LOGISTIC REGRESSION:
WHAT IS IT AND WHAT CAN I LEARN FROM IT?

MELODIE RUSH
SENIOR SYSTEMS ENGINEER
AGENDA

• Why would you use it?
  • Goal
  • Application
• What is Logistic Regression?
• Examples
  • Data layout
  • Simple
  • Multiple
WHAT IS OUR GOAL?
COMMON APPLICATIONS

- Target Marketing
- Attrition Prediction
- Credit Scoring
- Fraud Detection
- Customer Satisfaction
GOOD OR NO GOOD?
Logistic Regression is essentially a regression model tailored to fit a categorical dependent variable.
Response

Continuous

Categorical

Analysis

Linear Regression Analysis

Logistic Regression Analysis
### Response Variable

<table>
<thead>
<tr>
<th>Two Categories</th>
<th>Three or more Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Binary</strong></td>
<td><strong>Nominal</strong></td>
</tr>
<tr>
<td>- Yes, No</td>
<td>- Region</td>
</tr>
<tr>
<td>- 0, 1</td>
<td>- Ordinal</td>
</tr>
<tr>
<td>- Good, Bad</td>
<td>- Age Group</td>
</tr>
</tbody>
</table>

### Type of Logistic Regression

- **Binary**: Binary, Yes, No, 0, 1, Good, Bad
- **Nominal**: Region
- **Ordinal**: Age Group
WHY NOT USE REGRESSION (OLS)?

- Biggest issue is that the predicted values will take on values that have no meaning to your response
- Added mathematical inconvenience of not being able to assume normality and constant variance with the response variable that has only 2 values
LOGISTIC REGRESSION
MODEL

\[
\text{logit}(p_i) = \beta_0 + \beta_1 X_{1i} + \ldots + \beta_k X_{ki}
\]

Where

- \( \text{logit}(p_i) \) = logit of the probability of the event
- \( \beta_0 \) = intercept of the regression equation
- \( \beta_k \) = parameter estimate of the \( k^{th} \) predictor variable

\[
\text{logit}(p_i) = \log\left(\frac{p_i}{1-p_i}\right)
\]
# Mason Crosby’s Career

## Field Goal Statistics

<table>
<thead>
<tr>
<th>SEASON</th>
<th>TEAM</th>
<th>GP</th>
<th>FGM</th>
<th>FGA</th>
<th>PCT</th>
<th>1-19</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50+</th>
<th>LNG</th>
<th>XPPI</th>
<th>XPA</th>
<th>PTS</th>
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<tbody>
<tr>
<td>2007</td>
<td>GB</td>
<td>15</td>
<td>31</td>
<td>39</td>
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<td>11</td>
<td>14</td>
<td>5</td>
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<td>43</td>
<td>48</td>
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<td>27</td>
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<td>6</td>
<td>6</td>
<td>53</td>
<td>46</td>
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<td>36</td>
<td>75.0</td>
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<td>13</td>
<td>9</td>
<td>7</td>
<td>6</td>
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<tr>
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<td>GB</td>
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<td>22</td>
<td>26</td>
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<td>8</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>56</td>
<td>46</td>
<td>46</td>
<td>112</td>
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<td>2011</td>
<td>GB</td>
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<td>24</td>
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<td>14</td>
<td>5</td>
<td>3</td>
<td>58</td>
<td>63</td>
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<td>21</td>
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<td>7</td>
<td>12</td>
<td>9</td>
<td>54</td>
<td>50</td>
<td>50</td>
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<td>8</td>
<td>7</td>
<td>57</td>
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<td>141</td>
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<tr>
<td>Career</td>
<td></td>
<td>112</td>
<td>185</td>
<td>235</td>
<td>78.7</td>
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<td>60</td>
<td>67</td>
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<td>40</td>
<td>58</td>
<td>348</td>
<td>350</td>
<td>903</td>
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</tbody>
</table>

**Mason Crosby #2 K**

- **Height:** 6-1
- **Weight:** 207
- **Age:** 27
- **Born:** 9/3/1984 Lubbock, TX
- **College:** Colorado
- **Experience:** 6th season
- **High School:** Georgetown HS [TX]
MASON CROSBY’S CAREER
FIELD GOAL STATISTICS

<table>
<thead>
<tr>
<th>FGM</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Frequency</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>52</td>
<td>20.88</td>
<td>52</td>
<td>20.88</td>
</tr>
<tr>
<td>1</td>
<td>197</td>
<td>79.12</td>
<td>249</td>
<td>100.00</td>
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</tbody>
</table>

Distribution of FGM
WHAT MIGHT DETERMINE A SUCCESSFUL FIELD GOAL?
WHAT MIGHT DETERMINE A SUCCESSFUL FIELD GOAL?
PROC LOGISTIC DATA FOR
SIMPLE MODEL
CONTINUOUS PREDICTOR

Y = FGM (Field Goals Made)
X = Dist (Distance)
PROC LOGISTIC SYNTAX

PROC LOGISTIC <options>;
CLASS variable</v-options>;
MODEL response=<effects></options>;
ODDSRATIO <'label'> variable </options>;
ROC <'label'> < specification </options>;
ROCCONTRAST <'label'>< contrast </options>;
SCORE <options>;
UNITS predictor1=list1 </option>;
OUTPUT <OUT=SAS-data-set> keyword=name…
    keyword=name </option>;
RUN;
PROC LOGISTIC DATA=work.Crosby_FG;
  MODEL FGM (Event = '1')=DIST;
RUN;
PROC LOGISTIC OUTPUT
FOR SIMPLE MODEL
CONTINUOUS PREDICTOR

Predicted Probabilities for FGM=1
With 95% Confidence Limits

Observed
Predicted

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### Analysis of Maximum Likelihood Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DF</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>Wald Chi-Square</th>
<th>Pr &gt; ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1</td>
<td>6.2790</td>
<td>0.8976</td>
<td>48.9386</td>
<td>&lt;.0001</td>
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<tr>
<td>Dist</td>
<td>1</td>
<td>-0.1212</td>
<td>0.0202</td>
<td>36.1037</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

### Odds Ratio Estimates

<table>
<thead>
<tr>
<th>Effect</th>
<th>Point Estimate</th>
<th>95% Wald Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist</td>
<td>0.886</td>
<td>0.852, 0.922</td>
</tr>
</tbody>
</table>
Is the model any good?

- Counting concordant, discordant, and tied pairs is a way to assess how well the model predicts its own data and therefore how well the model fits.
- In general, you want a high percentage of concordant pairs and low percentages of discordant and tied pairs.

Closer the area under the curve is to 1 the better the model, the closer to 0.5 the worse the model.
**PROC LOGISTIC DATA**  
**SIMPLE MODEL CATEGORICAL PREDICTOR**

Mason Crosby's Field Goals (first 10)

<table>
<thead>
<tr>
<th>Row number</th>
<th>Year</th>
<th>G#</th>
<th>Opp</th>
<th>FGM</th>
<th>Dist</th>
<th>Distance Grouped</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2007</td>
<td>1</td>
<td>PHI</td>
<td>1</td>
<td>53</td>
<td>4. &gt;= 50 yards</td>
</tr>
<tr>
<td>2</td>
<td>2007</td>
<td>1</td>
<td>PHI</td>
<td>1</td>
<td>37</td>
<td>2. 30-39 yards</td>
</tr>
<tr>
<td>3</td>
<td>2007</td>
<td>1</td>
<td>PHI</td>
<td>1</td>
<td>42</td>
<td>3. 40-49 yards</td>
</tr>
<tr>
<td>4</td>
<td>2007</td>
<td>2</td>
<td>NYG</td>
<td>0</td>
<td>42</td>
<td>3. 40-49 yards</td>
</tr>
<tr>
<td>5</td>
<td>2007</td>
<td>3</td>
<td>SDG</td>
<td>1</td>
<td>28</td>
<td>1. &lt; 20 yards</td>
</tr>
<tr>
<td>6</td>
<td>2007</td>
<td>4</td>
<td>MIN</td>
<td>1</td>
<td>28</td>
<td>1. &lt; 20 yards</td>
</tr>
<tr>
<td>7</td>
<td>2007</td>
<td>4</td>
<td>MIN</td>
<td>1</td>
<td>44</td>
<td>3. 40-49 yards</td>
</tr>
<tr>
<td>8</td>
<td>2007</td>
<td>4</td>
<td>MIN</td>
<td>1</td>
<td>33</td>
<td>2. 30-39 yards</td>
</tr>
<tr>
<td>9</td>
<td>2007</td>
<td>5</td>
<td>CHI</td>
<td>1</td>
<td>37</td>
<td>2. 30-39 yards</td>
</tr>
<tr>
<td>10</td>
<td>2007</td>
<td>5</td>
<td>CHI</td>
<td>1</td>
<td>37</td>
<td>2. 30-39 yards</td>
</tr>
</tbody>
</table>

Y = FGM (Field Goals Made)  
X = Dist_grp (Distance Grouped)
PROC LOGISTIC CODE

SIMPLE MODEL – CATEGORICAL PREDICTOR

CREATE CATEGORICAL VARIABLE

(CASE
  WHEN t1.Dist <= 29 THEN '1. < 29 yards'
  WHEN t1.Dist >= 30 AND t1.Dist <= 39 THEN '2. 30-39 yards'
  WHEN t1.Dist >= 40 AND t1.Dist <= 49 THEN '3. 40-49 yards'
  WHEN t1.Dist >= 50 THEN '4. >= 50 yards'
  ELSE t1.Dist
END)

LABEL="Distance Grouped" AS Dist_Grp
**PROC LOGISTIC CODE**

**SIMPLE MODEL CATEGORICAL PREDICTOR**

```SAS
PROC LOGISTIC DATA=WORK.Crosby_FG;
   CLASS Dist_Grp(PARAM=EFFECT);
   MODEL FGM (Event = '1')=Dist_Grp;
RUN;
```
**PROC LOGISTIC CODE**

**SIMPLE MODEL - CATEGORICAL PREDICTOR**

<table>
<thead>
<tr>
<th>Effect</th>
<th>DF</th>
<th>Wald Chi-Square</th>
<th>Pr &gt; Chi Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist_Grp</td>
<td>3</td>
<td>32.0760</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**Odds Ratio Estimates**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Point Estimate</th>
<th>95% Wald Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist_Grp 1. &lt; 29 yards vs 4. &gt;= 50 yards</td>
<td>39.667</td>
<td>8.498 - 185.146</td>
</tr>
<tr>
<td>Dist_Grp 2. 30-39 yards vs 4. &gt;= 50 yards</td>
<td>7.583</td>
<td>3.033 - 18.958</td>
</tr>
<tr>
<td>Dist_Grp 3. 40-49 yards vs 4. &gt;= 50 yards</td>
<td>2.825</td>
<td>1.237 - 6.451</td>
</tr>
</tbody>
</table>

**Analysis of Maximum Likelihood Estimates**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DF</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>Wald Chi-Square</th>
<th>Pr &gt; Chi Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1</td>
<td>1.5321</td>
<td>0.2247</td>
<td>46.5000</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Dist_Grp 1. &lt; 29 yards</td>
<td>1</td>
<td>1.9943</td>
<td>0.5548</td>
<td>12.9203</td>
<td>0.0003</td>
</tr>
<tr>
<td>Dist_Grp 2. 30-39 yards</td>
<td>1</td>
<td>0.3397</td>
<td>0.3289</td>
<td>1.0671</td>
<td>0.3016</td>
</tr>
<tr>
<td>Dist_Grp 3. 40-49 yards</td>
<td>1</td>
<td>-0.6479</td>
<td>0.2961</td>
<td>4.7878</td>
<td>0.0287</td>
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</table>
Is the model any good?

Better or worse than the Continuous Model?
PROC LOGISTIC DATA  MULTIPLE MODEL

Mason Crosby's Field Goals (first 10)

<table>
<thead>
<tr>
<th>Row number</th>
<th>Year</th>
<th>G#</th>
<th>Opp</th>
<th>Quarter</th>
<th>FGM</th>
<th>Dist</th>
<th>Win or Loss</th>
<th>Home or Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2007</td>
<td>1</td>
<td>PHI</td>
<td>1</td>
<td>1</td>
<td>53</td>
<td>W</td>
<td>Home</td>
</tr>
<tr>
<td>2</td>
<td>2007</td>
<td>1</td>
<td>PHI</td>
<td>3</td>
<td>1</td>
<td>37</td>
<td>W</td>
<td>Home</td>
</tr>
<tr>
<td>3</td>
<td>2007</td>
<td>1</td>
<td>PHI</td>
<td>4</td>
<td>1</td>
<td>42</td>
<td>W</td>
<td>Home</td>
</tr>
<tr>
<td>4</td>
<td>2007</td>
<td>2</td>
<td>NYG</td>
<td>1</td>
<td>0</td>
<td>42</td>
<td>W</td>
<td>Home</td>
</tr>
<tr>
<td>5</td>
<td>2007</td>
<td>3</td>
<td>SDG</td>
<td>1</td>
<td>1</td>
<td>28</td>
<td>W</td>
<td>Home</td>
</tr>
<tr>
<td>6</td>
<td>2007</td>
<td>4</td>
<td>MIN</td>
<td>2</td>
<td>1</td>
<td>28</td>
<td>W</td>
<td>Away</td>
</tr>
<tr>
<td>7</td>
<td>2007</td>
<td>4</td>
<td>MIN</td>
<td>3</td>
<td>1</td>
<td>44</td>
<td>W</td>
<td>Away</td>
</tr>
<tr>
<td>8</td>
<td>2007</td>
<td>4</td>
<td>MIN</td>
<td>4</td>
<td>1</td>
<td>33</td>
<td>W</td>
<td>Away</td>
</tr>
<tr>
<td>9</td>
<td>2007</td>
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<td>CHI</td>
<td>2</td>
<td>1</td>
<td>37</td>
<td>L</td>
<td>Home</td>
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<td>10</td>
<td>2007</td>
<td>5</td>
<td>CHI</td>
<td>3</td>
<td>1</td>
<td>37</td>
<td>L</td>
<td>Home</td>
</tr>
</tbody>
</table>

Y = FGM (Field Goals Made)
X = Dist (Distance)
   Year, Quarter, Win or Loss, Home or Away
PROC LOGISTIC CODE

MULTIPLE MODEL

PROC LOGISTIC DATA=WORK.Crosby_FG;
CLASS Year Away_Game Quarter Win_or_Loss;
MODEL FGM (Event = '1')=Dist Year Away_Game Quarter Win_or_Loss ;
RUN;
Predicted Probabilities for FGM=1
At Quarter=5 Win_or_Loss=W Home_Away=Home

Year
2007 2008 2009 2010
2011 2012 2013
### PROC LOGISTIC CODE

#### MULTIPLE MODEL

#### Type 3 Analysis of Effects

<table>
<thead>
<tr>
<th>Effect</th>
<th>DF</th>
<th>Wald</th>
<th>Pr &gt; Chi Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist</td>
<td>1</td>
<td>33.5013</td>
<td>&lt;.0001</td>
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<td>4.8456</td>
<td>0.5638</td>
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<tr>
<td>Quarter</td>
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<td>0.9535</td>
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<tr>
<td>Win_or_Loss</td>
<td>2</td>
<td>0.0133</td>
<td>0.9934</td>
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<tr>
<td>Home_Away</td>
<td>1</td>
<td>1.1795</td>
<td>0.2775</td>
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</table>

#### Analysis of Maximum Likelihood Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DF</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>Wald</th>
<th>Pr &gt; Chi Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1</td>
<td>0.8271</td>
<td>0.9918</td>
<td>0.0111</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Dist</td>
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<td>0.2090</td>
<td>33.5013</td>
<td>&lt;.0001</td>
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<td>Year 2007</td>
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<td>0.0991</td>
<td>0.4107</td>
<td>0.0582</td>
<td>0.8094</td>
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<td>Year 2008</td>
<td>1</td>
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<td>0.4681</td>
<td>0.0019</td>
<td>0.9653</td>
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<td>Year 2009</td>
<td>1</td>
<td>-0.4247</td>
<td>0.4195</td>
<td>1.0247</td>
<td>0.3114</td>
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<td>Year 2010</td>
<td>1</td>
<td>-0.2057</td>
<td>0.4538</td>
<td>0.2056</td>
<td>0.6503</td>
</tr>
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<td>Year 2011</td>
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<td>0.3019</td>
<td>0.5468</td>
<td>0.3048</td>
<td>0.5809</td>
</tr>
<tr>
<td>Year 2012</td>
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<td>0.3908</td>
<td>1.9587</td>
<td>0.1617</td>
</tr>
<tr>
<td>Quarter 1</td>
<td>1</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.9991</td>
</tr>
<tr>
<td>Quarter 2</td>
<td>1</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.9977</td>
</tr>
<tr>
<td>Quarter 3</td>
<td>1</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.9987</td>
</tr>
<tr>
<td>Quarter 4</td>
<td>1</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.9979</td>
</tr>
<tr>
<td>Win_or_Loss L vs W</td>
<td>1</td>
<td>-2.6277</td>
<td>1.163</td>
<td>0.0005</td>
<td>0.9620</td>
</tr>
<tr>
<td>Win_or_Loss T vs W</td>
<td>1</td>
<td>5.3022</td>
<td>232.7</td>
<td>0.0005</td>
<td>0.9818</td>
</tr>
<tr>
<td>Home_Away Away vs Home</td>
<td>1</td>
<td>0.2064</td>
<td>0.1900</td>
<td>1.1795</td>
<td>0.2775</td>
</tr>
</tbody>
</table>

#### Odds Ratio Estimates

<table>
<thead>
<tr>
<th>Effect</th>
<th>Point Estimate</th>
<th>95% Wald Confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist</td>
<td>0.886</td>
<td>0.860-0.923</td>
</tr>
<tr>
<td>Year 2007 vs 2013</td>
<td>0.498</td>
<td>0.119-2.090</td>
</tr>
<tr>
<td>Year 2008 vs 2013</td>
<td>0.442</td>
<td>0.097-2.010</td>
</tr>
<tr>
<td>Year 2009 vs 2013</td>
<td>0.295</td>
<td>0.070-1.241</td>
</tr>
<tr>
<td>Year 2010 vs 2013</td>
<td>0.387</td>
<td>0.082-1.635</td>
</tr>
<tr>
<td>Year 2011 vs 2013</td>
<td>0.610</td>
<td>0.117-3.182</td>
</tr>
<tr>
<td>Year 2012 vs 2013</td>
<td>0.261</td>
<td>0.064-1.066</td>
</tr>
<tr>
<td>Quarter 1 vs 5</td>
<td>1.606</td>
<td>&lt;0.001-999.999</td>
</tr>
<tr>
<td>Quarter 2 vs 5</td>
<td>2.382</td>
<td>&lt;0.001-999.999</td>
</tr>
<tr>
<td>Quarter 3 vs 5</td>
<td>2.127</td>
<td>&lt;0.001-999.999</td>
</tr>
<tr>
<td>Quarter 4 vs 5</td>
<td>2.333</td>
<td>&lt;0.001-999.999</td>
</tr>
<tr>
<td>Win_or_Loss L vs W</td>
<td>1.048</td>
<td>0.466-2.354</td>
</tr>
<tr>
<td>Win_or_Loss T vs W</td>
<td>1.048</td>
<td>0.466-2.354</td>
</tr>
<tr>
<td>Home_Away Away vs Home</td>
<td>1.511</td>
<td>0.717-3.182</td>
</tr>
</tbody>
</table>
Is the model any good?

Better or worse than the Simple Models?

**Association of Predicted Probabilities and Observed Responses**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Concordant</td>
<td>81.9</td>
</tr>
<tr>
<td>Percent Discordant</td>
<td>18.1</td>
</tr>
<tr>
<td>Percent Tied</td>
<td>0.0</td>
</tr>
<tr>
<td>Pairs</td>
<td>10244 c</td>
</tr>
</tbody>
</table>

**Somers' D** 0.639  
**Gamma** 0.639  
**Tau-a** 0.212  

**ROC Curve for Model**

Area Under the Curve = 0.8193
• Missing Value
• Errors and Outliers
• Massive Data size
• Operational vs. observational
It’s Good!
Papers
• A Tutorial on Logistic Regression by Ying So

Public SAS Courses
• Statistics 1: Introduction to ANOVA, Regression, and Logistic Regression
• Predictive Modeling Using Logistic Regression
• Categorical Data Analysis Using Logistic Regression

Books
• Logistic Regression Using SAS Theory and Application, Second Edition by Paul D Allison

Online Tutorials
• Logistic Regression in SAS Enterprise Guide Example 1
• Logistic Regression in SAS Enterprise Guide Example 2
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- From A to Z: A SAS® Enterprise Guide Case Study - October 21
- Getting Started With SAS® Enterprise Guide – November 18
- Hidden Gems in SAS® Enterprise Guide® - November 19
- Getting Started with SAS® Enterprise Miner – November 3
- Getting Started With SAS® Forecast Server – November 10
- Getting Started With SAS® Text Miner – November 17
- Data Mining Tasks With SAS® Enterprise Guide 6.1 – November 24
- Introduction to SAS Add-in for Microsoft office – November 6
- Introduction to SAS Enterprise Business Intelligence Server – November 13
- Top 10 SAS Support Resources – December 9
RESOURCES  LIVE WEBINARS FROM CUSTOMER LOYALTY

• What’s New in 9.4 for Foundation (programmers) – November 4
• Top 10 Ways to Optimize Your SAS code - October 29
• Introduction to SAS Administration: The Basics – December 1
• Overview of Administration Task in SAS Visual Analytics – November 25
• Advanced SAS Administration Tasks in SAS 9.4: Backup Strategies and SAS Server logging – October 15
• SAS 9.4 Metadata Security Overview – October 20
• Metadata Server Clustering – October 28
• Considerations for Transitioning from PC to Server – November 5
QUESTIONS?

Thank you for your time and attention!

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Twitter: @SAS_MelodieRush