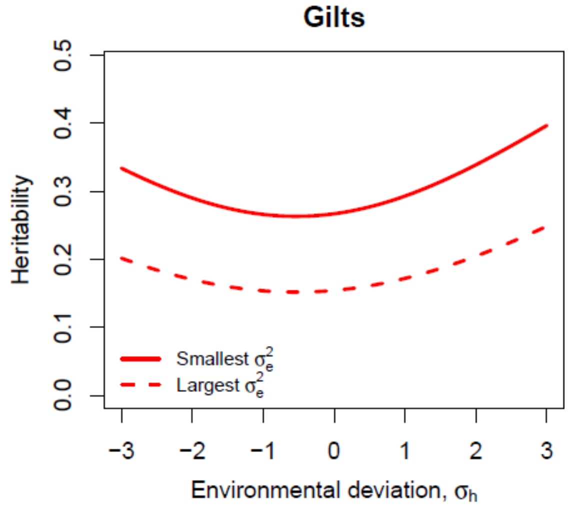
[a] significantly different from zero



r_g and ch^2


Gilts
Correlation
0.0
0.2
0.4
0.6
0.8
1.0
−3 σh
0 σh
3 σh
−3
−2
−1
0
1
2
3
Environmental deviation, σh


Gilts
Coheritability
0.00
0.10
0.20
0.30
Smallest σe2
Largest σe2
−3
−2
−1
0
1
2
3
Environmental deviation, σh


Gilts
Heritability
0.0
0.1
0.2
0.3
0.4
0.5
Smallest σe2
Largest σe2
−3
−2
−1
0
1
2
3
Environmental deviation, σh

Benefits of the iterative update

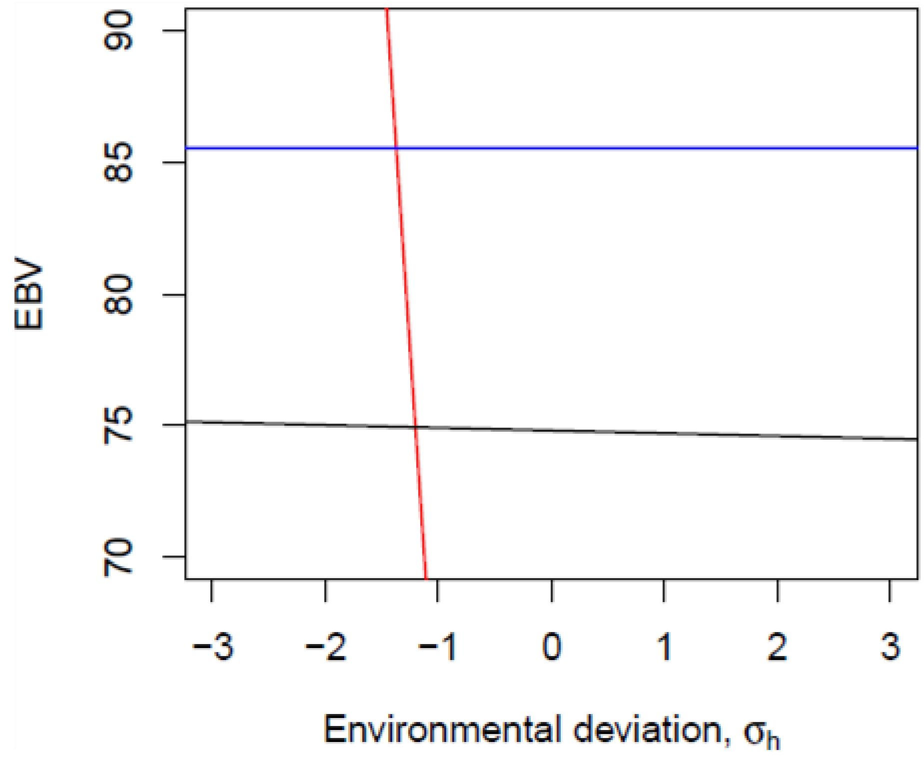
- Comparison between
  - Iteratively updated covariate model (I)
  - Phenotypic means as covariate model (PM)

Prediction ability	Boars		Gilts	
	I	PM	I	PM
Direct EBV	0.69	0.59	0.74	0.72
Macro-ES EBV	0.77	0.58	0.90	0.73

Bias	Boars		Gilts	
	I	PM	I	PM
Direct EBV	0.98 (0.03)	0.73 (0.03)	1.00 (0.03)	0.73 (0.02)
Macro-ES EBV	0.69 (0.02)	0.70 (0.03)	0.86 (0.01)	0.74 (0.02)

How to use it

- Decrease macro-ES
  - Less response to change
- Decrease G×E
  - Similar response to change
- Environment specific selection
  - InterBull



Take home message

Thank you

- G×E allows for adjusting macro-ES
- Growth rate in Danish Duroc exhibits G×E
- Reducing macro-ES of ADG in Danish Duroc will not reduce the level
- Coheritability can increase even if genetic correlations decrease
- The iteratively updated model performed better than a model with phenotypic means.