maximum aposteriori Bayesian estimates, as evaluated in step 1 above. Posterior expectation is a more commonly used as Bayesian estimator, but it requires additional calculations, and is currently not implemented in ADMB-RE. For more details, see [12]. The classical criticism of empirical Bayes is that the uncertainty about the hyper-parameters is ignored, and hence that the total uncertainty about the random effects is underestimated. ADMB-RE does, however, take this into account and uses the following formula:  $cov(u) = -\left[\frac{\partial^2 \log p(u \mid, data; \theta)}{\partial u \partial u'}\right]^{-1} + \frac{\partial u}{\partial \theta} cov(\theta) \left(\frac{\partial u}{\partial \theta}\right)'$ (3.1)

**Empirical Bayes** is commonly used to refer to Bayesian estimates of the random effects, with the hyper-parameters fixed at their maximum likelihood estimates. ADMB-RE uses

where u is the vector of random effect,  $\theta$  is the vector of hyper-parameters, and  $\partial u/\partial \theta$  is the sensitivity of the penalized likelihood estimator on the value of  $\theta$ . The first term on the r.h.s. is the ordinary Fisher information based variance of u, while the second term accounts for the uncertainty in  $\theta$ .