

## Linear Programming 1

### Exercise 1: Sparse Quantile Regression

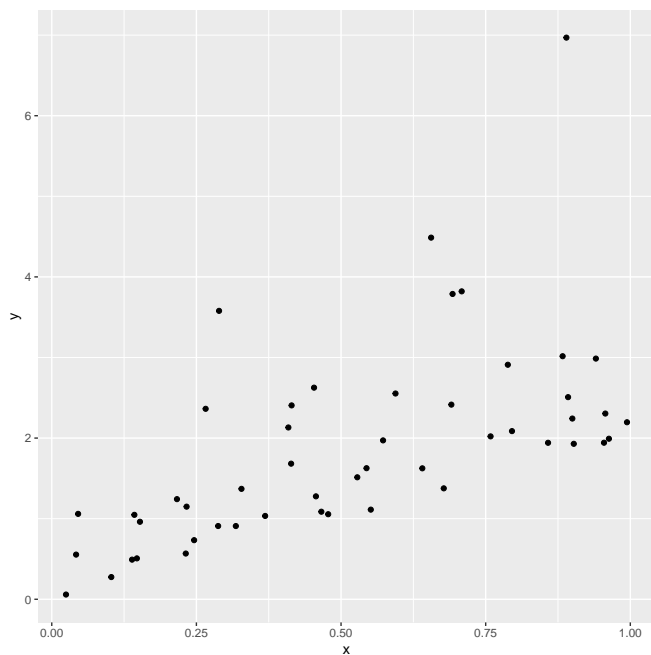
You are given the following data situation:

```
library(ggplot2)

set.seed(123)

# generate 50 numerical observations with skewed error distribution (gamma)
n = 50
x = runif(n)
y = 2 * x + rgamma(n, shape = 1)

ggplot(data.frame(x = x, y = y), aes(x=x, y=y)) +
  geom_point()
```



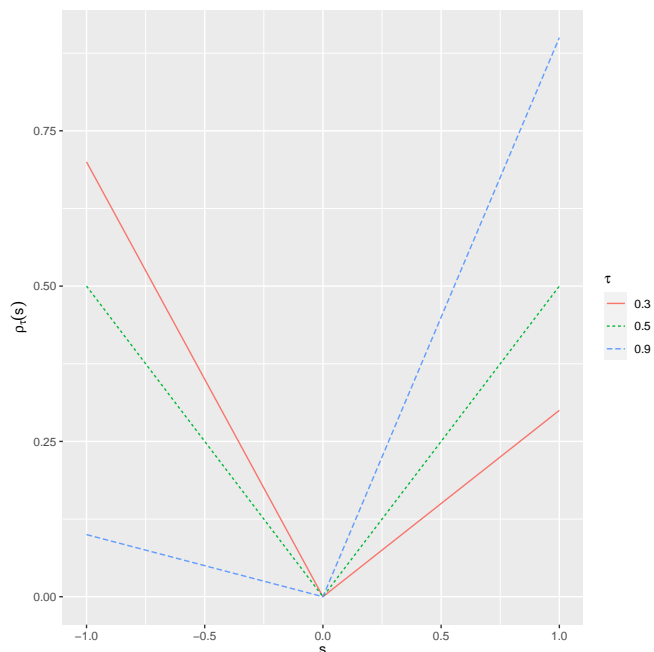
The general multivariate sparse quantile regression can be stated as in the lecture such as

$$\min_{\beta \in \mathbb{R}^p} \underbrace{\frac{1}{n} \sum_{i=1}^n \rho_{\tau}(y^{(i)} - \beta_0 - \beta^{\top} \mathbf{x}^{(i)})}_{=\mathcal{R}_{\text{emp}}} \quad \text{s.t.} \quad \|\beta\|_1 \leq t$$

with  $\tau \in (0, 1)$

$$\rho_{\tau}(s) = \begin{cases} \tau \cdot s & \text{for } s > 0 \\ -(1 - \tau) \cdot s & \text{for } s \leq 0 \end{cases}$$

The  $\rho_{\tau}(s)$  function is also called pinball loss. For  $\tau \neq 0.5$ , it asymmetrically assigns weights to the residuals:



In the following we consider only the univariate case:

- Find the standard form (as defined in the lecture) of the one-dimensional sparse quantile regression  
*Hint:* If an unconstrained variable  $x$  is decomposed into two non-negative variables such that  $x = x^+ - x^-$ , then the absolute value  $|x| = x^+ + x^-$ . This works since the optimization algorithm ensures that at most one of the variables  $x^+, x^-$  is not zero.
- Plot  $\mathcal{R}_{\text{emp}}$  for  $(\beta_0, \beta_1) \in [-3, 3] \times [-3, 3]$  and  $\tau = 0.4$  and mark the feasible region ( $t = 1.7$ )
- Use the `solveLP` command in `R` to solve the sparse 40% quantile regression ( $t = 1.7$ )
- State the corresponding dual formulation of a) (as defined in the lecture)