**Question 8.2**

# *Using crime data from* [*http://www.statsci.org/data/general/uscrime.txt*](http://www.statsci.org/data/general/uscrime.txt) *(file uscrime.txt, description at* [*http://www.statsci.org/data/general/uscrime.html*](http://www.statsci.org/data/general/uscrime.html) *), use regression (a useful R function is lm or glm) to predict the observed crime rate in a city with the following data:*

# *M = 14.0*

*So = 0*

# *Ed = 10.0*

*Po1 = 12.0*

# *Po2 = 15.5*

*LF = 0.640*

# *M.F = 94.0*

*Pop = 150*

# *NW = 1.1*

*U1 = 0.120*

# *U2 = 3.6*

*Wealth = 3200*

# *Ineq = 20.1*

*Prob = 0.04*

# *Time = 39.0*

# *Show your model (factors used and their coefficients), the software output, and the quality of fit.*

***Note*** *that because there are only 47 data points and 15 predictors, you’ll probably notice some overfitting. We’ll see ways of dealing with this sort of problem later in the course.*

Here’s one possible solution. Please note that a good solution doesn’t have to include everything in the code; all the stuff in the code is shown to help you learn, but it’s not necessary.

# Please read through to the end, because the beginning intentionally includes a common error to demonstrate why you need to avoid it!

# The file solution 8.2.R shows R code for this problem, first in detail using lm(), and then showing the commands if using glm(). It first reads in the data and uses lm() to fit a simple linear regression model with all 15 factors. Using this model, the estimate for the new data point is approximately Crime = 155. But that’s a problem, because the lowest Crime in our data set is 342, more than twice as high, even though the new data point’s factor values are all within the range of the uscrime.txt factor values. What’s going on?

# The problem is that the 15-factor model includes a lot of factors that don’t seem to be significant – they have high p-values (see output below). Removing factors with high p-values isn’t always a good or helpful idea (please remember that!), but let’s try it here as a simple way to reduce the number of factors used (we’ll see better ways later in the course). When we re-fit the model using only factors whose initial p-values were 0.10 or lower, we find that they all have p-values less than 0.05 , and we get a more-reasonable Crime prediction for the new data point: 1304.

# Initial model output

## Coefficients:

## Estimate Std. Error t value Pr(>|t|)

## (Intercept) -5.984e+03 1.628e+03 -3.675 0.000893 \*\*\*

## M 8.783e+01 4.171e+01 2.106 0.043443 \*

## So -3.803e+00 1.488e+02 -0.026 0.979765

## Ed 1.883e+02 6.209e+01 3.033 0.004861 \*\*

## Po1 1.928e+02 1.061e+02 1.817 0.078892 .

## Po2 -1.094e+02 1.175e+02 -0.931 0.358830

## LF -6.638e+02 1.470e+03 -0.452 0.654654

## M.F 1.741e+01 2.035e+01 0.855 0.398995

## Pop -7.330e-01 1.290e+00 -0.568 0.573845

## NW 4.204e+00 6.481e+00 0.649 0.521279

## U1 -5.827e+03 4.210e+03 -1.384 0.176238

## U2 1.678e+02 8.234e+01 2.038 0.050161 .

## Wealth 9.617e-02 1.037e-01 0.928 0.360754

## Ineq 7.067e+01 2.272e+01 3.111 0.003983 \*\*

## Prob -4.855e+03 2.272e+03 -2.137 0.040627 \*

## Time -3.479e+00 7.165e+00 -0.486 0.630708

## ---

# ## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

Smaller model output

## Coefficients:

## Estimate Std. Error t value Pr(>|t|)

## (Intercept) -5040.50 899.84 -5.602 1.72e-06 \*\*\*

## Ed 196.47 44.75 4.390 8.07e-05 \*\*\*

## Po1 115.02 13.75 8.363 2.56e-10 \*\*\*

## Ineq 67.65 13.94 4.855 1.88e-05 \*\*\*

## M 105.02 33.30 3.154 0.00305 \*\*

## Prob -3801.84 1528.10 -2.488 0.01711 \*

## U2 89.37 40.91 2.185 0.03483 \*

## ---

## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

# Now let’s look at quality of the model. The first model’s R2 on training data was 0.803, and the second’s was 0.766 – including the factors with high p-values leads to some overfitting. But measuring on training data isn’t a good estimate, also because of the possibility of overfitting. We can use cross-validation to estimate the quality of this model. In the R-code, I used 5-fold cross-validation, and found an R2 of about 0.638. This is lower than the performance on the training data, indicating that there was still some overfitting going on. And that’s not surprising. We have just 47 data points, and 15 factors, a ratio of about 3:1, and it’s usually good to have a ratio of 10:1 or more. Even the smaller model’s ratio was below 10:1. (We’ll see in Module 11 ways we can try to get around this problem.)

# But note that the 15-factor model (including the factors with high p-values) was much worse – its cross-validation R2 was just 0.413 (compared to its reported performance on training data of 0.803). That’s almost a factor of 2 difference; it suggests a lot of overfitting, and demonstrates why we can’t just use a fitted model’s reported R2 without doing some kind of validation!

# Looking at the adjusted R2 values gives the same sort of insights: the models are still overfit, especially the 15-factor model that includes factors with high p-values.

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| --- | --- | --- |
| Model | R2 | Adjusted R2 |
| 15-factor, directly evaluated on training set | 0.803 | 0.708 |
| 15-factor, cross-validated | 0.413 | 0.130 |
| 6-factor, directly evaluated on training set | 0.766 | 0.731 |
| 6-factor, cross-validated | 0.638 | 0.584 |