

Logistic Regression

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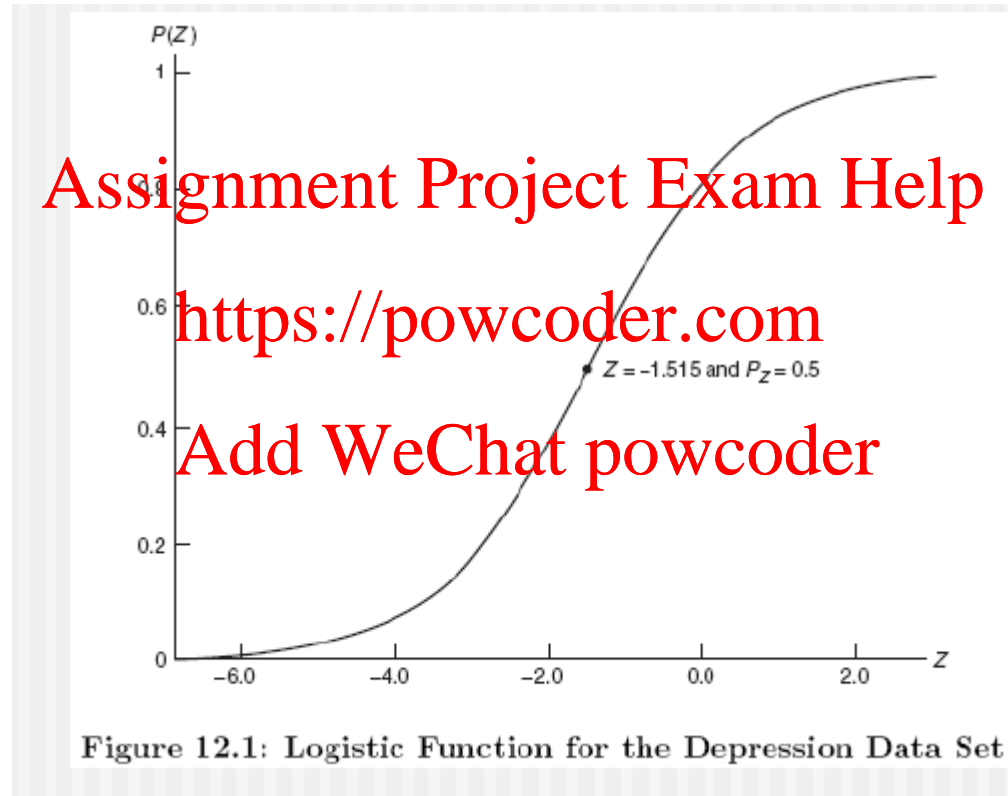
Logistic Regression

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$$\pi(x) = \frac{e^{\alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p}}{1 + e^{\alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p}}$$

Logistic Regression



This is a Logistic Function – Hence Logistic Regression

Logistic Regression – Model Odds are multiplicative

- $\ln(\text{odds}) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p$
- Odds = $e^{\alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p}$
 - $= (e^\alpha) (e^{\beta_1 X_1}) (\dots) (e^{\beta_p X_p})$
- Or: Odds = constant * exp (constant * X_1)
 - * exp (constant * X_p)

Logistic Regression – Model

Log (Odds) are additive

- $\ln(\text{odds}) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p$

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- Or: $\ln(\text{Odds}) = \text{constant} + (\text{constant} * X_1)$

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$$\begin{array}{c} \bullet \quad \bullet \quad \bullet \\ + (\text{constant} * X_p) \end{array}$$

Logistic Regression – Model Flexibility

- X (independent) variables can be continuous or categorical
- Interactions can be incorporated
- Coefficients are estimated by maximum likelihood
- Most computer programs implicitly use prior probabilities estimated from sample.

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Logistic Regression – Model

Generalized Linear Model (GLM)

- Logistic regression is an example of the GLM
- Define $Y = \text{outcome} = 1$ (event) or 0 (not)
- $E(Y|X's) = \mu = P(1|X's)$
- Find a function $g(\mu)$, called the *link* function, such that:
$$g(\mu) = \text{linear function of the } X's$$
- This is called the GLM
- Here we take $g(\mu) = \ln(\text{odds}) = \text{logit function}$

Logistic Regression – Model Estimation

- Model is: $g(\mu) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_p X_p$
- Need to estimate: $\alpha, \beta_1, \beta_2, \dots, \beta_p$
- Use an iterative process called Iterative Weighted Least Squares:
 1. Start with initial estimates of parameters
 2. Evaluate the score equations (derivative of log-likelihood = 0)
 3. Solve the score equations and get new estimates of parameters
 4. Repeat until convergence.

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Logistic Regression – Model

Example: Depression Data Set

Adjusted Risk Ratio

- $RR = P(Y=1 | X=1) / P(Y=1 | X=0)$
- $P(Y=1 | X) = e^{LC} / (1 + e^{LC})$, $LC = A + B_1 X_1 + \dots$
- Example: Depression, $X = \text{sex} = 1$ if F, age = 30, income = 10 (\$10K/year)
- Find adjusted RR for F vs. M
- $LC = -0.676 - 0.021 \text{ Age} - 0.037 \text{ Income} + 0.929 \text{ Sex}$

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