The relationship between heritability and genotype-by-environment interaction using reaction norm analyses in Merino sheep traits

G. E. Pollott[1] and J. C. Greeff[2]

[1]Imperial College London, Department of Agricultural Sciences, Wye, Ashford, Kent, TN25 5AH, UK.,

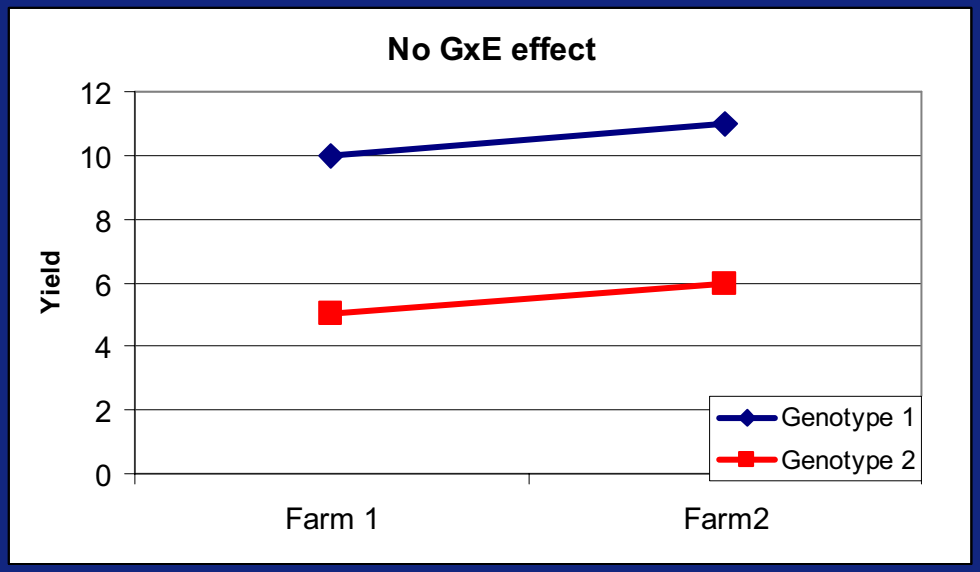
[2]Great Southern Agricultural Research Institute, 10 Dore Street, Katanning, WA 6317, Australia,

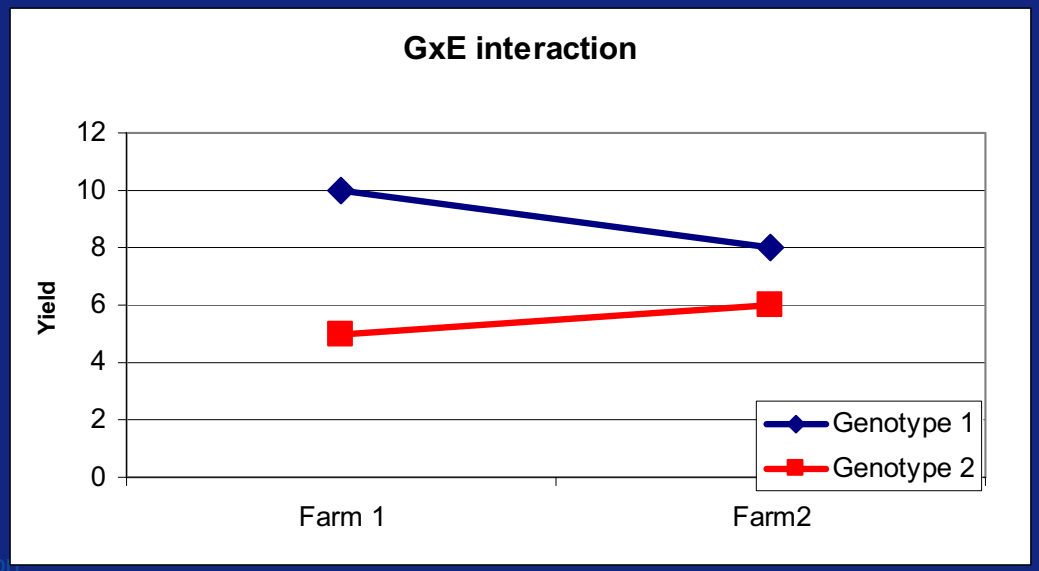
Introduction

A genotype-by-environment interaction is said to occur when the mean value of a genotype/environment subgroup significantly differs from the mean of the two main effects

$GE_{ij} >< (G_i + E_j)/2$

GxE interaction





Measuring GxE effects 1 – variance components

$Y_{ijk} = G_i + E_j + GE_{ij} + residual_{ijk}$

Commonly G_i, GE_{ij} and $residual_{ijk}$ are random effects with estimable variances, whilst E are fixed effects (e.g. farm)

The ratio $\sigma_{GE}^2 / \sigma_P^2$ gives an indication of the relative size of the GxE effect

Measuring GxE effects 2 - reaction norms

$Y_{ij} = G_{ai} + G_{bi}(E) + covG_{ab} + residual_{ij}$

In this model E is some measure of the environment on a continuous scale

The variance of G_{ai} and G_{bi} are estimable

Heritability (h^2)of Y can be estimated at given values of E

Variable h^2 across environments indicates a GxE effect

Variance of G_b may indicate a GxE effect

Data

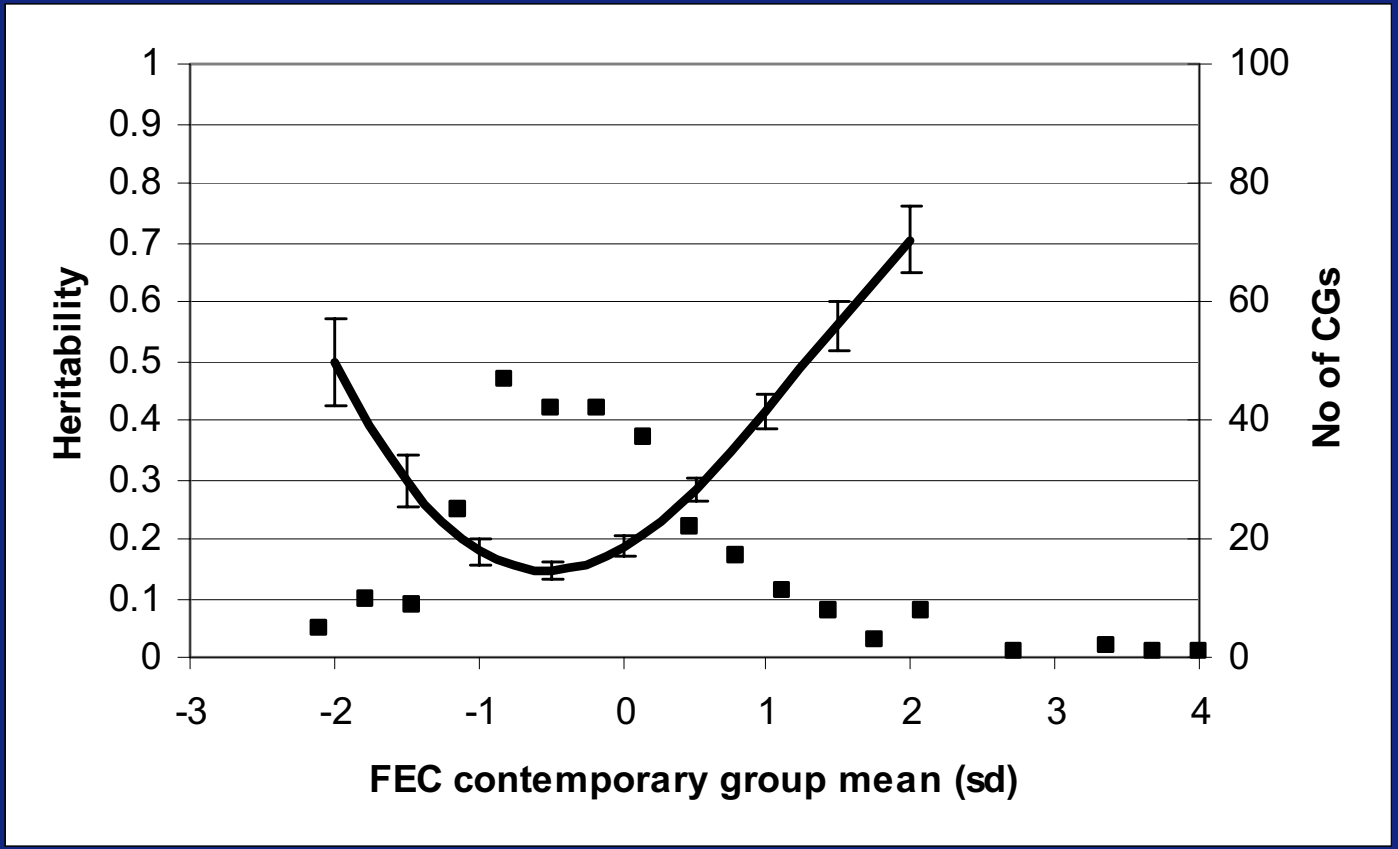
- Pollott and Greeff (2004) analysed 12 wool, body and parasite resistance traits of up to 127,723 Merino sheep
- Data from 55 flocks from different parts of Australia
- Flocks linked by reference sires
- Estimated GxE effects by both variance ratio and reaction norm methods
- Standardized data used for these analyses (Mean 0, SD = 1 within a contemporary group)

GxE variance for 12 sheep traits

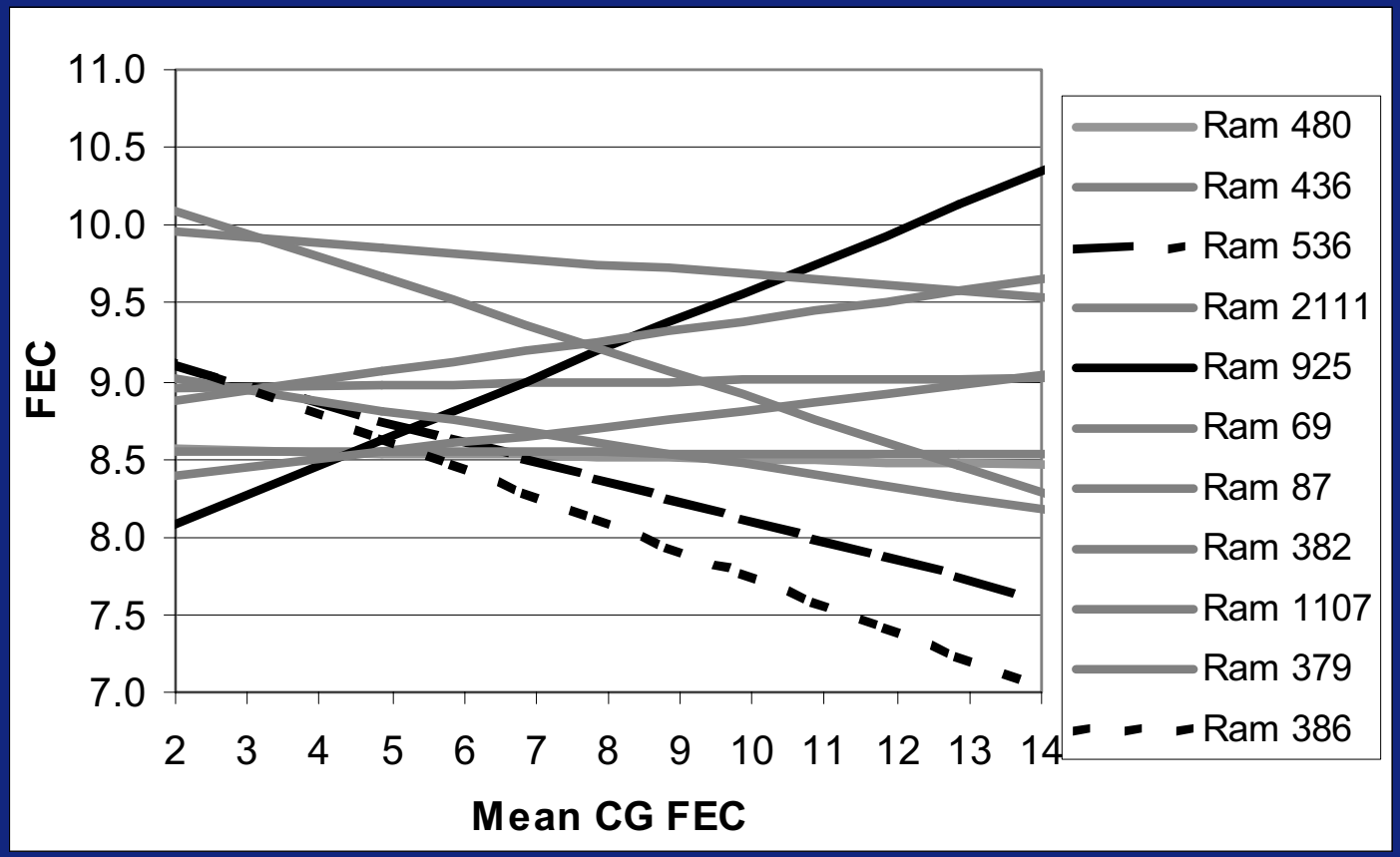
Trait	Heritability	SE	GxE*	SE
Faecal egg count	0.24	0.016	0.030	0.004
Greasy fleece weight	0.44	0.017	0.039	0.003
Clean fleece weight	0.47	0.020	0.031	0.003
Fibre diameter	0.50	0.018	0.023	0.002
Fibre diameter CV	0.30	0.013	0.009	0.002
Comfort factor	0.30	0.021	0.010	0.003
Staple strength	0.43	0.043	0.010	0.005
Staple length	0.61	0.045	0.005^{NS}	0.004
Fibre curvature	0.51	0.041	0.006^{NS}	0.004
Bodyweight	0.39	0.019	0.024	0.002
Fat depth	0.26	0.030	0.014	0.006
Eye-muscle depth	0.23	0.030	0.012	0.007

**GxE variance as a proportion of phenotypic variance*

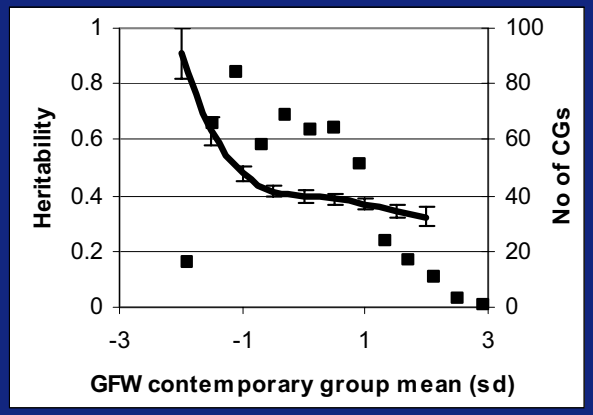
Reaction norm results for faecal egg count

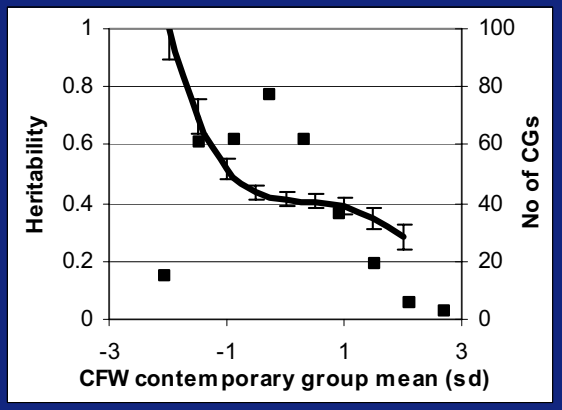


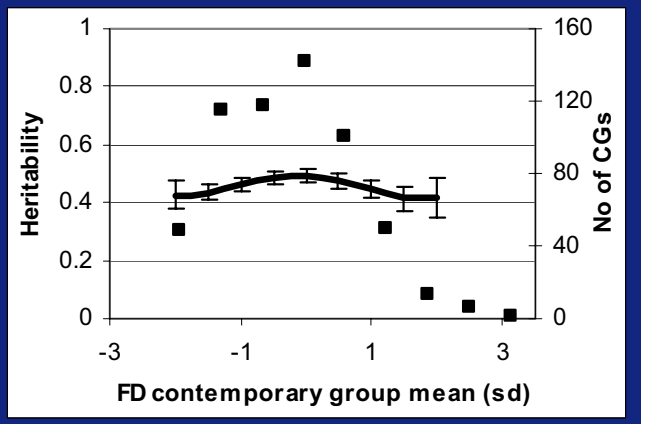
Reaction norm results for faecal egg count (cube root eggs per gram)

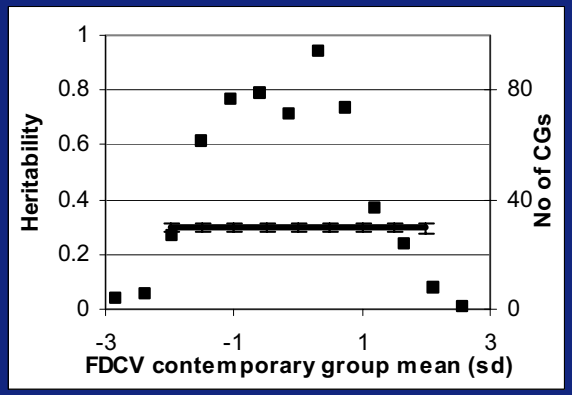


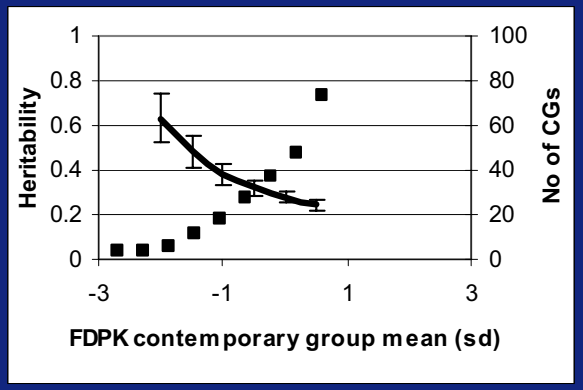
Reaction norm results for six traits

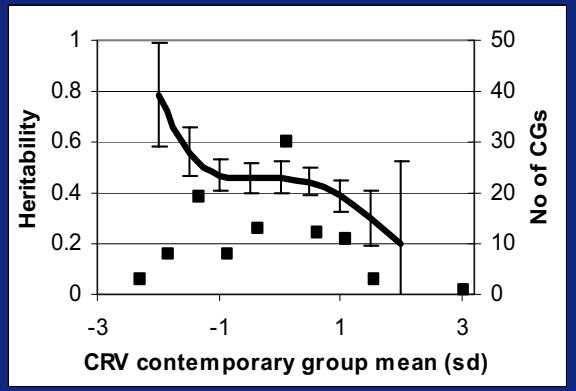




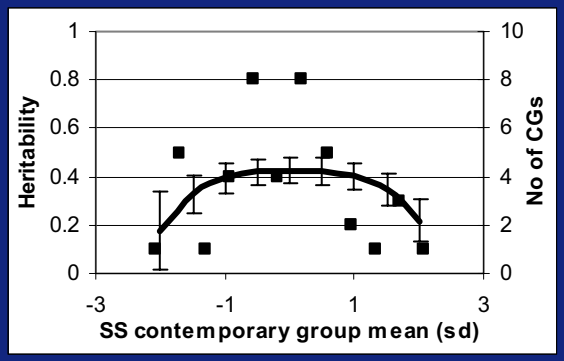


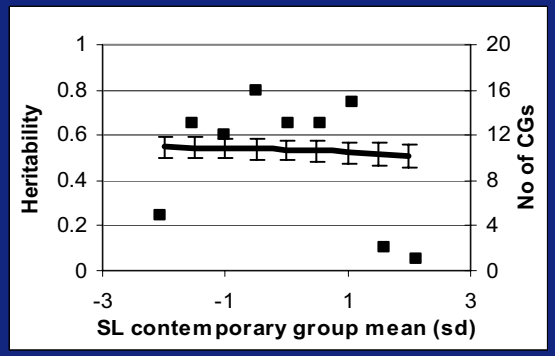


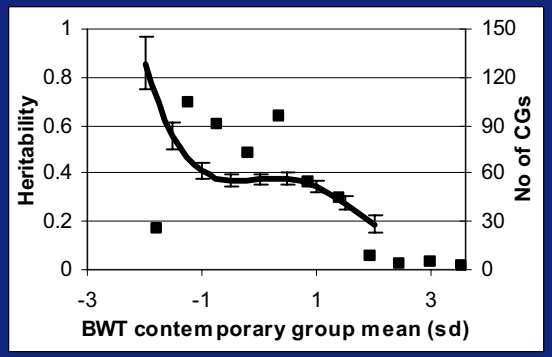


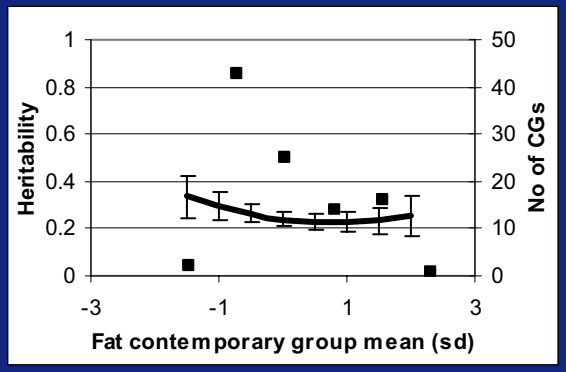


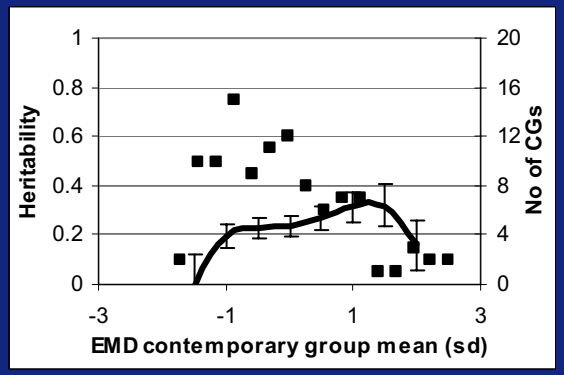
Reaction norm results for five more traits











Comparing methods – shape of heritability curve

Trait	Heritability
Faecal egg count	Yes
Greasy fleece weight	Yes
Clean fleece weight	Yes
Fibre diameter	Yes?
Fibre diameter CV	No
Comfort factor	Yes?
Staple strength	Yes?
Staple length	No
Fibre curvature	Yes?
Bodyweight	Yes
Fat depth	Yes?
Eye-muscle depth	Yes?

Comparing methods 2

Trait	Heritability	GxE*
Greasy fleece weight	Yes	0.039
Clean fleece weight	Yes	0.031
Faecal egg count	Yes	0.030
Bodyweight	Yes	0.024
Fibre diameter	Yes?	0.023
Fat depth	Yes?	0.014
Eye-muscle depth	Yes?	0.012
Comfort factor	Yes?	0.010
Staple strength	Yes?	0.010
Fibre diameter CV	No	0.009
Staple length	No	NS
Fibre curvature	Yes?	NS

**GxE variance as a proportion of phenotypic variance*

Comparing methods 3

Trait	Heritability	GxE*	Slope**
Greasy fleece weight	Yes	0.039	0.008
Clean fleece weight	Yes	0.031	0.018
Faecal egg count	Yes	0.030	0.001
Bodyweight	Yes	0.024	0.046
Fibre diameter	Yes?	0.023	0.024
Fat depth	Yes?	0.014	0.024
Eye-muscle depth	Yes?	0.012	0.027
Comfort factor	Yes?	0.010	0.007
Staple strength	Yes?	0.010	0.000
Fibre diameter CV	No	0.009	0.001
Staple length	No	NS	0.000
Fibre curvature	Yes?	NS	0.062

**GxE variance as a proportion of phenotypic variance*

*** Variance of random regression slopes as a proportion of phenotypic variance*

Conclusions

- There is some agreement between the shape of the heritability curve across environments and the GxE variance as a proportion of phenotypic variance
- Random regression slope variance does not always agree with the other two measures of genotype by environment interaction

Acknowledgements

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