2. $\overline{err} = \frac{1}{N}\sum_{i=1}^{N}(y_i - x_i^T\hat{\beta})^2$ $\quad\quad \overline{Err} = \frac{1}{M}\sum_{i=1}^{M}(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2$

$$\mathbb{E}[\overline{Err}] = \mathbb{E}\left[\frac{1}{M}\sum_{i=1}^{M}(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2\right]$$
$$= \frac{1}{M}\sum_{i=1}^{M}\mathbb{E}[(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2]$$
$$= \mathbb{E}[(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2] \text{ since each } \tilde{y}_i - \tilde{x}_i^T\hat{\beta} \text{ is i.i.d}$$

This means that $\mathbb{E}[\overline{Err}]$ is independent of M so we can set $M = N$, $\mathbb{E}[\overline{Err}] = \mathbb{E}\left[\frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2\right]$

Then given $((\tilde{x}_1, \tilde{y}_1), \ldots (\tilde{x}_N, \tilde{y}_N))$ we will define new OLS estimate for this set $\hat{\hat{\beta}} = \underset{\beta}{\text{argmin}} \sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\beta)^2$

Thus by definition we know that $\hat{\hat{\beta}}$ minimizes $\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\beta)^2$ so

$$\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\hat{\beta}})^2 \le \sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\beta)^2 \text{ for any } \beta \text{ so we choose } \hat{\beta} \text{ for this}$$

$$\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\hat{\beta}})^2 \le \sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2$$

$$\frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\hat{\beta}})^2 \le \frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2$$

$$\mathbb{E}\left[\frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\hat{\beta}})^2\right] \le \mathbb{E}\left[\frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\beta})^2\right]$$

$$\mathbb{E}\left[\frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\hat{\beta}})^2\right] \le \mathbb{E}[\overline{Err}]$$

$\frac{1}{N}\sum_{i=1}^{N}(\tilde{y}_i - \tilde{x}_i^T\hat{\hat{\beta}})^2$ and $\frac{1}{N}\sum_{i=1}^{N}(y_i - x_i^T\hat{\beta})^2$ are identically distributed so their expectations are equal

$$\mathbb{E}[\overline{err}] \le \mathbb{E}[\overline{Err}]$$