Sec 12.1
Inference For Regression

- Is there a linear association between 2 quantitative variables in a population?

- First, need to know if there is a linear relationship between 2 quantitative variables from a random sample...
Given 2 \((x, y)\) variables, is there a linear relationship?

- Scatterplot
- Correlation \((\text{Lin Reg } a + bx)\)
- Residual Plot

No Pattern / Random

Linear Model \(\hat{y} = a + bx\)

Pattern / Not Random

No Linear Model \(\hat{y}\)
LINEAR REGRESSION T TEST

This test is used to determine if there is a linear relationship between 2 quantitative variables in a population.

Child development researchers explored the relationship between the crying of infants 4 to 10 days old and their later IQ scores. The number of peaks in the most active 20 seconds of crying were counted and recorded. The tables contain data from a random sample of 36 infants.

<table>
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<tr>
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<th>10</th>
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<th>9</th>
<th>16</th>
<th>18</th>
<th>15</th>
<th>12</th>
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<td>109</td>
<td>113</td>
<td>119</td>
<td>124</td>
<td>135</td>
</tr>
</tbody>
</table>

Do these data provide convincing evidence of a linear relationship between crying counts and IQ in the population of infants 4 to 10 days old?

DETERMINE IF THERE IS A LINEAR RELATIONSHIP FROM THE SAMPLE

1) Scatterplot (Cry Counts, IQ)

![Scatterplot Image](image)

2) Calculate \( r \) and LSRL

\[
\hat{y} = 87.91 + 1.55x \quad \Rightarrow \quad IQ = 87.91 + 1.55(Cry\ Count)
\]

3) Check residual plot for randomness

![Residual Plot Image](image)
PERFORM TEST:

P) STATE POPULATION PARAMETER:

\[ \beta = \text{true slope of population regression line determined by crying counts and IQ} \]

H) STATE HYPOTHESES:

\[ H_0: \beta = 0 \]
\[ H_1: \beta \neq 0 \]

A) VERIFY ASSUMPTIONS REQUIRED FOR TEST:

Linear- moderately strong linear relationship exists with a random residual plot

Independent- IQs independent and \( N > 10(36) > 360 \) infants

Normal (Residuals)- NPP of residuals linear and \( n > 30 \)

Equal variance- residuals equally scattered around \( x = 0 \)

Random- random sample taken

T) PERFORM TEST:

a) Using Formula:

\[ t = \frac{b}{SE_b} \text{ with } df = n - 2 \text{ where } SE_b = \sqrt{\frac{(y_i - \hat{y})^2}{n - 2}} \sqrt{\sum(x_i - \bar{x})^2} \]

b) Using Minitab Output?

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T</th>
<th>P</th>
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<tbody>
<tr>
<td>Constant</td>
<td>87.9055</td>
<td>8.934</td>
<td>10.22</td>
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<tr>
<td>Crycount</td>
<td>1.5517</td>
<td>0.4094</td>
<td><strong>3.79</strong></td>
<td><strong>0.0005</strong></td>
</tr>
</tbody>
</table>

\( s = 14.25 \quad \text{R-Sq} = 29.8\% \quad \text{R-Sq (adj)} = 28.5\% \)
c) Using Calculator:

**STAT → TESTS → Lin Reg T Test → \( t = 3.79 \), \( P\)-value = .0005

S) STATE CONCLUSION:

At \( \alpha = .05 \), there is strong evidence to reject \( H_0 \) and conclude a linear relationship exists between crying and IQ in the population of infants.

CONFIDENCE INTERVAL

A 99% confidence interval for the true population slope can be found using:

a) Formula:

\[
CI = b \pm t^* SE_b = 1.55 \pm (2.750)(.4094) = (.43, 2.66)
\]

\[
Table B \quad SE_b = \frac{b}{t}
\]

b) Calculator?

**STAT → TESTS → Lin Reg T Interval = (.43, 2.66)**

*We are 99% confident that for every cry count, IQ increases between .43 and 2.66 points.*

Calculator Note:

\( H_0: \beta = 0 \) \hspace{1cm} \( H_a: \rho = 0 \) \hspace{1cm} If \( \beta = 0, \rho = 0 \)

- \( \beta > 0, \rho > 0 \)
- \( \beta < 0, \rho < 0 \)

\( \text{rho (population correlation)} \)
Table entry for $p$ and $C$ is the critical value $t^*$ with probability $p$ lying to its right and probability $C$ lying between $-t^*$ and $t^*$.

### Table D

**t distribution critical values**

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<tr>
<th>df</th>
<th>.25</th>
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<th>.025</th>
<th>.01</th>
<th>.005</th>
<th>.0025</th>
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<table>
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<th>Confidence level C</th>
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<tbody>
<tr>
<td>50%</td>
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</tbody>
</table>

Note: The critical value $t^*$ is used to determine the confidence interval for a given confidence level $C$. For a two-tailed test, the critical value $t^*$ is used for both tails of the distribution.
Sec 12.2
Making Predictions

Linear Model
\hat{y} = a + bx

Exponential Model
\hat{y} = ab^x

Power Model
\hat{y} = ax^b
Find a model to predict population in 2010:

<table>
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<tr>
<th>Year (X)</th>
<th>US Pop (y)</th>
</tr>
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<td>1920</td>
<td>105.7</td>
</tr>
<tr>
<td>1930</td>
<td>122.8</td>
</tr>
<tr>
<td>1940</td>
<td>131.7</td>
</tr>
<tr>
<td>1950</td>
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<td>1960</td>
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<td>1970</td>
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<td>248.7</td>
</tr>
<tr>
<td>2000</td>
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</table>
Begin with a linear model...
1) Scatterplot \((L_1, L_2)\)

2) Calculate Correlation \((L_1, L_2)\)

\[ r = 0.9928 \]
3) Create residual plot $(L, \text{RESID})$

\[ \text{NOT random... linear model no good} \]
See If An Exponential Model “Works”...
1) Create new list

\[
\frac{L_1}{X} \quad \frac{L_2}{Y} \quad \frac{L_3}{\log y} \quad \ln y \quad \text{Either}
\]
2) Scatterplot \((L_1, L_3)\)

\[\log(\text{pop}) \quad \ln(\text{pop})\]

\[\text{Year}\]

\#3) Linear Regression \((L_1, L_3)\)

\[r = 0.9976\]
4) Create New Residual Plot \((L_i, \text{RESID})\)

\[
\begin{array}{c}
  \text{Random } \theta \\
  \text{exponential model appropriate}
\end{array}
\]
5) Write Exponential Model

\[ y = ab^x \]
(a) Transform Linear Equation

\[ \log y \]

\[ \hat{y} = -8.28 + 0.005x \]

\[ \log y = -8.28 + 0.005x \]

\[ \hat{y} = 10^{-8.28 + 0.005x} \]

\[ \hat{y} = (10^{-8.28})(10^{0.005x}) \]

\[ \ln y \]

\[ \hat{y} = -19.06 + 0.0124x \]

\[ \ln y = -19.06 + 0.0124x \]

\[ \hat{y} = e^{-19.06 + 0.0124x} \]

\[ \hat{y} = (e^{-19.06})(e^{0.0124x}) \]

\[ P^{\text{pop}} = (5.3 \times 10^9)(1.01)^{\text{year}} \]
b) Use Calculator?

\[
\text{STAT} \rightarrow \text{CALC} \rightarrow \text{ExpReg} \ (L_1, L_2)
\]

\[
\hat{P}_{\text{pop}} = (5.29 \times 10^{-9}) (1.01)^{\text{Year}}
\]
Making Predictions - Use model to predict population in 2010 > 309.3M

1) Plug'n Chug (Use log/ln form w/out rounding)

\[ \hat{\text{pop}} = 10^{\hat{\text{log}} \text{pop}} \]  

\[ \hat{\text{log}} \text{pop} = -8.276051195 + 0.0053661533 \text{ (year)} \]

\[ \hat{\text{log}} \text{pop} = 2.509916943 \]

\[ \hat{\text{pop}} = 10^{2.509916943} = 323.5 \text{ M} \]
b) $\ln \hat{\text{pop}} = -19.05631211 + .0123560246 (\text{years})$

$\ln \hat{\text{pop}} = 5.779297336$

$\hat{\text{pop}} = e^{5.779297336} = 323.5 \text{ M}$
2) Using Calculator
   
a) Store LSRL when calculating
      \[ \text{CALC} \rightarrow \text{LinReg} \ L_1, L_2, Y_1 \]
   
b) Define \( Y_2 \)
      \[ Y_2 = 10 \land Y_1 \quad Y_2 = e \land Y_1 \]
   
c) Use \( \boxed{\text{VARS}} \) to enter \( X \)-value
      \[ Y_2(2010) = 323.5 \ M \]
2) Using Calculator
   a) Store $\text{ExpReg}$ when calculating
      \[ \text{CALC} \rightarrow \text{ExpReg} \ L_1, L_2, Y_1 \]
   b) Use $\text{VARS}$ to enter X-value
      \[ Y_1 (2010) = 323.5 \text{ M} \]
Given 2 \((x, y)\) variables, is there an exponential relationship?

Scatterplot \((x, \log y)\) \n\nCorrelation \((\text{Lin Reg} a + bx)\) \n\nResidual Plot \n\n\begin{align*}
\text{No Pattern / Random} & \quad \text{Pattern / Not Random} \\
\text{Exponential Model} \hat{y} & \quad \text{No Exponential Model} \hat{y}
\end{align*}

\hat{y} = a b^x
Sec 12.2 cont
(Power Regression)
ROCKFISH

Find a model to predict the weight of a rockfish given its length

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Length (cm)</th>
<th>Weight (g)</th>
<th>Age (yr)</th>
<th>Length (cm)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.2</td>
<td>2</td>
<td>11</td>
<td>28.2</td>
<td>318</td>
</tr>
<tr>
<td>2</td>
<td>8.5</td>
<td>8</td>
<td>12</td>
<td>29.6</td>
<td>371</td>
</tr>
<tr>
<td>3</td>
<td>11.5</td>
<td>21</td>
<td>13</td>
<td>30.8</td>
<td>455</td>
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<tr>
<td>4</td>
<td>14.3</td>
<td>38</td>
<td>14</td>
<td>32.0</td>
<td>504</td>
</tr>
<tr>
<td>5</td>
<td>16.8</td>
<td>69</td>
<td>15</td>
<td>33.0</td>
<td>518</td>
</tr>
<tr>
<td>6</td>
<td>19.2</td>
<td>117</td>
<td>16</td>
<td>34.0</td>
<td>537</td>
</tr>
<tr>
<td>7</td>
<td>21.3</td>
<td>148</td>
<td>17</td>
<td>34.9</td>
<td>651</td>
</tr>
<tr>
<td>8</td>
<td>23.3</td>
<td>190</td>
<td>18</td>
<td>36.4</td>
<td>719</td>
</tr>
<tr>
<td>9</td>
<td>25.0</td>
<td>264</td>
<td>19</td>
<td>37.1</td>
<td>726</td>
</tr>
<tr>
<td>10</td>
<td>26.7</td>
<td>293</td>
<td>20</td>
<td>37.7</td>
<td>810</td>
</tr>
</tbody>
</table>
Begin with a linear model...
1) Scatterplot \((L_1, L_2)\)

2) Calculate Correlation

\[ r = 0.9461 \]
3) Create Residual Plot \((L1, RESID)\)

- Pattern
  - Linear Model
  - No Good

\[\text{Pattern... Linear Model No Good} \]
See If An Exponential Model Works...
1) Create new list

\[
\begin{array}{ccc}
L_1 & L_2 & L_3 \\
X & Y & \log y
\end{array}
\]

\(\ln y\) Either
2) Scatterplot \((L_1, L_3)\)

3) Calculate Correlation \((L_1, L_3)\)

\[ r = .963 \]
4) Create Residual Plot \((L_i, \text{RESID})\)

- Pattern: Exponential Model
- No Good
See If A Power Model Works...
1) Create another new list

\[ L_1 \quad L_2 \quad L_3 \quad L_4 \]

\[ x \quad y \quad \log y \quad \log x \]

\[ \ln y \quad \ln x \quad \text{Either} \]
2) Scatterplot \((L_4, L_3)\)

\[
\text{logy} / \ln y \\
\text{log x} / \ln x
\]

3) Calculate Correlation \((L_4, L_3)\)

\[r = .999\]
4) Create Residual Plot (L4, RESID)

\[
\text{Random} \quad \text{Power Model Best}
\]
5) Write Power Model \( (y = ax^b) \)

\[
\hat{y} = -1.8994 + 3.0494x
\]

\[
\hat{y} = (10^{-1.8994})(x^{3.0494})
\]

\[
\hat{y} = \ln y = -4.3735 + 3.0494 \ln x
\]

\[
\hat{y} = (e^{-4.3735})(x^{3.0494})
\]

Weight = \((0.0126)(\text{length})^{3.0494}\)
Making Predictions - Find weight if length is 24 cm

1) Plug 'n Chug (Use log/ln form without rounding)

a) \( \hat{\log y} = -1.8994 + 3.0494 \left( \log x \right)^{24} \)

\[ \hat{\text{Weight}} = 10^{2.30941616} = 204 \text{ g} \]

b) \( \hat{\ln y} = -4.3735 + 3.0494 \left( \ln x \right)^{24} \)

\[ \hat{\text{Weight}} = e^{5.31765735} = 204 \text{ g} \]
2) Using calculator

a) Let $Y_i = \text{LSRL} \ (L4, L3)$

b) Define $Y_2 = (10 \wedge a)(x \wedge b)$ or $(e \wedge a)(x \wedge b)$

C) $\text{VARS} \rightarrow 5: \text{Statistics} \rightarrow \text{EQ}$

$\text{VARS} \rightarrow Y-\text{VARS} \rightarrow \text{Function} \rightarrow Y_2(24) = 204 \, g$
Notes

1) Using \texttt{CALC} \rightarrow \texttt{PwrReg} \ L_1, L_2 \ may \ not \ work

2) Not a lot of these calculations on AP Exam...

See MC Example (next page)
28. Two measures $x$ and $y$ were taken on 18 subjects. The first of two regressions, Regression I, yielded
$\hat{y} = 24.5 + 16.1x$ and had the following residual plot.

The second regression, Regression II, yielded $\log(y) = 1.6 + 0.51 \log(x)$ and had the following residual plot.

Which of the following conclusions is best supported by the evidence above?

(A) There is a linear relationship between $x$ and $y$, and Regression I yields a better fit.
(B) There is a linear relationship between $x$ and $y$, and Regression II yields a better fit.
(C) There is a negative correlation between $x$ and $y$.
(D) There is a nonlinear relationship between $x$ and $y$, and Regression I yields a better fit.
(E) There is a nonlinear relationship between $x$ and $y$, and Regression II yields a better fit.
Given 2 \((x, y)\) variables, is there a power relationship?

- Scatterplot \((\log x, \log y)\)
- Correlation \((\text{Lin Reg} a + bx)\)
- Residual Plot
  - No Pattern/Random
  - Power Model: \(\hat{y} = a x^b\)
  - Pattern/Not Random
  - No Power Model
Review

<table>
<thead>
<tr>
<th>Linear</th>
<th>Log Y</th>
<th>Exponential</th>
<th>Log Y</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>log Y</td>
<td>X</td>
<td>log Y</td>
<td>log x</td>
</tr>
</tbody>
</table>

Note

There are other models!

\[ \hat{y} = \frac{c}{1 + ae^{-bx}} \]