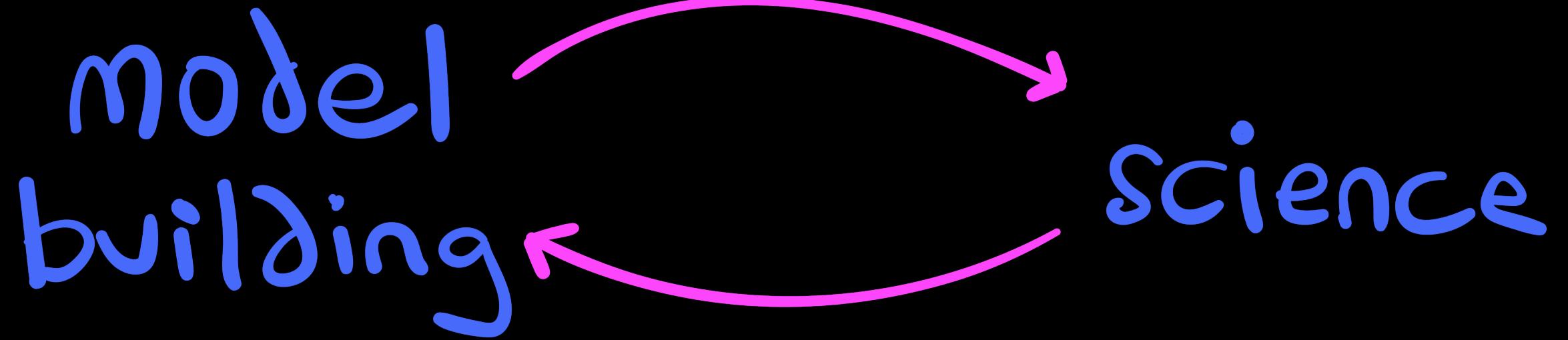


6. Connecting theory to practice: a first look at model building



6.1. Data and random samples

S



$\rightarrow R$

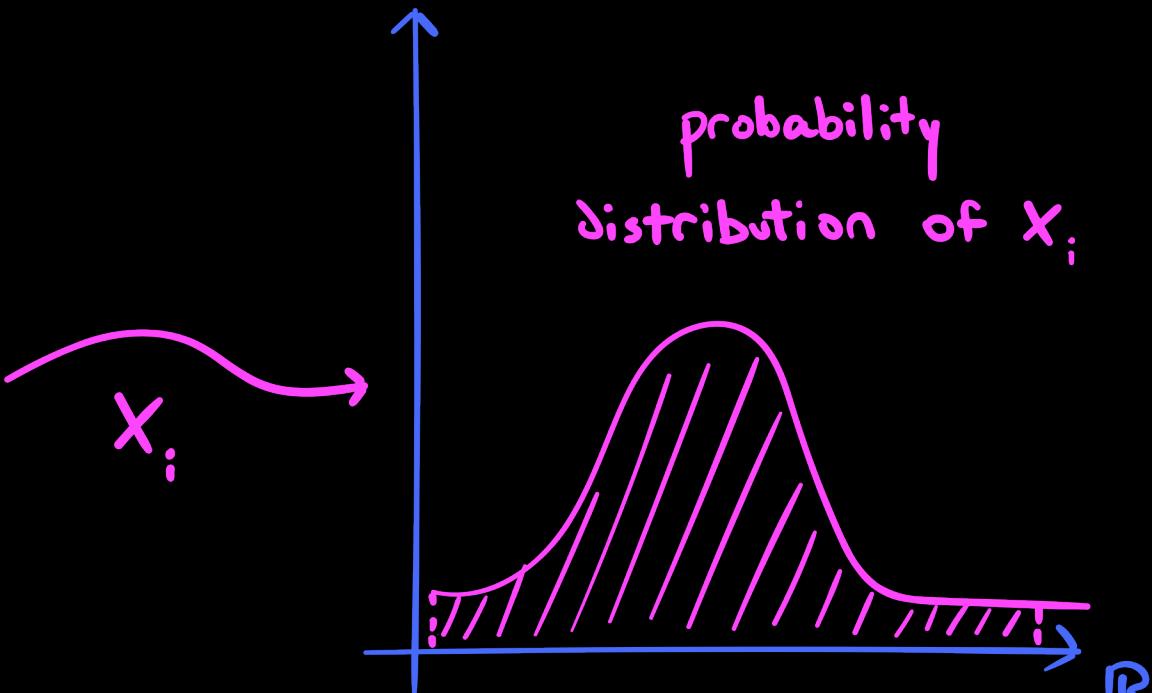
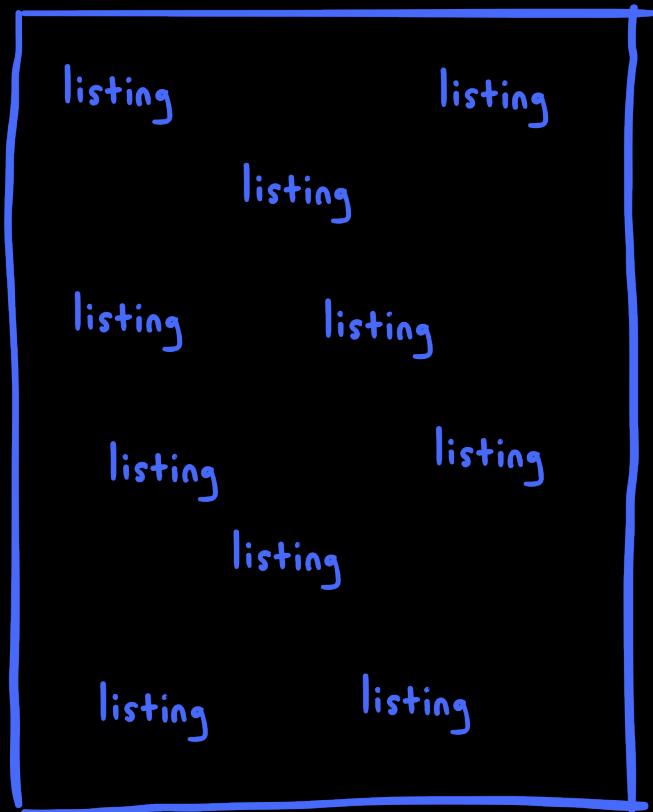
$X = \text{price}$

(listing 1, listing 2, listing 3, ..., listing n)

$x_1 \downarrow$ $x_2 \downarrow$ $x_3 \downarrow$ $x_n \downarrow$

(price 1, price 2, price 3, ..., price n)

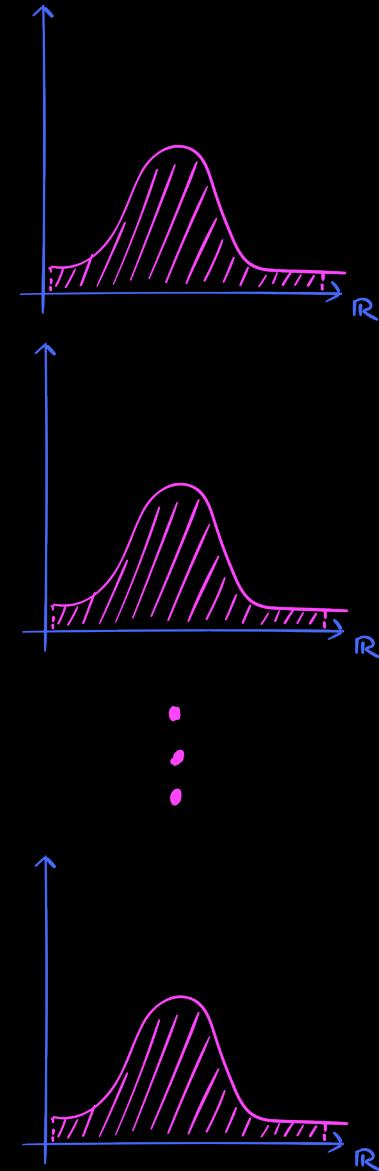
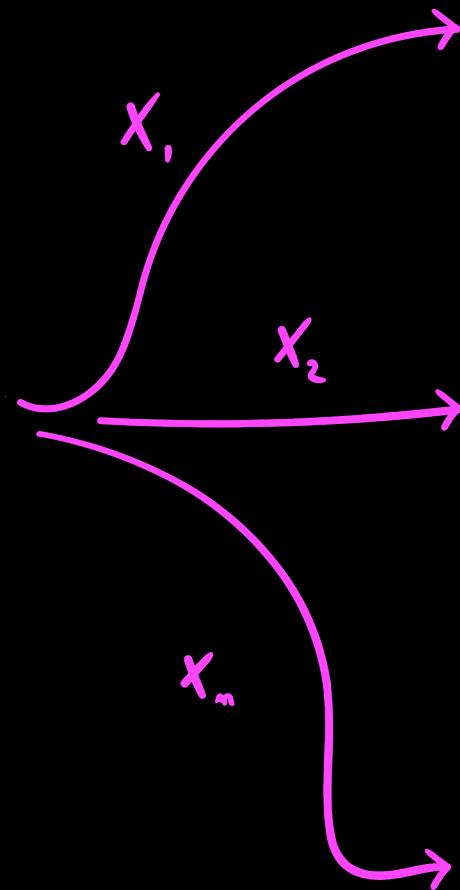
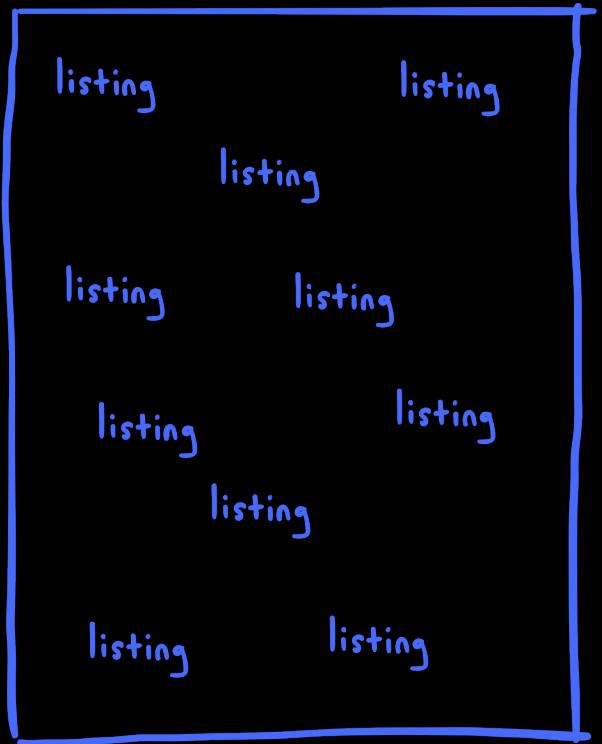
S



these prices
are common...

...these ones
less so

S



identical
distributions!!!

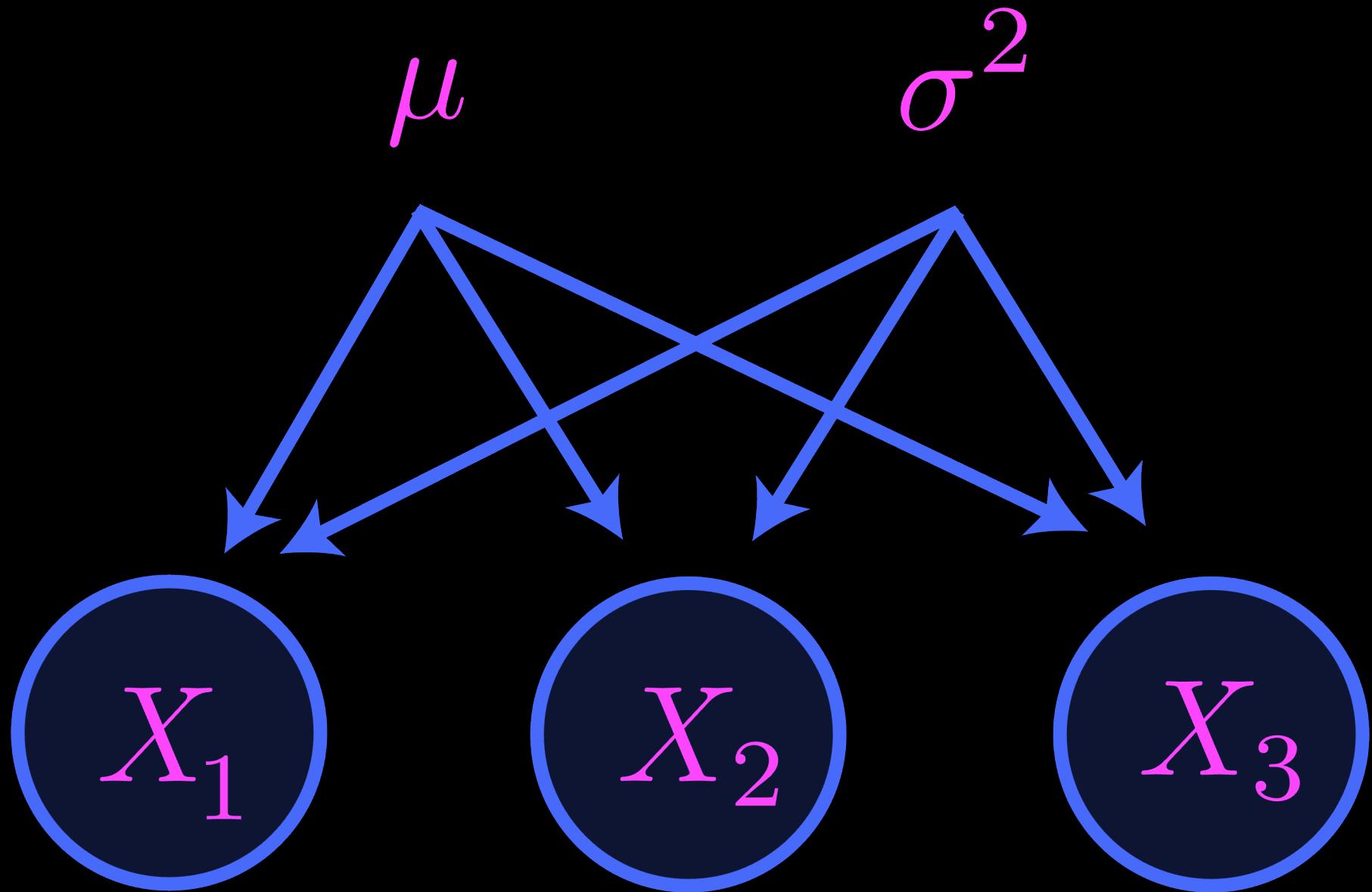
 **Definition 6.1**

Let X_1, X_2, \dots, X_m be a sequence of random variables, all defined on the same probability space.

- The random variables are called a *random sample* if they are *independent* and *identically distributed* (IID).

Provided that the sequence is a random sample, an *observed random sample*, or a *dataset*, is a sequence of real numbers x_1, x_2, \dots, x_m where x_i is an observed value of X_i .

6.2. Probabilistic models and empirical distributions



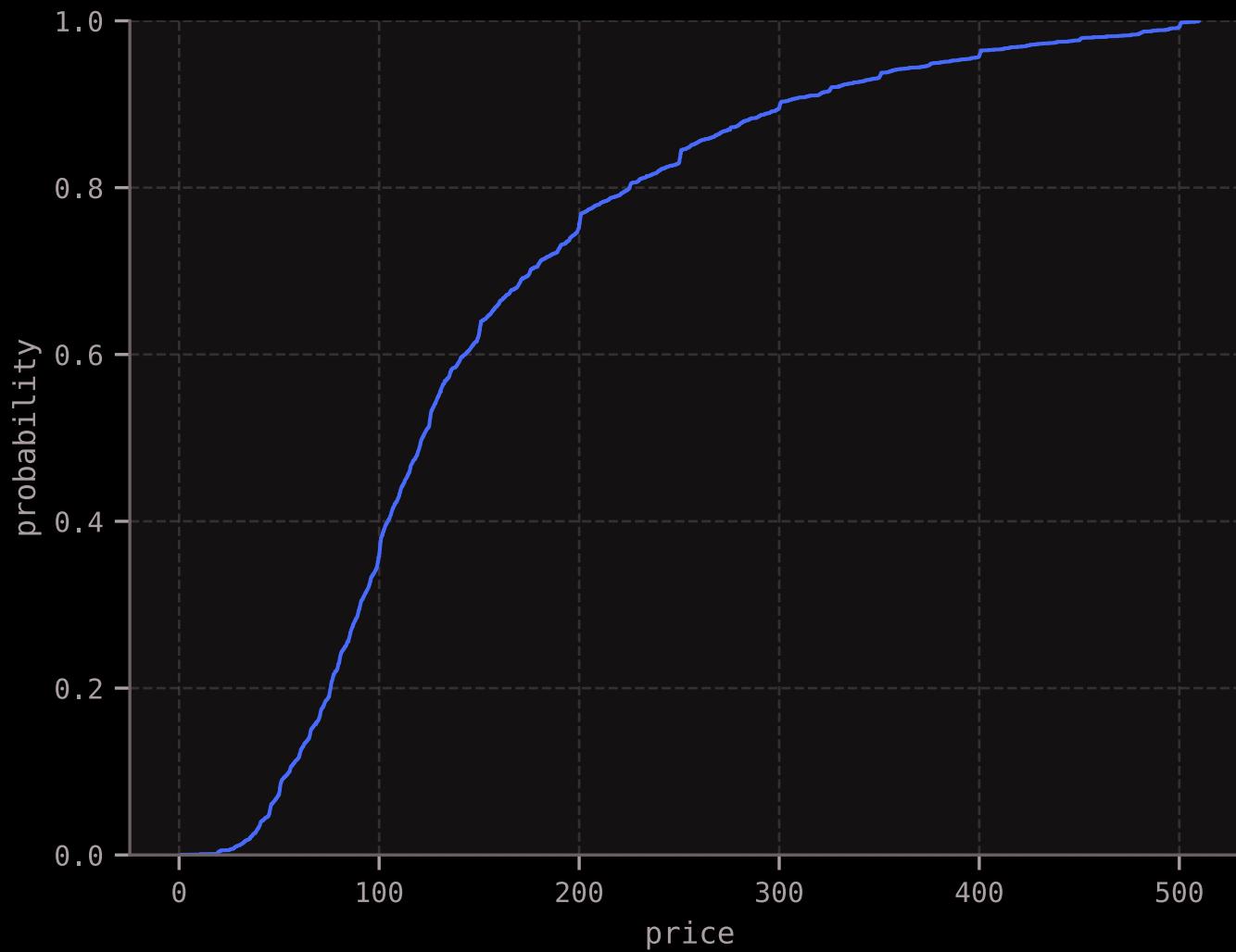
Definition 6.2

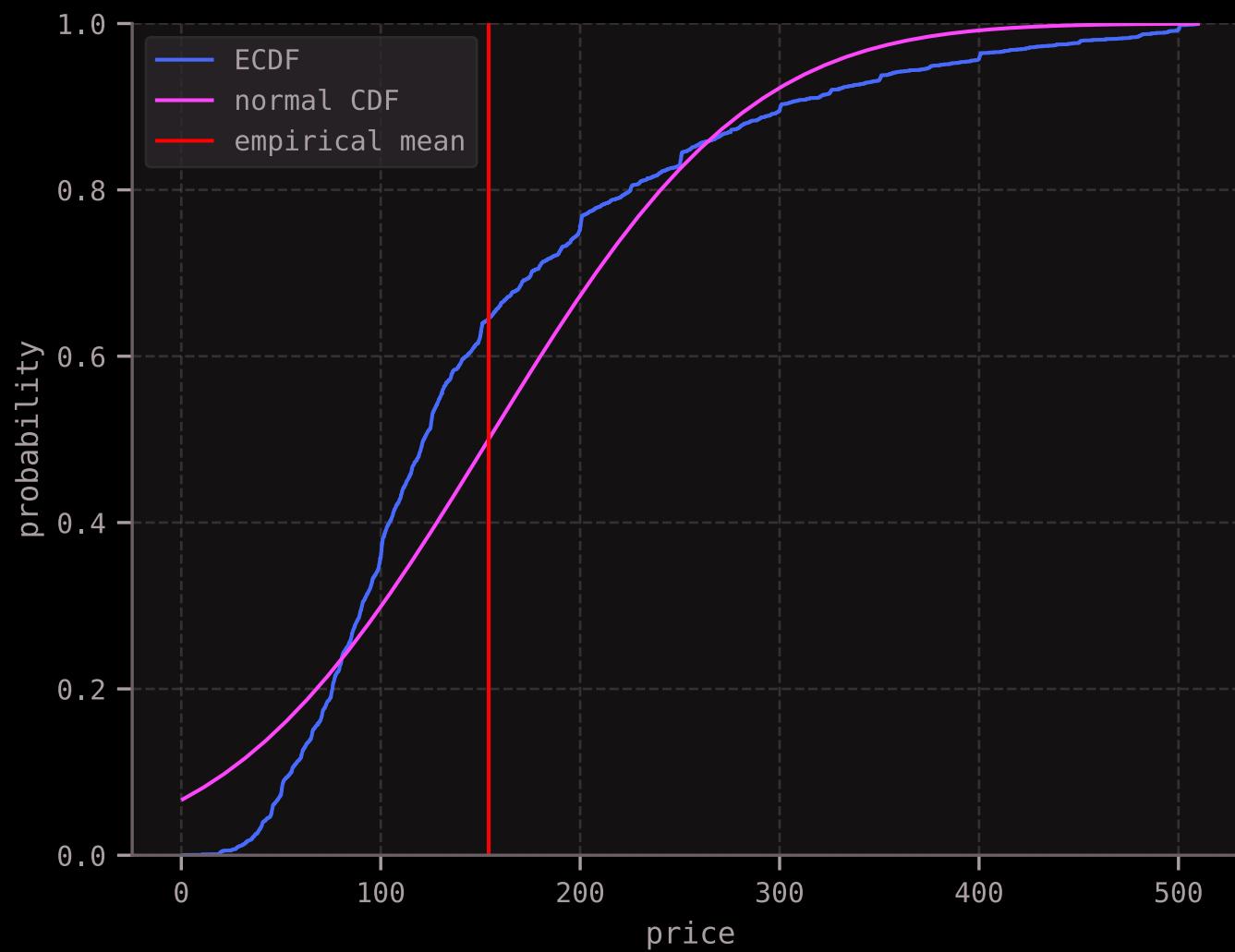
Let $X_1, X_2, \dots, X_m \sim F$ be a random sample from an unknown distribution function F , and let x_1, x_2, \dots, x_m be an *observed* random sample. Then the *empirical distribution* of the dataset is the discrete probability measure on \mathbb{R} with probability mass function

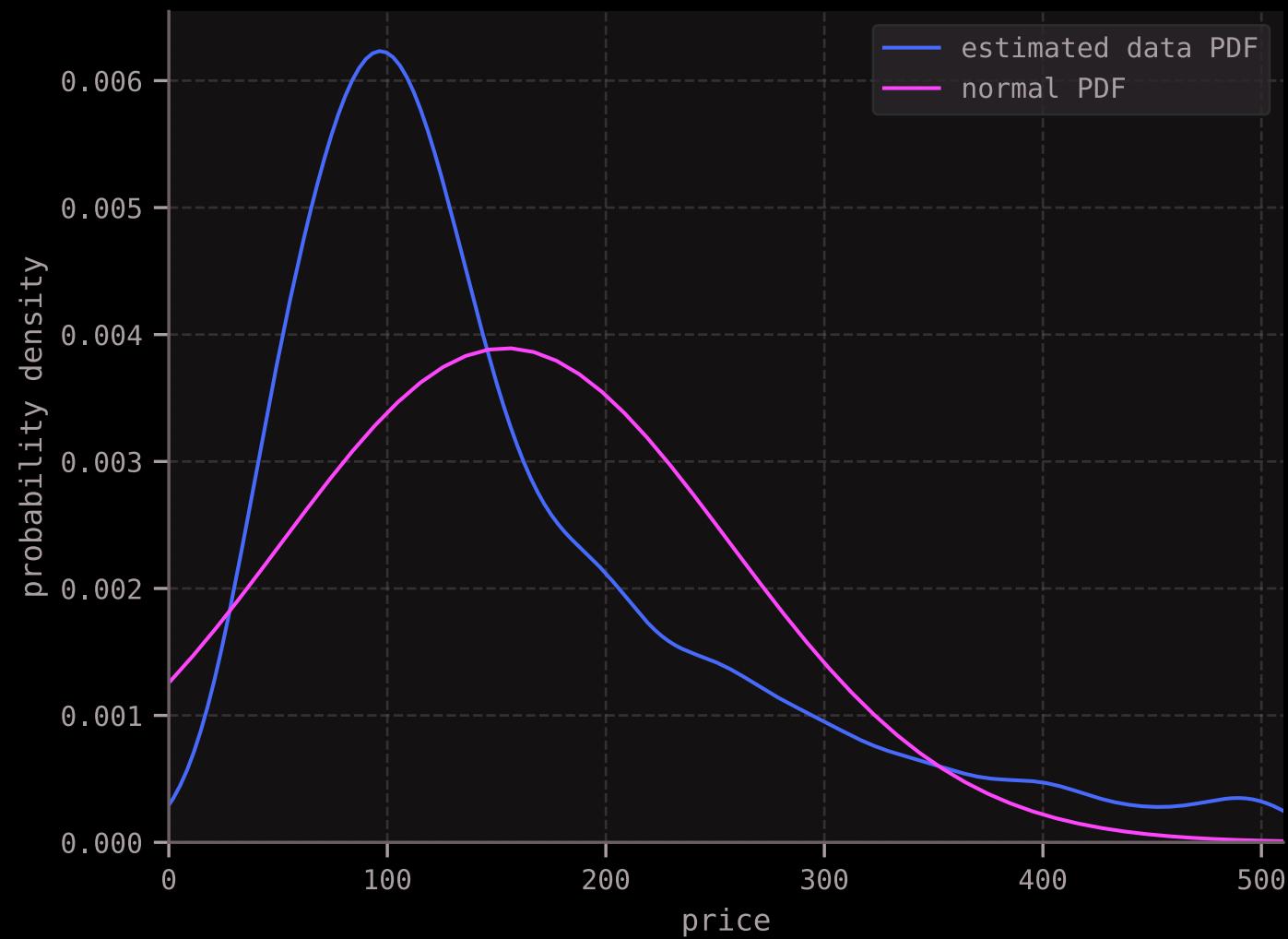
$$p(x) = \frac{\text{number of data points } x_i \text{ that match } x}{m}. \quad (6.1)$$

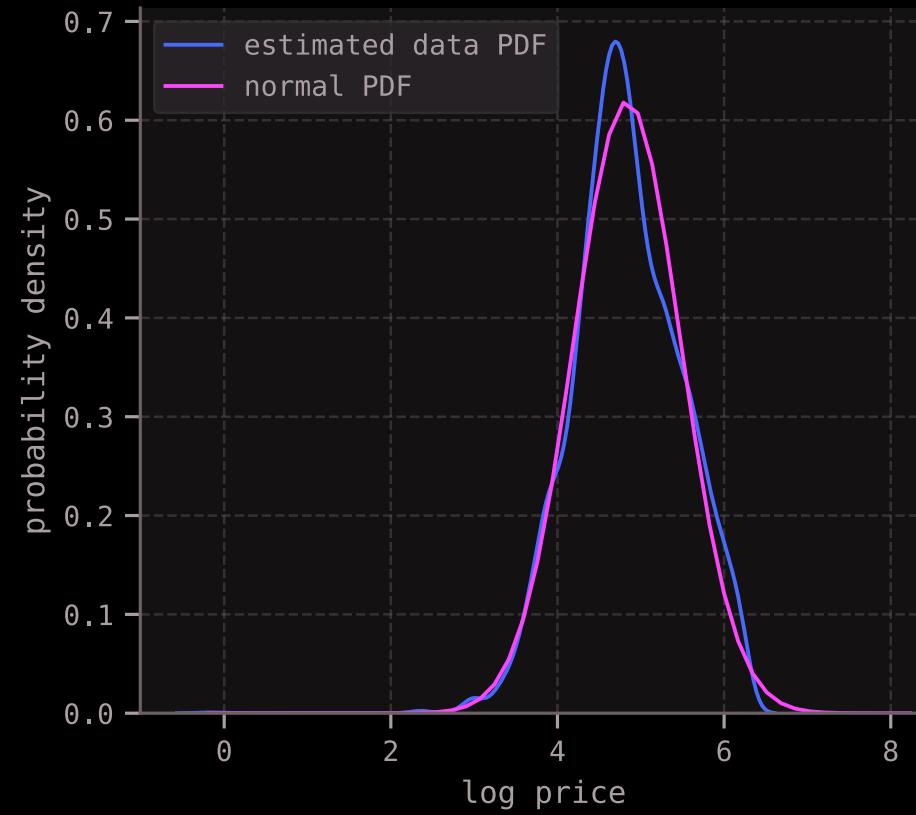
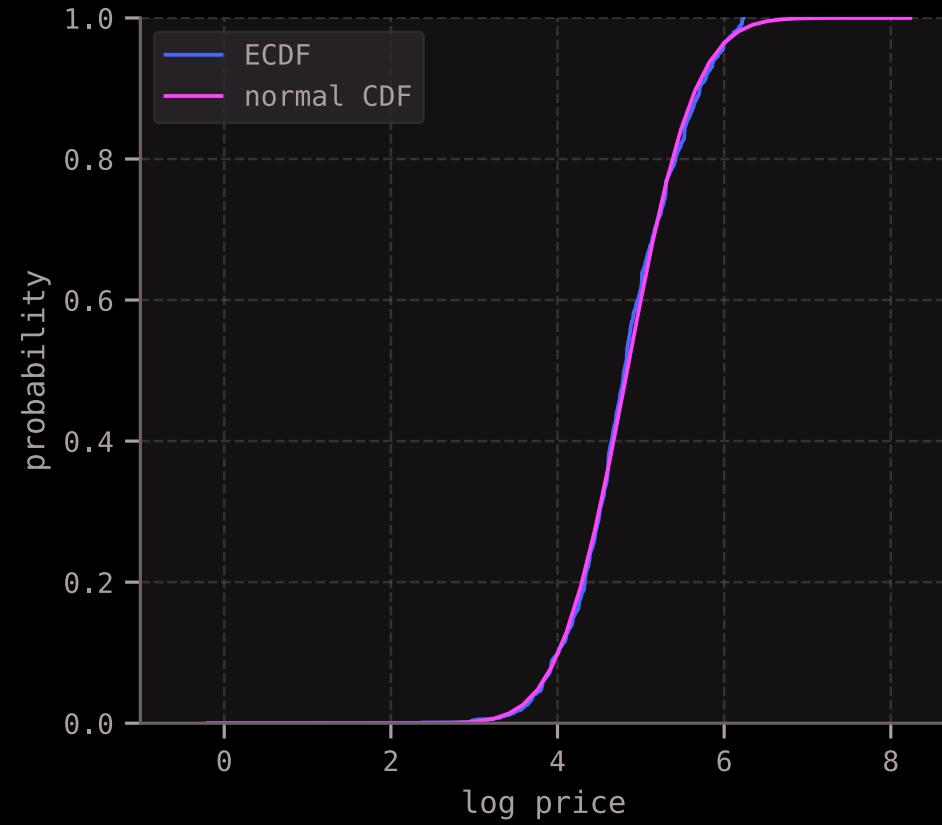
The *empirical cumulative distribution function* (ECDF) of the dataset is the CDF of the empirical distribution. It is often denoted $\hat{F}(x)$, and it is given by the usual formula

$$\hat{F}(x) = \sum_{y \leq x} p(y) = \frac{\text{number of data points } x_i \text{ with } x_i \leq x}{m}.$$







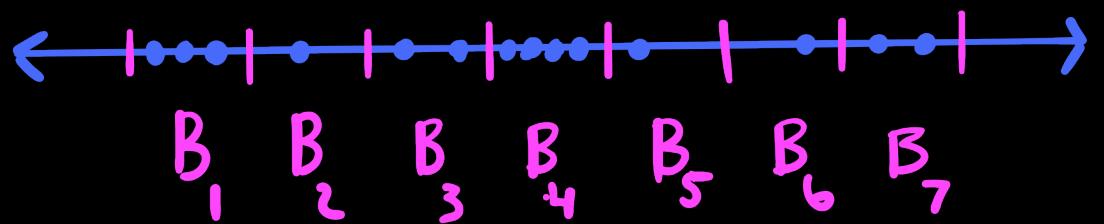


6.3. Histograms

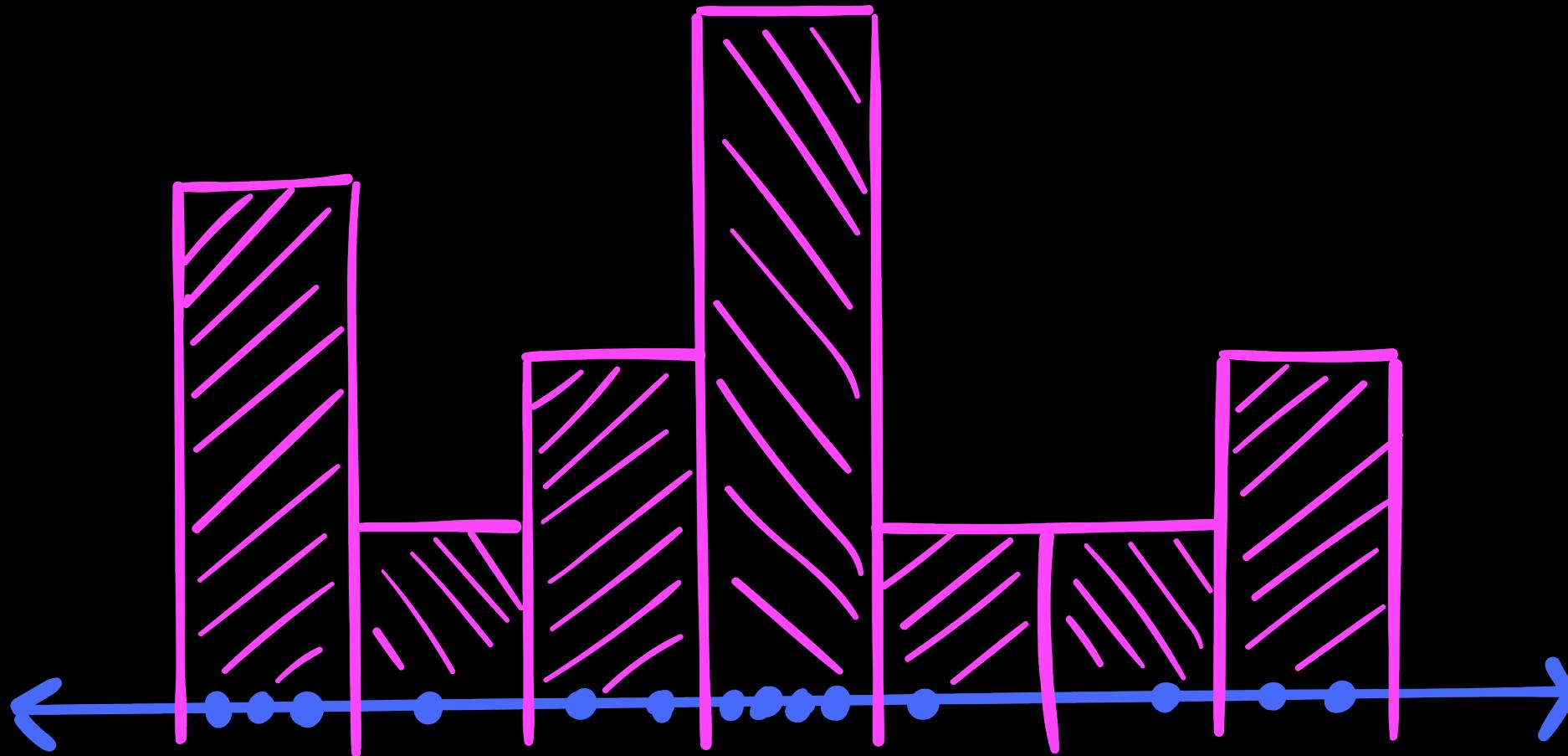
dataset

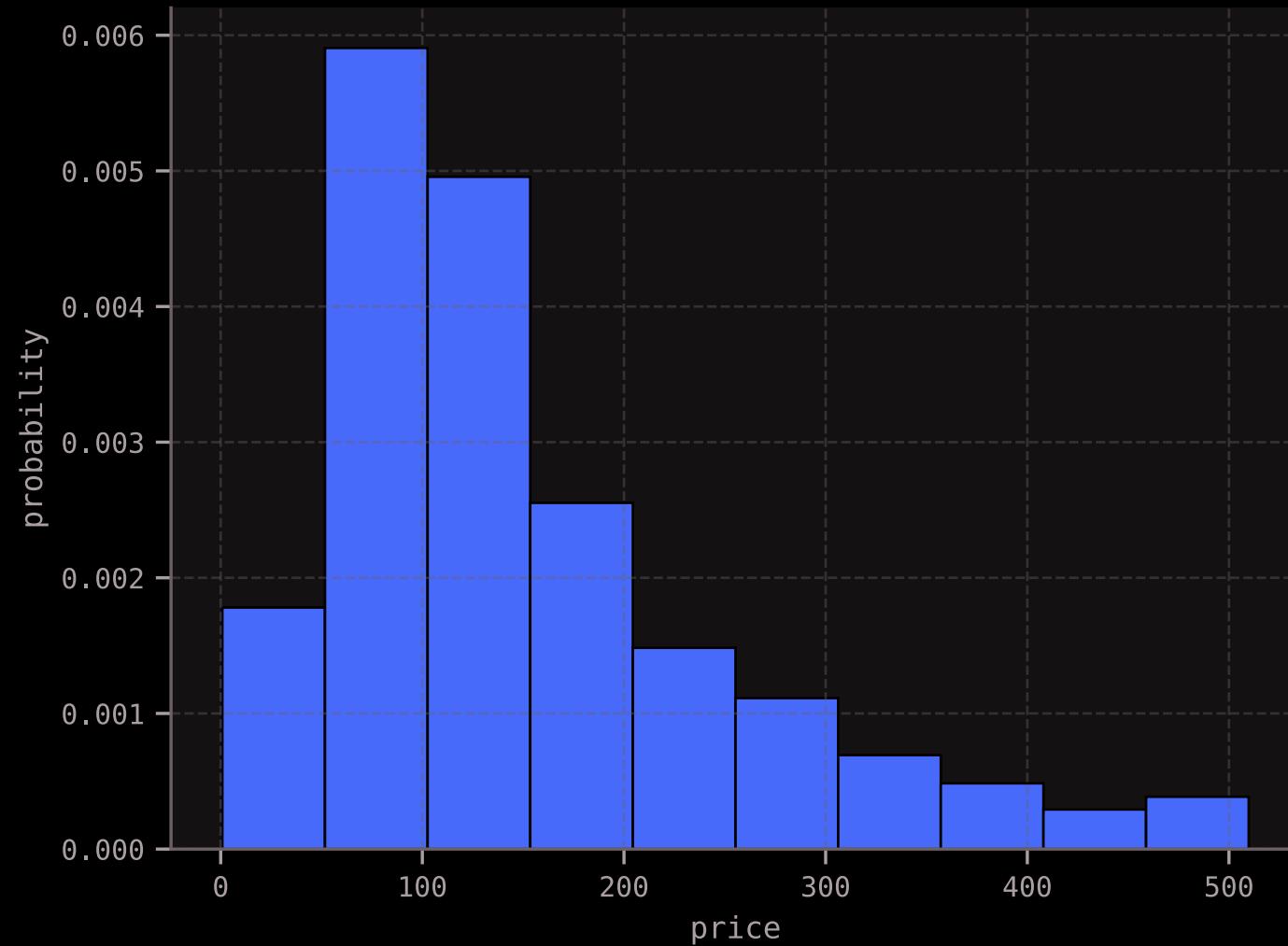


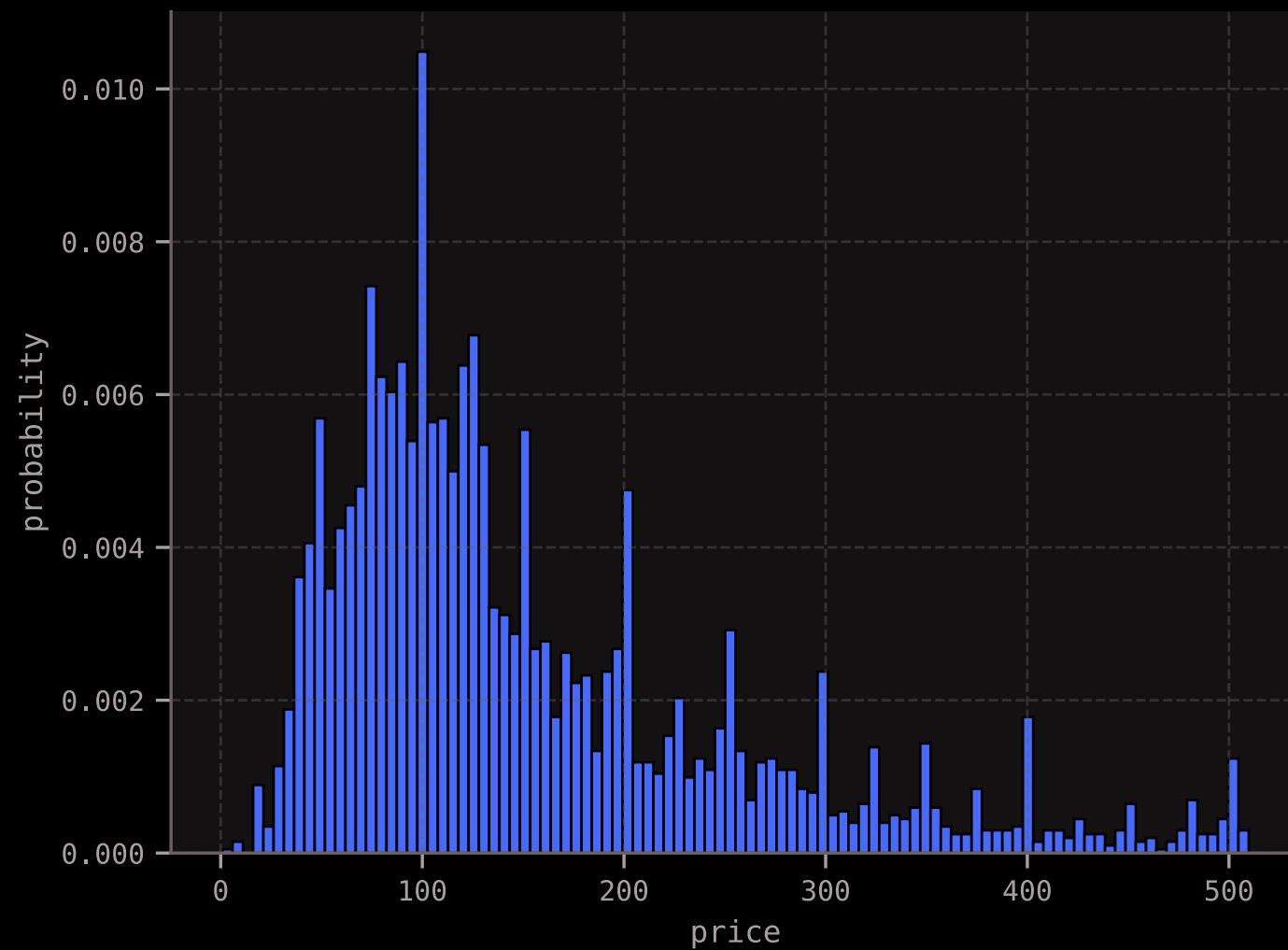
dataset in bins

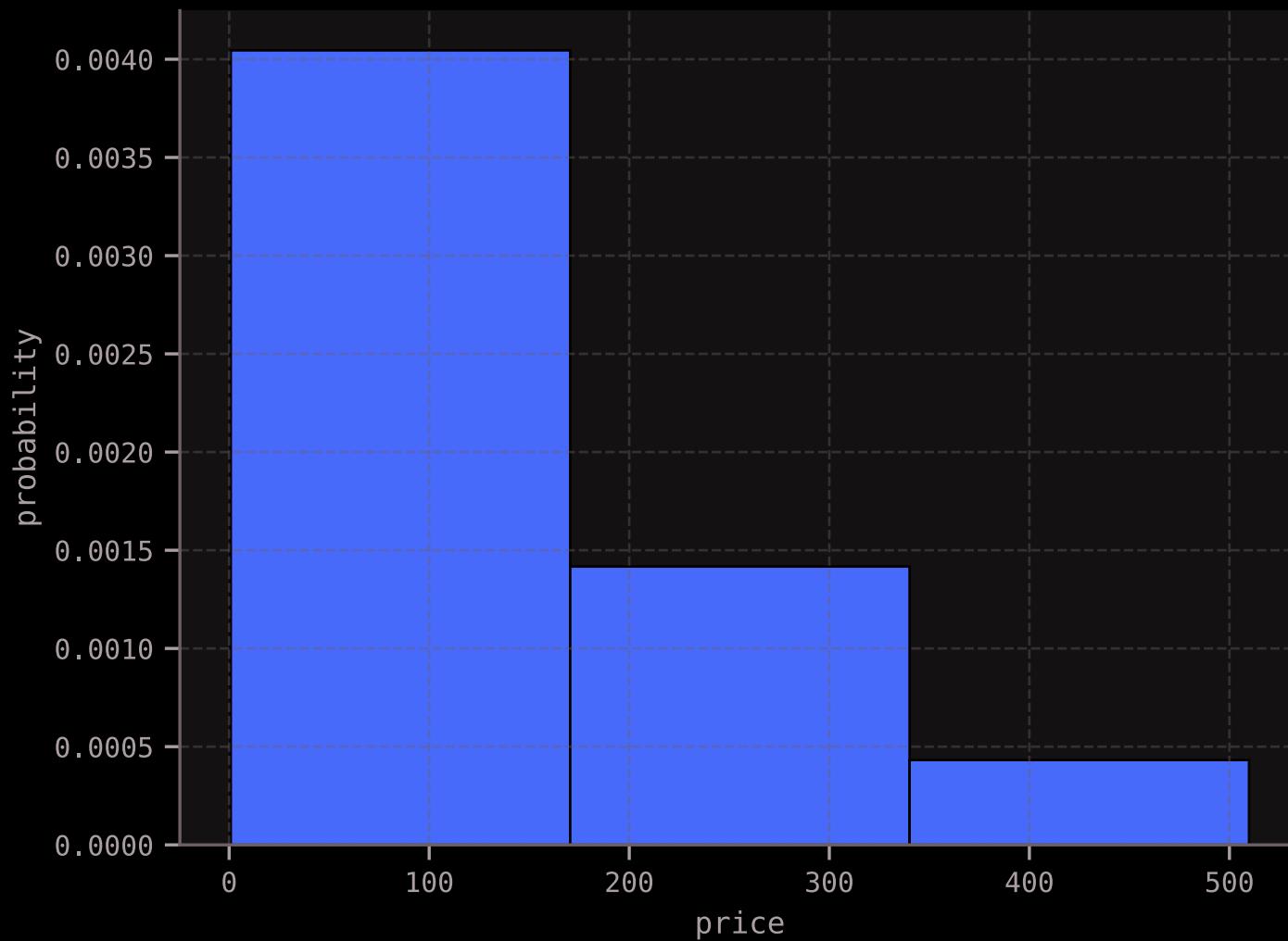


histogram



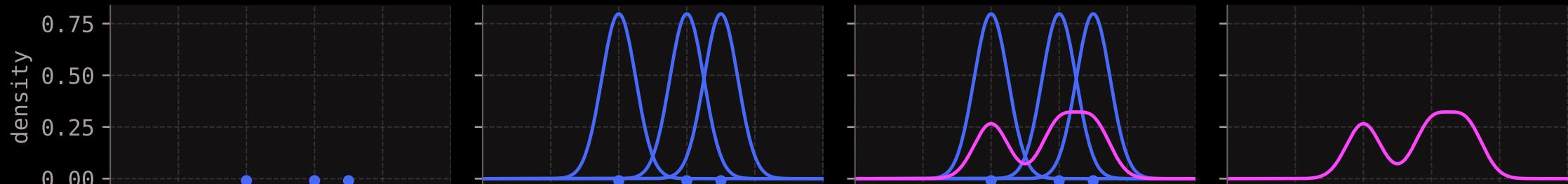




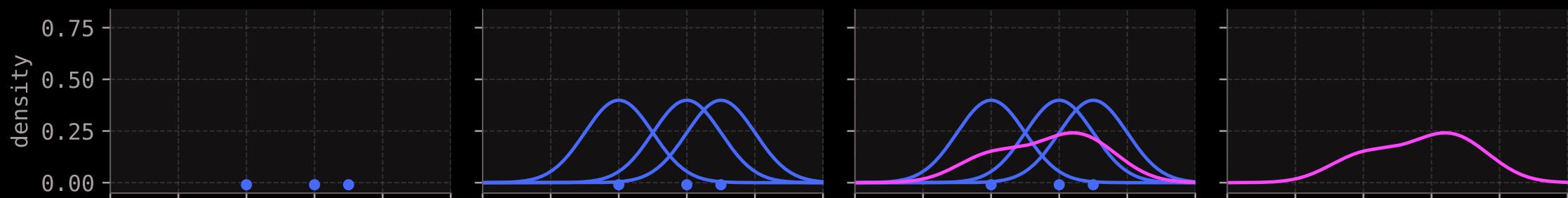


6.4. Kernel density estimation

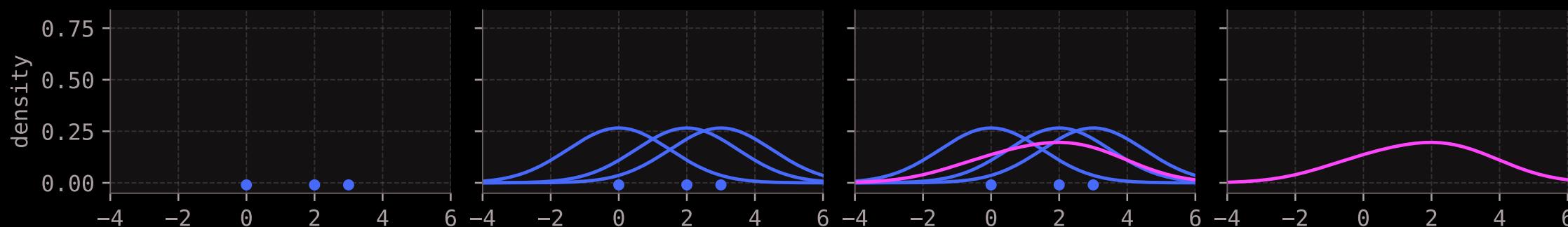
bandwidth $h = 0.5$

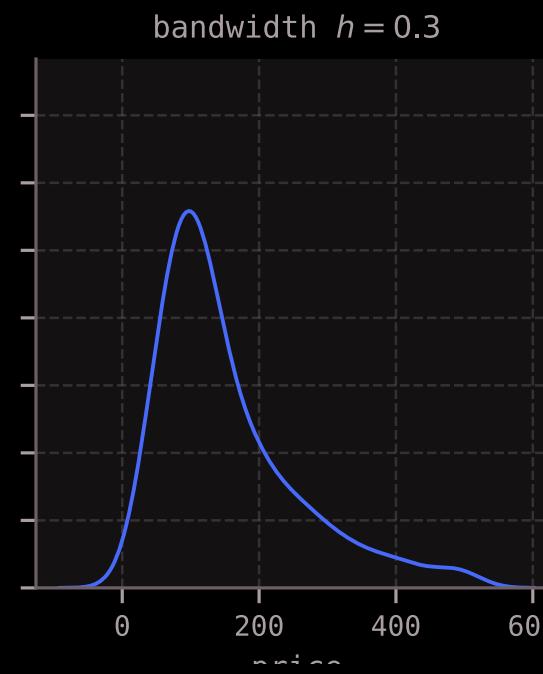
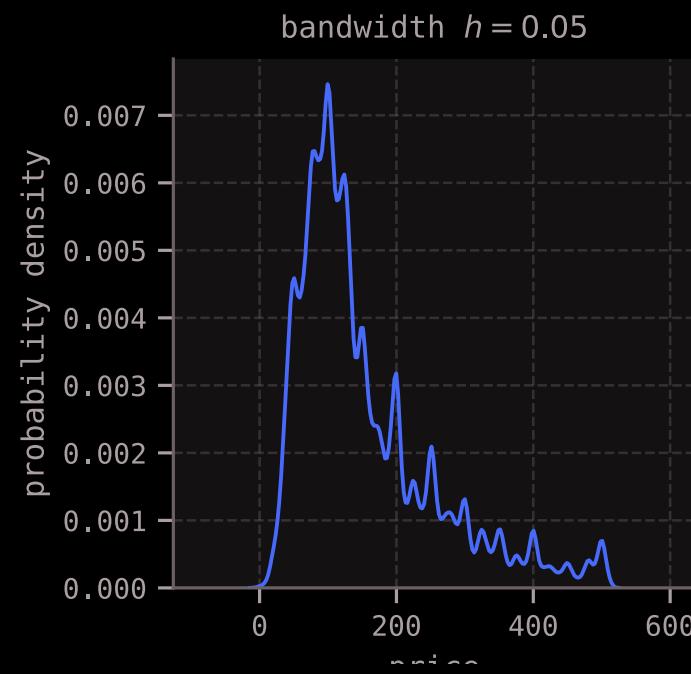


bandwidth $h = 1$



bandwidth $h = 1.5$





6.5. Empirical statistics



Definition 6.3

Let x_1, x_2, \dots, x_m be an observed random sample (i.e., a dataset). The *empirical mean* is defined to be the number

$$\bar{x} = \frac{1}{m} \sum_{i=1}^m x_i,$$

while the *empirical variance* is defined to be the number

$$s^2 = \frac{1}{m-1} \sum_{i=1}^m (x_i - \bar{x})^2.$$

The *empirical standard deviation* s is defined, as usual, as the positive square root of the empirical variance, $s = \sqrt{s^2}$.



Definition 6.4

Let x_1, x_2, \dots, x_m be an observed random sample, written in non-decreasing order:

$$x_1 \leq x_2 \leq \dots \leq x_m. \quad (6.2)$$

For each $i = 1, 2, \dots, m$, the datapoint x_i is called the *empirical q-quantile* where

$$q = \frac{i - 1}{m - 1}. \quad (6.3)$$



Definition 6.5

Let x_1, x_2, \dots, x_m be an observed random sample. The *empirical interquartile range* (*empirical IQR*) is the difference

(empirical 0.75-quantile) – (empirical 0.25-quantile).



Definition 6.6

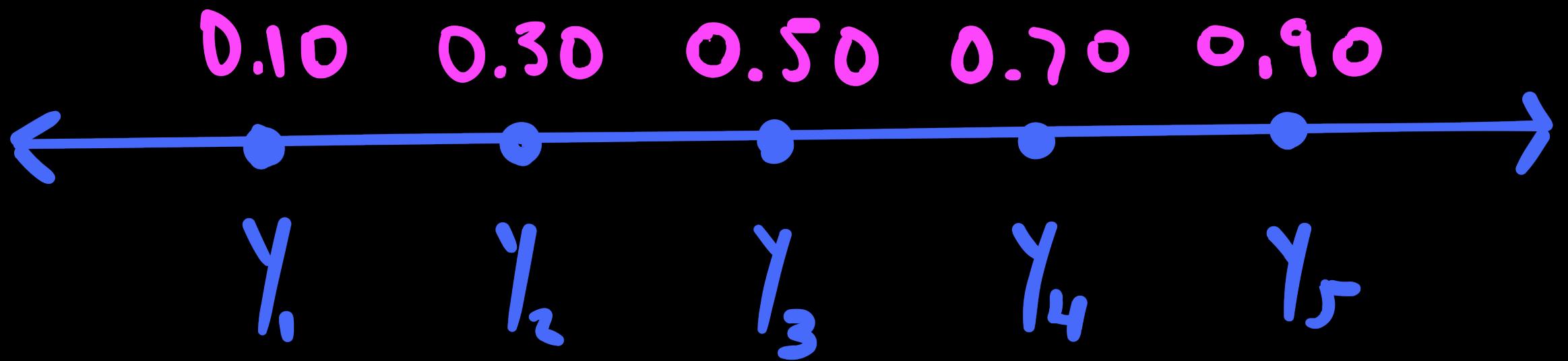
Let x_1, x_2, \dots, x_m be an observed random sample. Then a data point x_i is called an *outlier* if it is above an upper threshold value

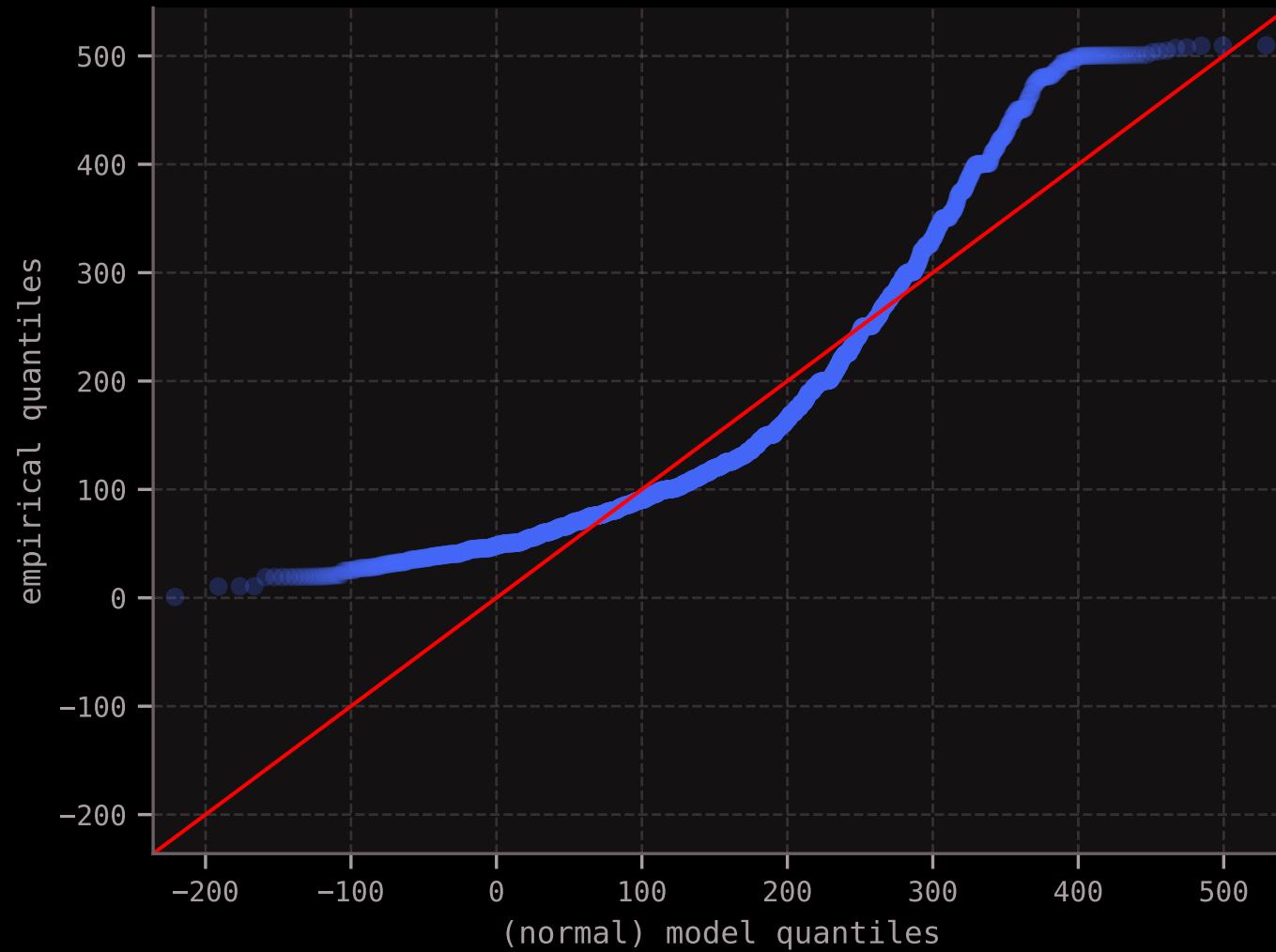
$$x_i > (\text{empirical 0.75-quantile}) + 1.5 \times (\text{empirical IQR}),$$

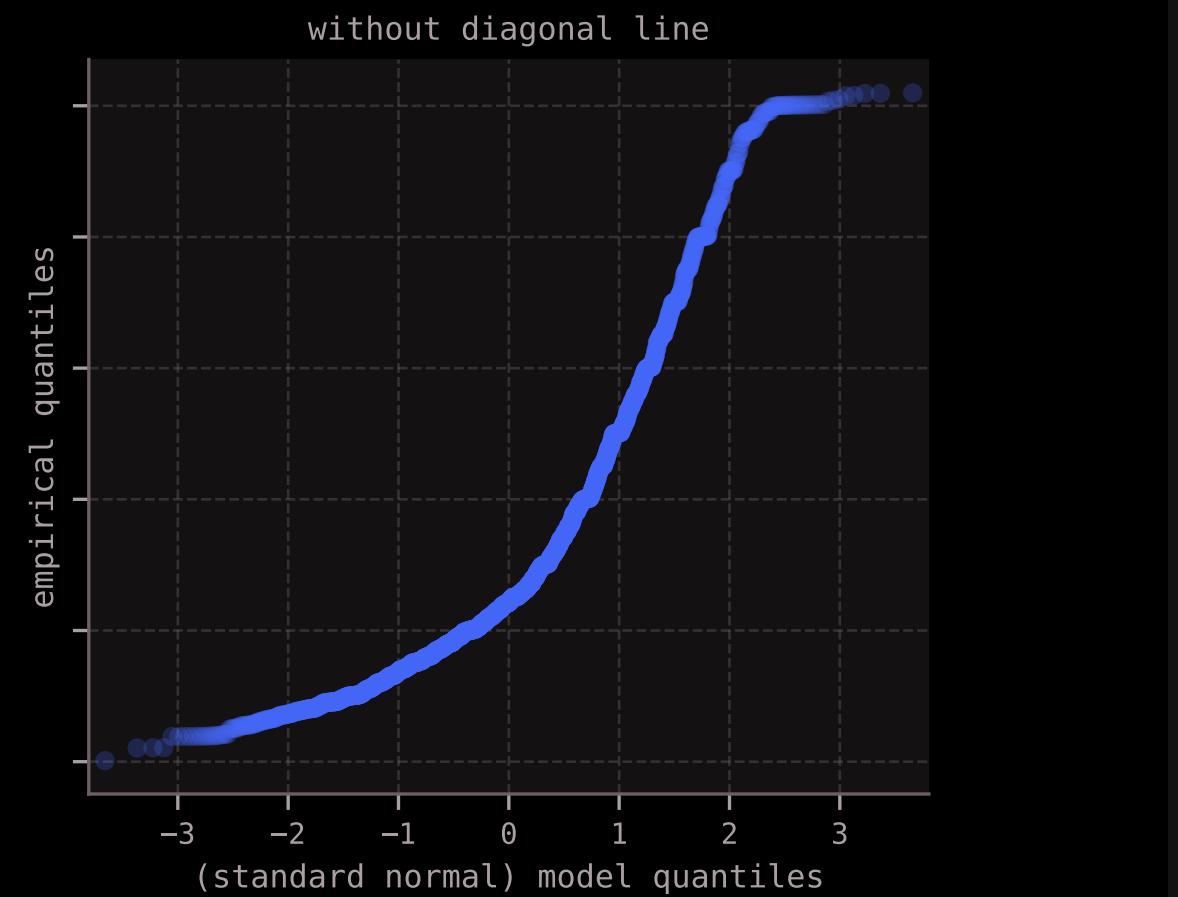
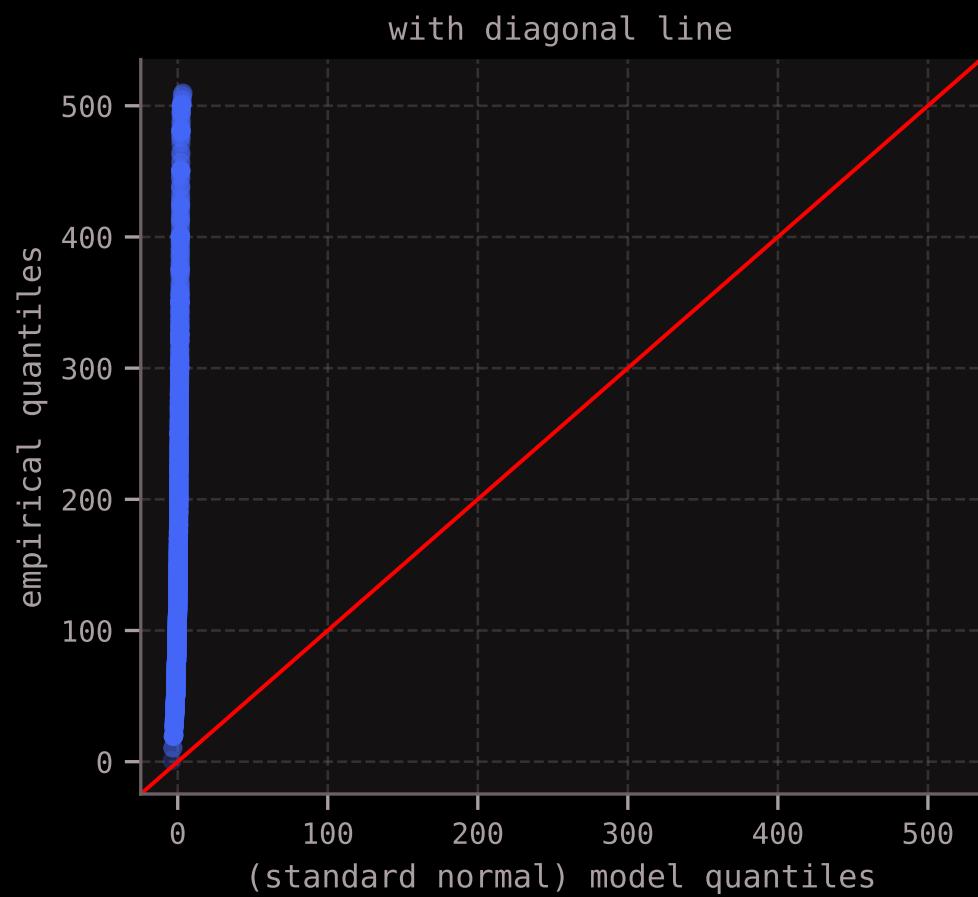
or if it is below a lower threshold value

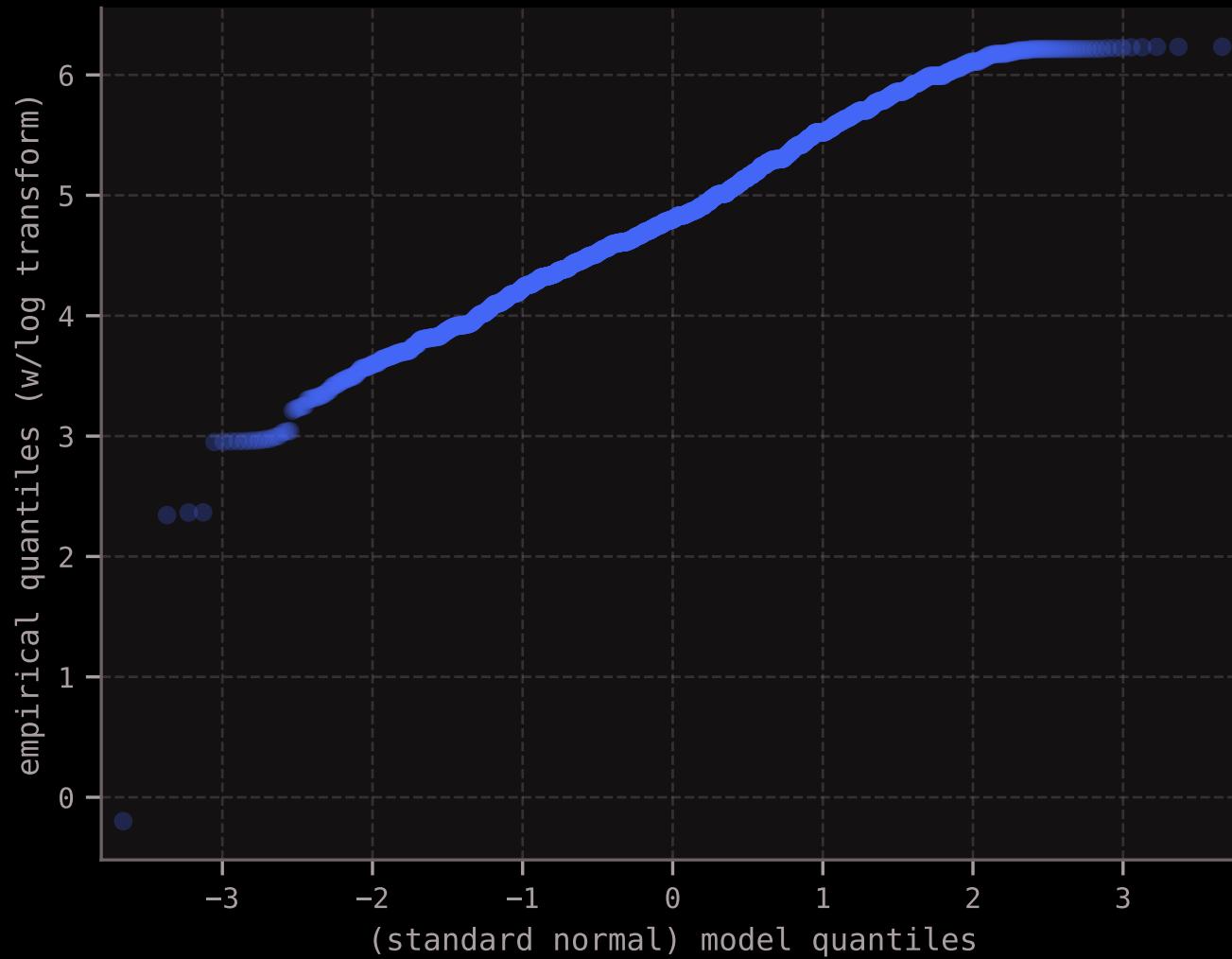
$$x_i < (\text{empirical 0.25-quantile}) - 1.5 \times (\text{empirical IQR}).$$

6.6. QQ-plots









6.7. Box plots and violin plots

