

Testing a non-linear hypothesis in regression: The SAT data

```
> rm(list=ls()); options(scipen=999) # To avoid scientific notation
> sat = read.table("http://www.utstat.toronto.edu/~brunner/data/legal/opensAT.data.txt")
> head(sat); attach(sat)
  VERBAL MATH  GPA
1    578  567 2.68
2    474  653 2.51
3    546  657 1.95
4    664  686 2.81
5    600  619 2.79
6    488  738 2.36
> mod = lm(GPA ~ VERBAL+MATH); summary(mod)
```

```
Call:
lm(formula = GPA ~ VERBAL + MATH)
http://www.utstat.toronto.edu/~brunner/oldclass/2101f19
Residuals:
    Min       1Q   Median       3Q      Max
-1.70296 -0.36750  0.02644  0.38869  1.24830
```

```
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.6080747  0.4413074   1.378   0.170
VERBAL       0.0023070  0.0005521   4.178 0.0000441 ***
MATH         0.0009974  0.0006095   1.636   0.103
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.5484 on 197 degrees of freedom
Multiple R-squared:  0.116, Adjusted R-squared:  0.107
F-statistic: 12.93 on 2 and 197 DF, p-value: 0.000005305
```

```
> betahat = coefficients(mod); betahat
(Intercept)      VERBAL      MATH
0.6080747411 0.0023070007 0.0009973607
> mseXtXinv = vcov(mod); mseXtXinv
            (Intercept)      VERBAL      MATH
(Intercept)  0.1947522360 -0.00012145876063 -0.00018613178991
VERBAL       -0.0001214588  0.00000030485303 -0.00000009257555
MATH         -0.0001861318 -0.00000009257555  0.00000037145642
> gdot = cbind(0,betahat[3],betahat[2]); gdot # A row vector, 1x3
      [,1]      [,2]      [,3]
MATH    0 0.0009973607 0.002307001
```

$$\hat{v} = (0, \widehat{\beta}_2, \widehat{\beta}_1) \text{MSE}(\mathbf{X}^T \mathbf{X})^{-1} \begin{pmatrix} 0 \\ \widehat{\beta}_2 \\ \widehat{\beta}_1 \end{pmatrix}$$

```
> vhat = as.numeric( gdot %*% mseXtXinv %*% t(gdot) ); vhat
[1] 0.0000000000001854214
> Z = betahat[2]*betahat[3]/sqrt(vhat); Z
VERBAL
1.68974
> pval = 2 * pnorm(-abs(Z)); pval
VERBAL
0.09107762
```

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