An Observation About Subsection 6.6: On Average Training MSE Underestimates Validation MSE

The expected value of the validating mean squared error, taken over the distribution of training data y and validating data y_v is shown in equation (6.65) on page 285:

$$E_y(\text{MSE}_t) = \sigma^2 + \frac{1}{N} \sum_i \text{Var}(\hat{y}_{v,i}) + \text{bias}^2. \tag{6.65}$$

The expected value of the training mean squared error, taken over the distribution of training data y is shown in equation (6.66):

$$E_y(\text{MSE}_t) = \sigma^2 + \frac{1}{N} \sum_i \text{Var}(\hat{y}_i) + \text{bias}^2 - \frac{2}{N} \sum_i \text{Cov}(y_i, \hat{y}_i). \tag{6.66}$$

The predicted values in training and validating data are $\hat{y}_i = \hat{f}(x_i)$ and $\hat{y}_{v,i} = \hat{f}(x_{v,i})$, a function of known covariates x_i and $x_{v,i}$, respectively. These covariates are not necessarily the same. However if the the covariates in the training and validating data take the same values, $\text{Var}(\hat{y}_{v,i}) = \text{Var}(\hat{y}_i)$. In addition, if the number of records in training and validating data is the same, (N), then it follows that

$$E_y(\text{MSE}_t) = E_{y,y_v}(\text{MSE}_v) - \frac{2}{N} \sum_i \text{Cov}(y_i, \hat{y}_i). \tag{6.67}$$

References