Social Data Science

SOCIOL 114
Winter 2025

What is a model?

Learning goals for today

By the end of class, you will be able to

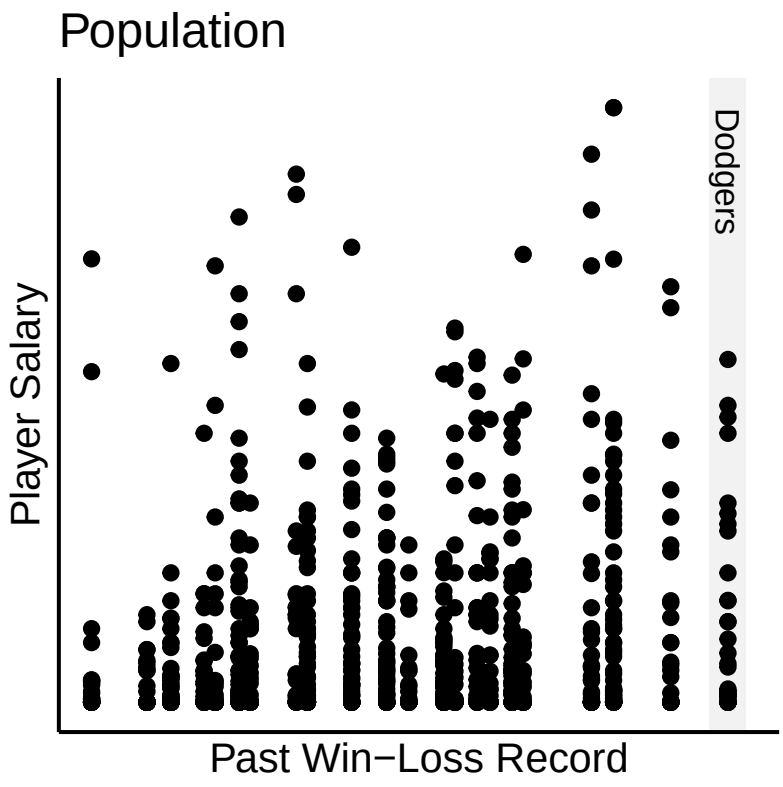
- use statistical learning to estimate when data are sparse
- work with models that are "wrong"

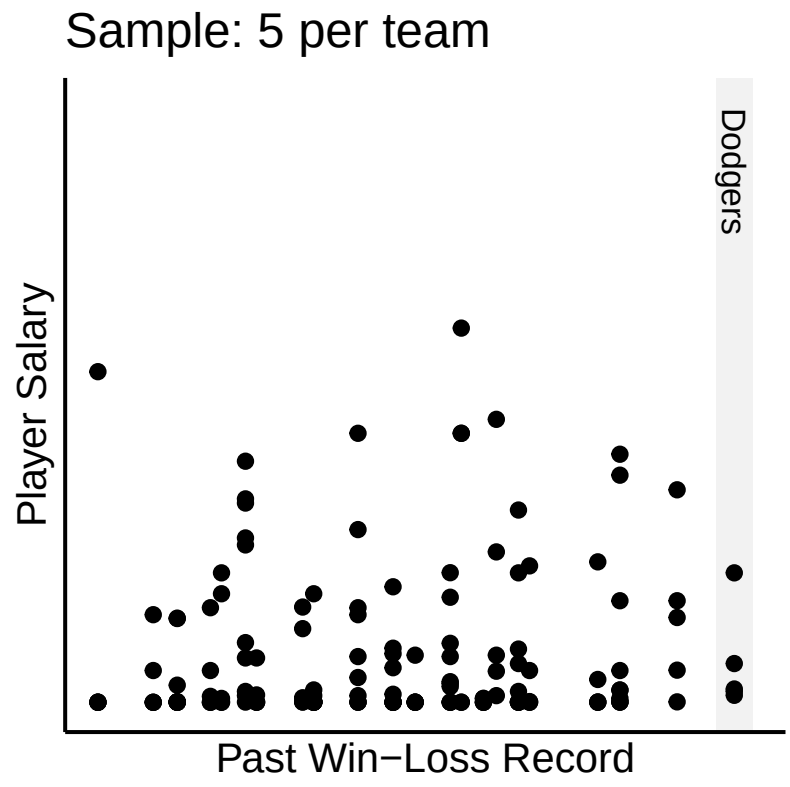
models: the idea

illustrated by a

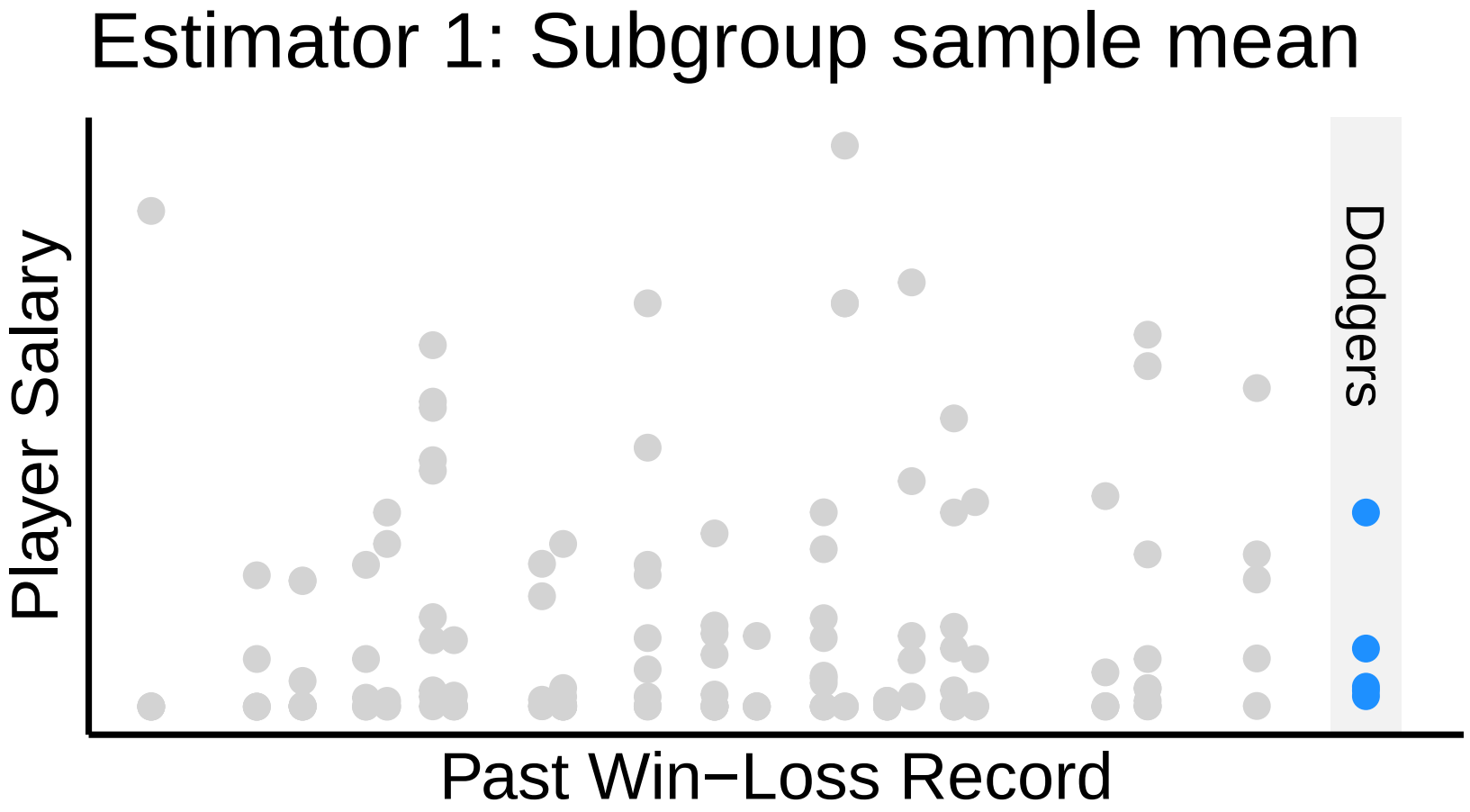
- discrete numeric predictor
- continuous numeric predictor

With only the sample, how would you estimate the mean salary of all the Dodgers?





Three estimators for the Dodgers' mean salary



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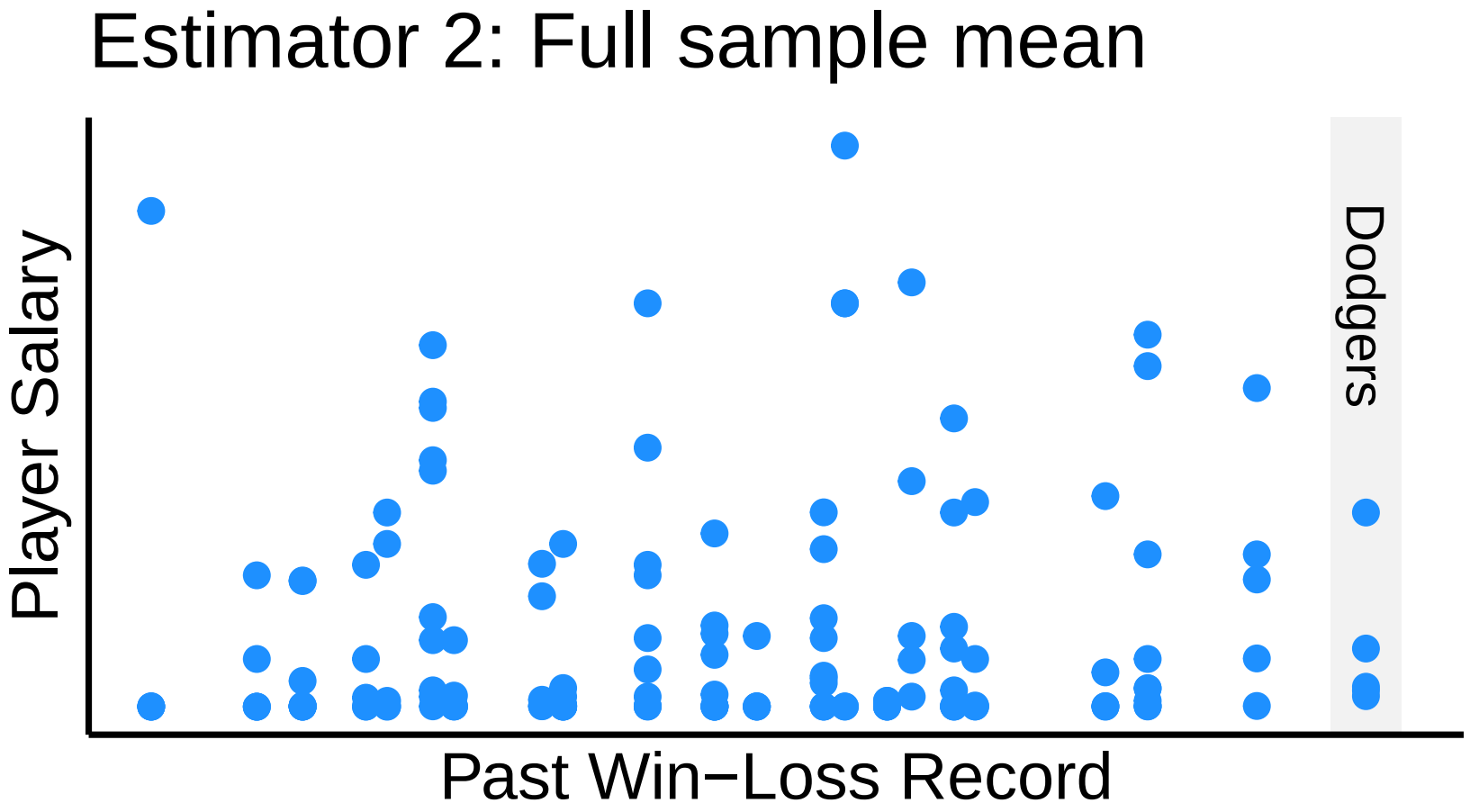

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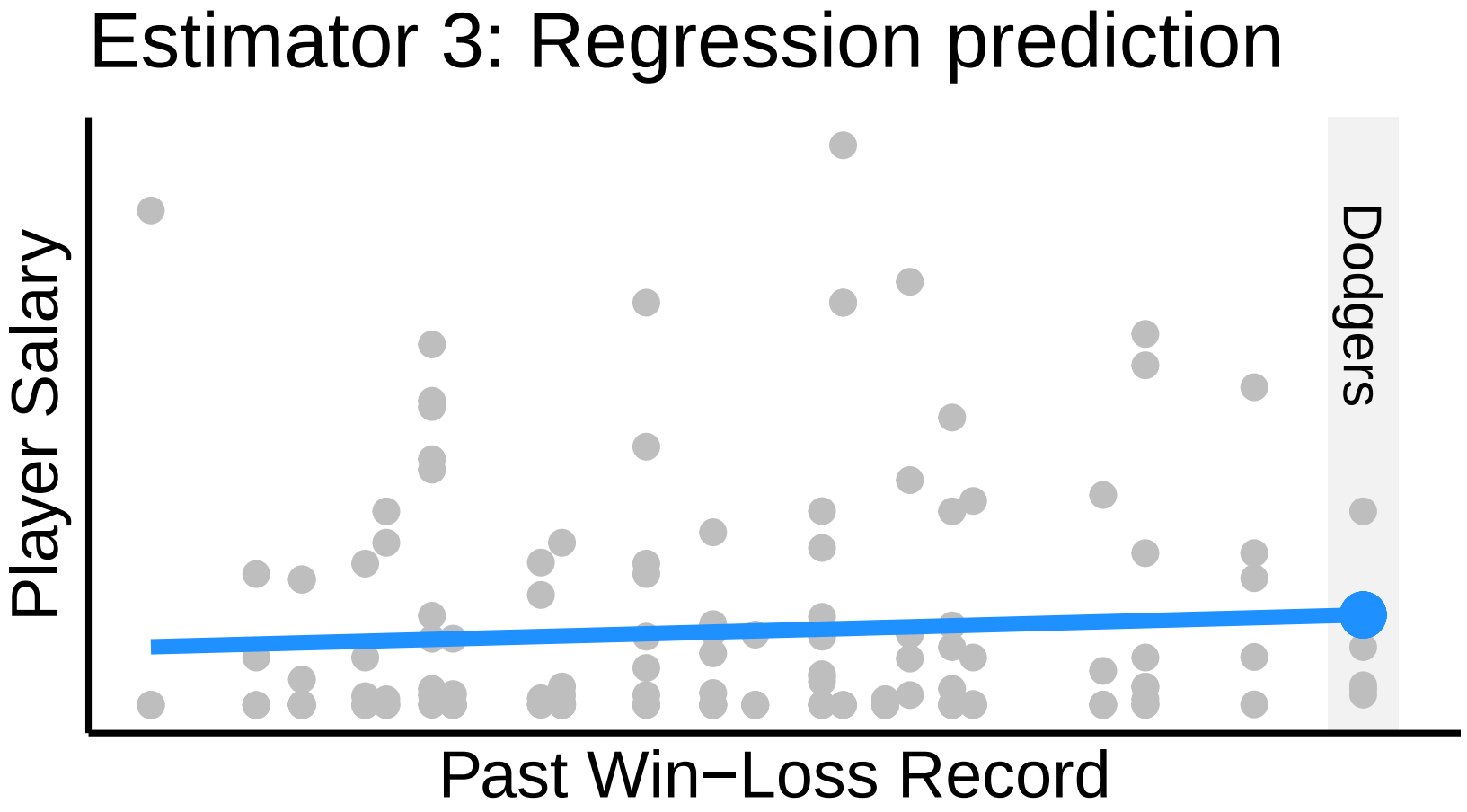

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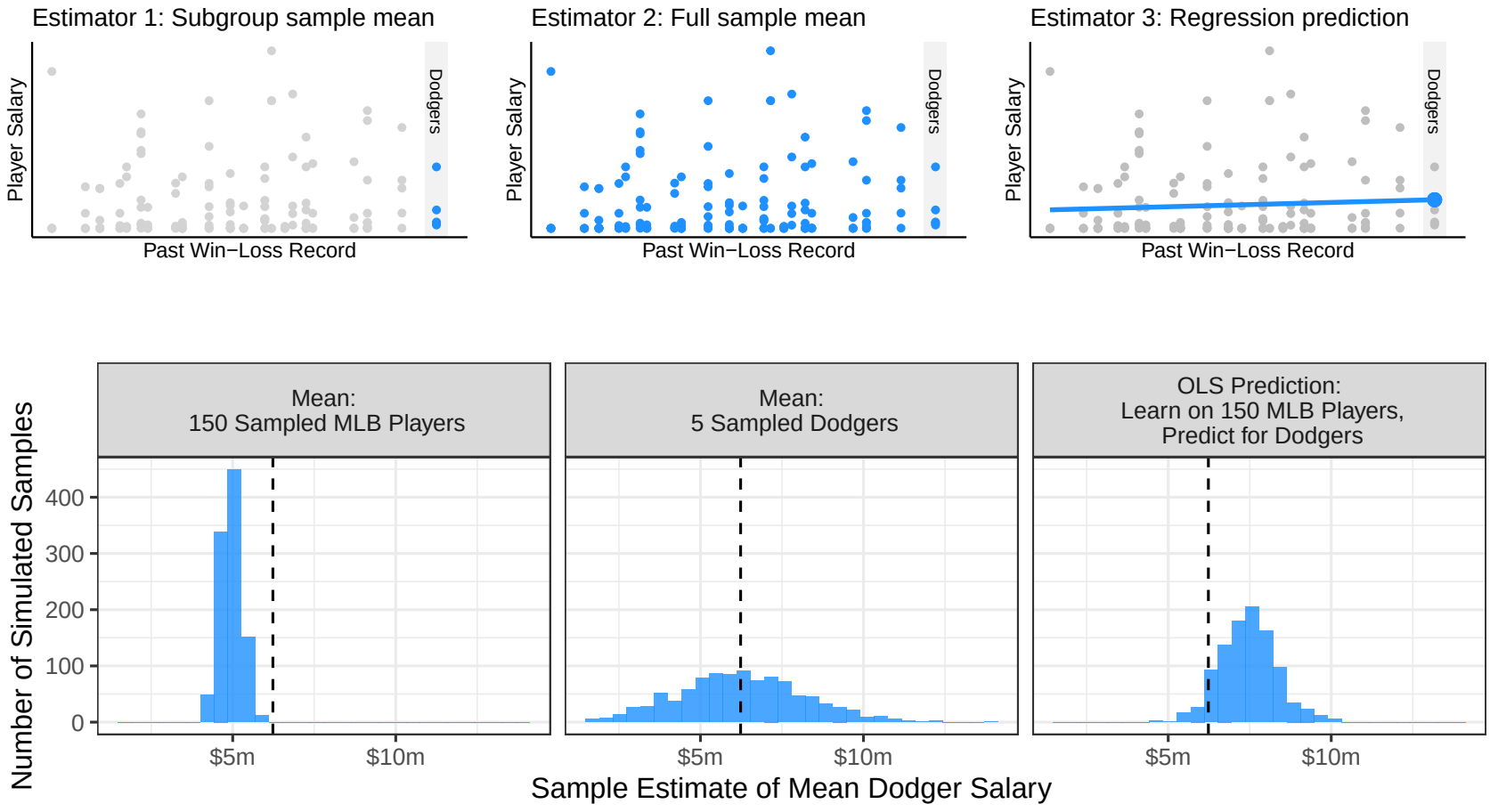

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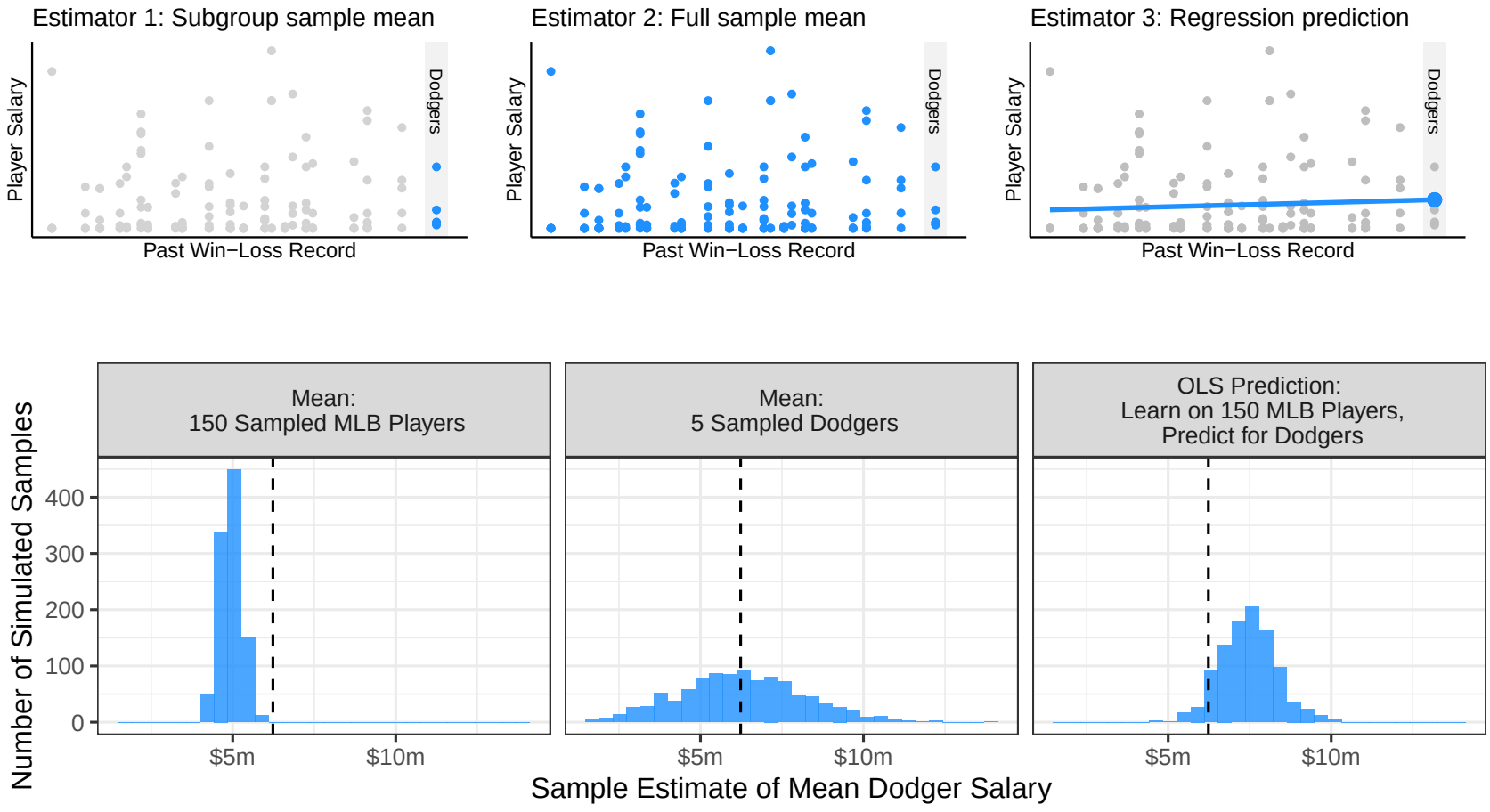

Which do you prefer? Why is your choice a little weird?

Statistical learning: A somewhat unusual view

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1. the entire goal of modeling is to solve sparse data
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     by the Dodger sample mean

Statistical learning: A somewhat unusual view

1. the entire goal of modeling is to solve sparse data
   - we sample very few Dodgers,
     so we use non-Dodgers to help our estimate
2. in a huge sample, a model is unnecessary
   - estimate Dodger population mean
     by the Dodger sample mean
3. in a tiny sample, models may perform poorly
   - might even better to estimate a subgroup mean (Dodgers)
     by taking the mean of the whole sample (all MLB)

statistical learning: the idea

illustrated by a

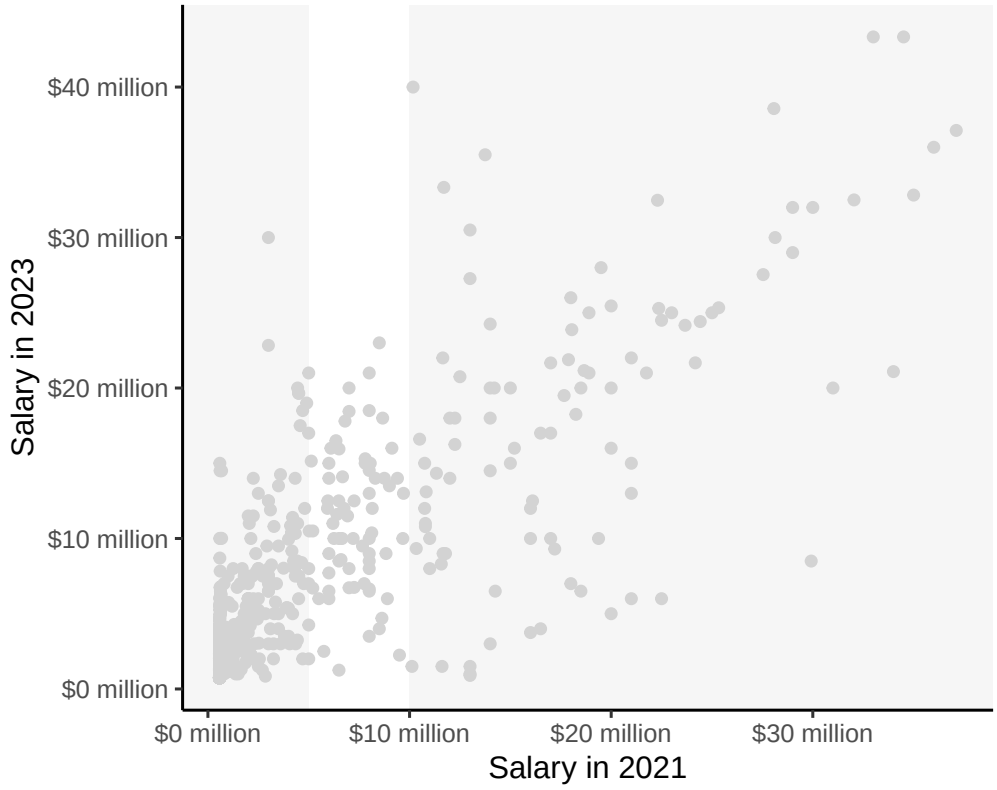
- discrete numeric predictor
- continuous numeric predictor

What is the mean 2023 salary among players
who in 2021 earned $5-10 million?

Goal: Estimate a target population mean from a sample

Method: Sample subgroup mean

Begin with the population



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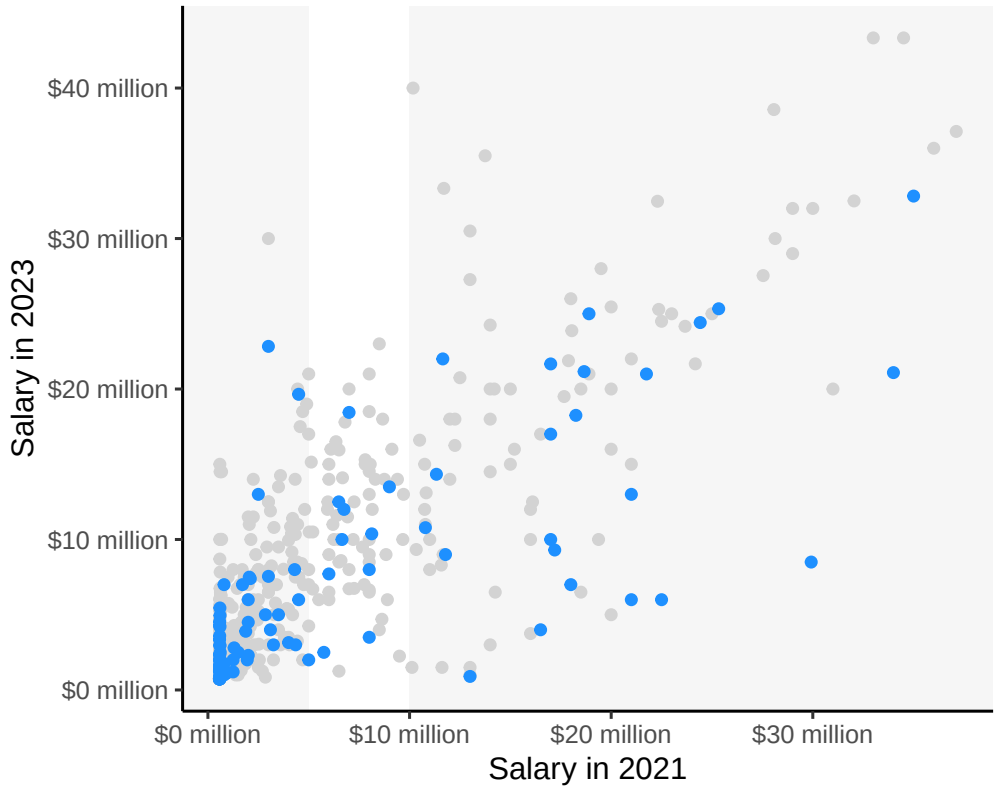

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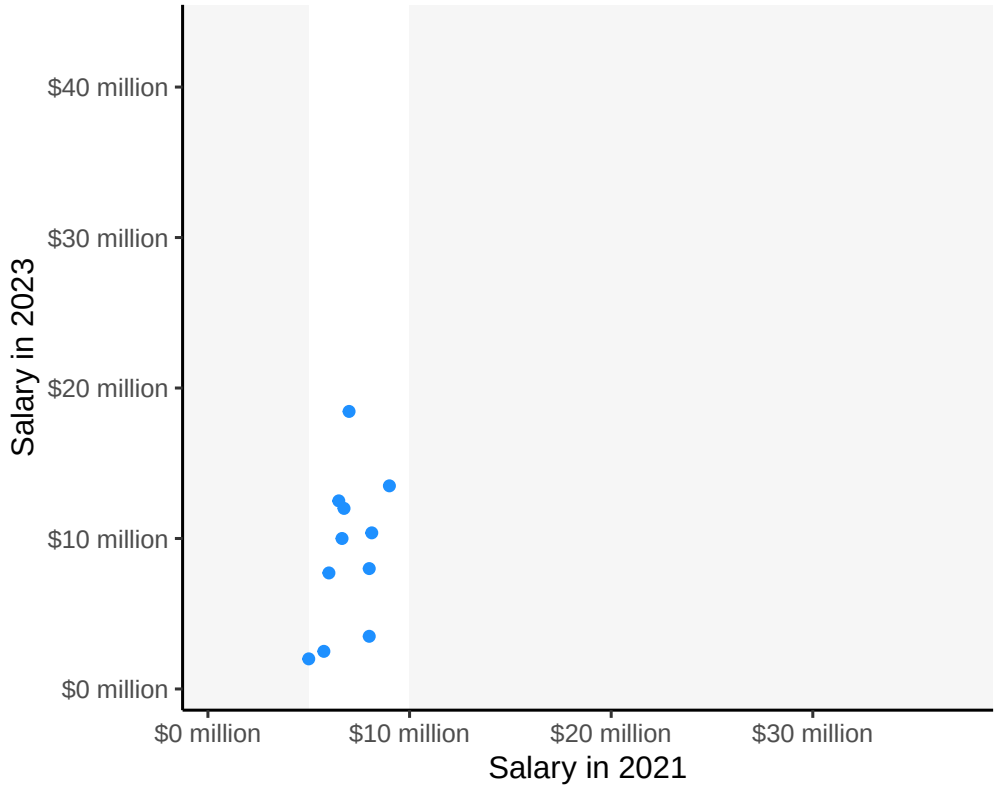

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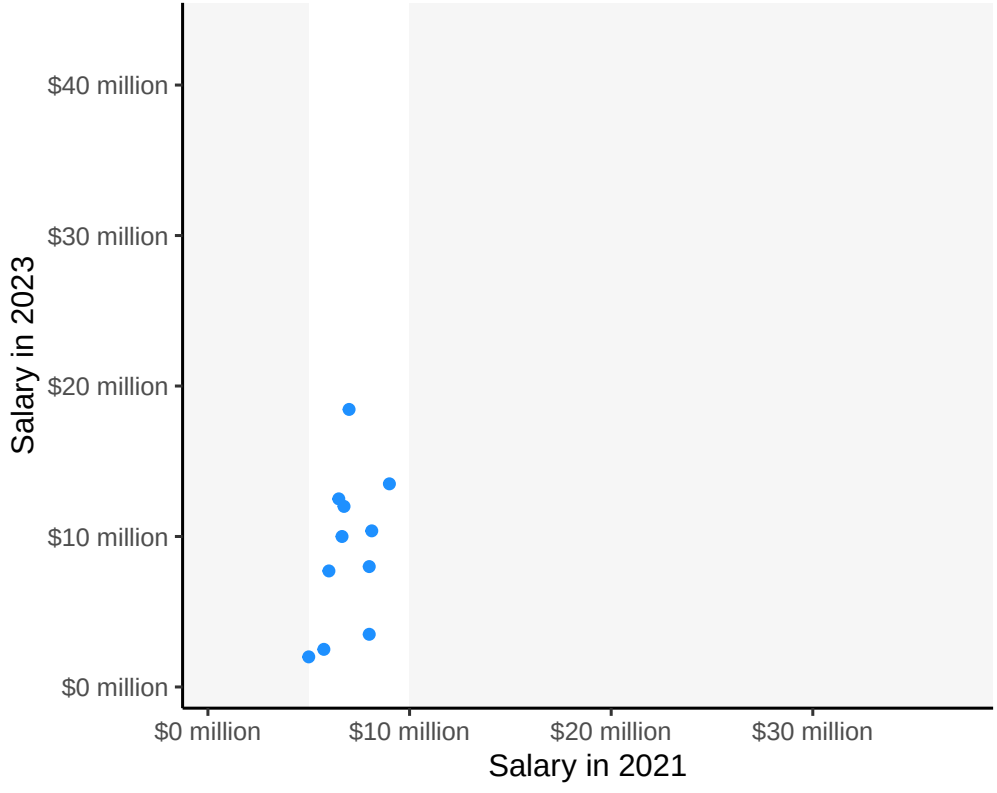

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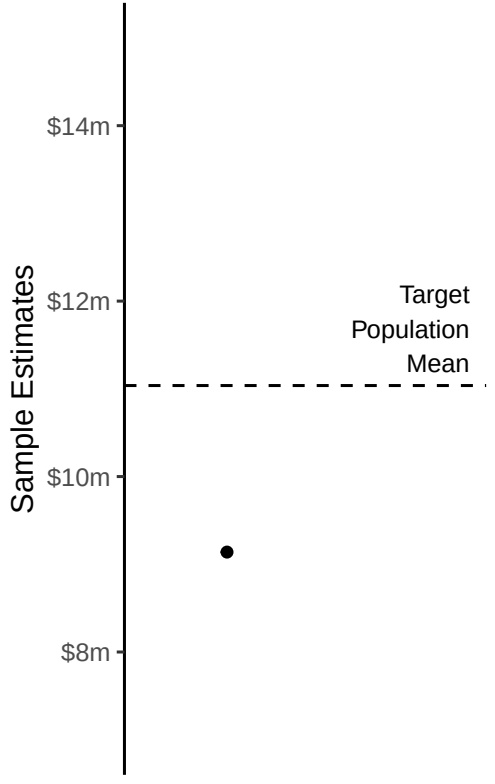

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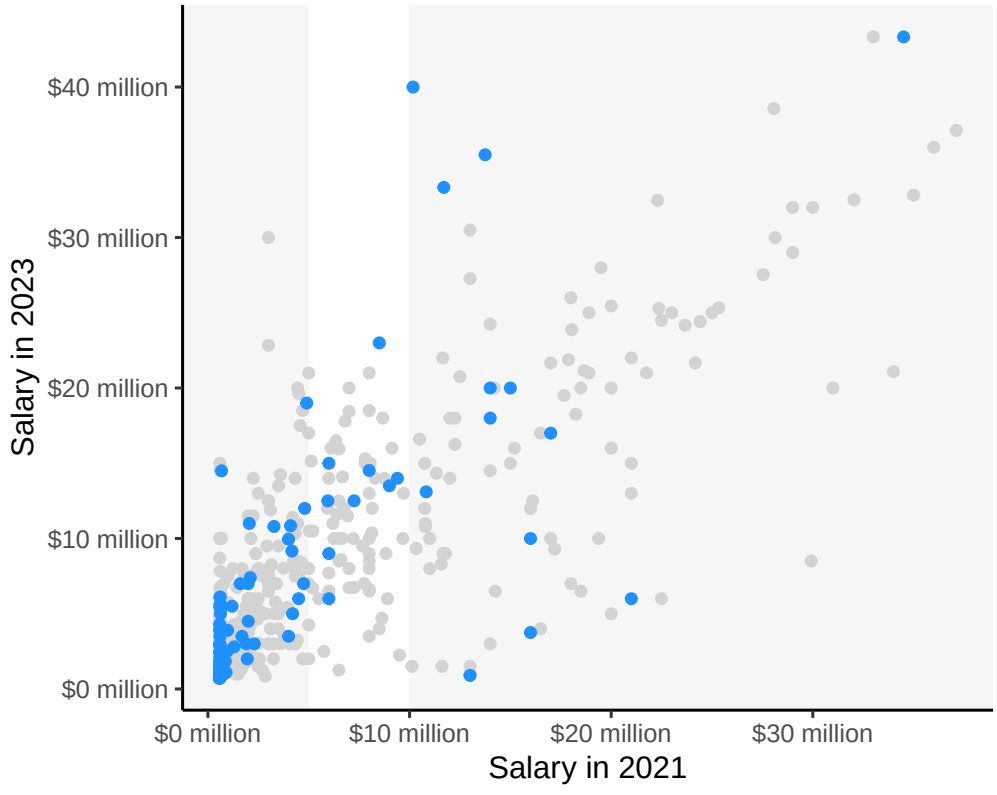

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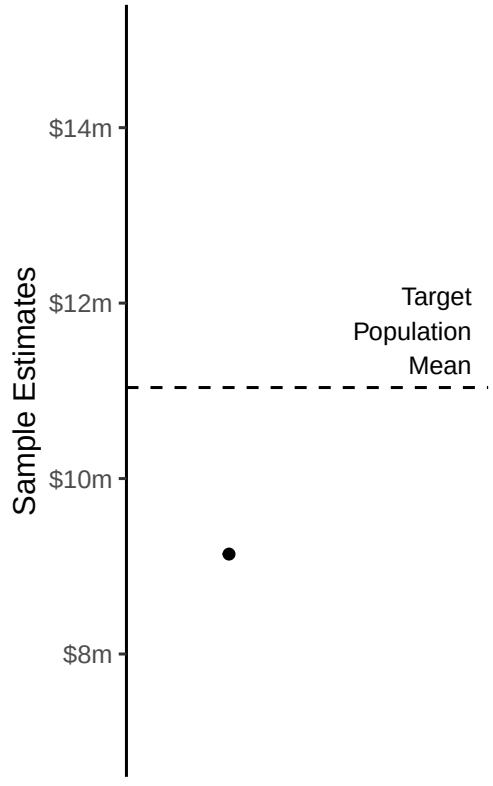

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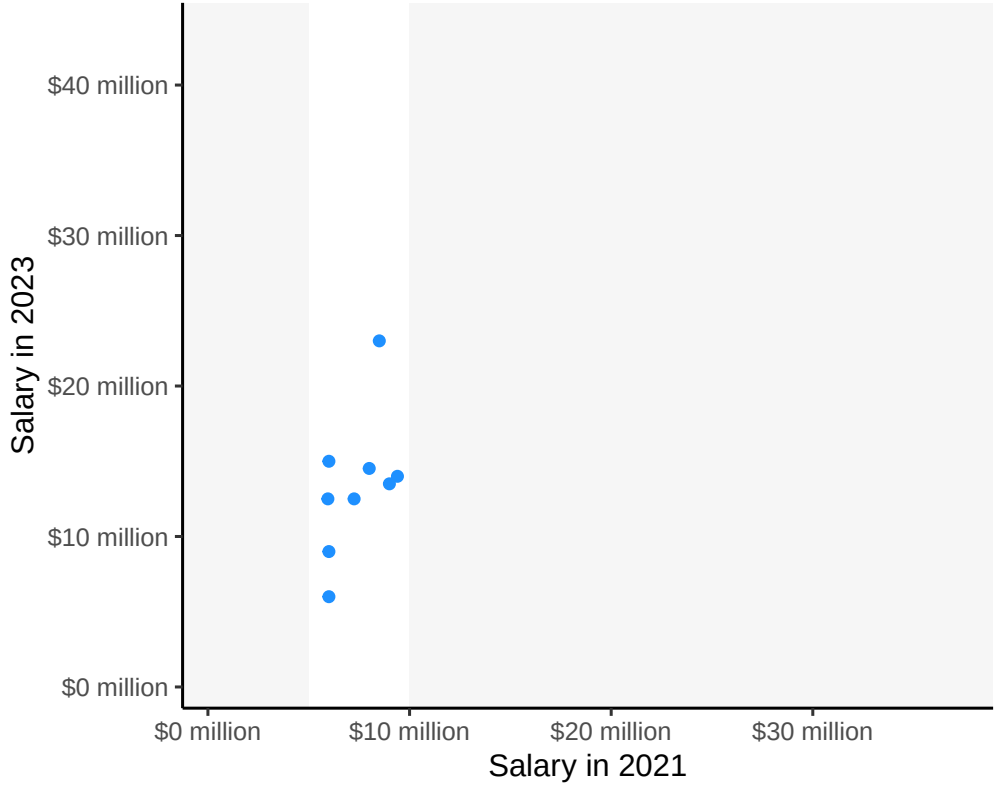

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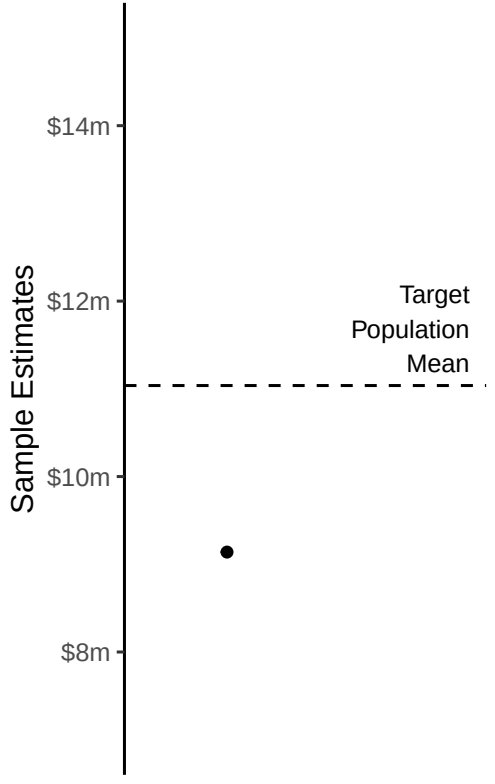

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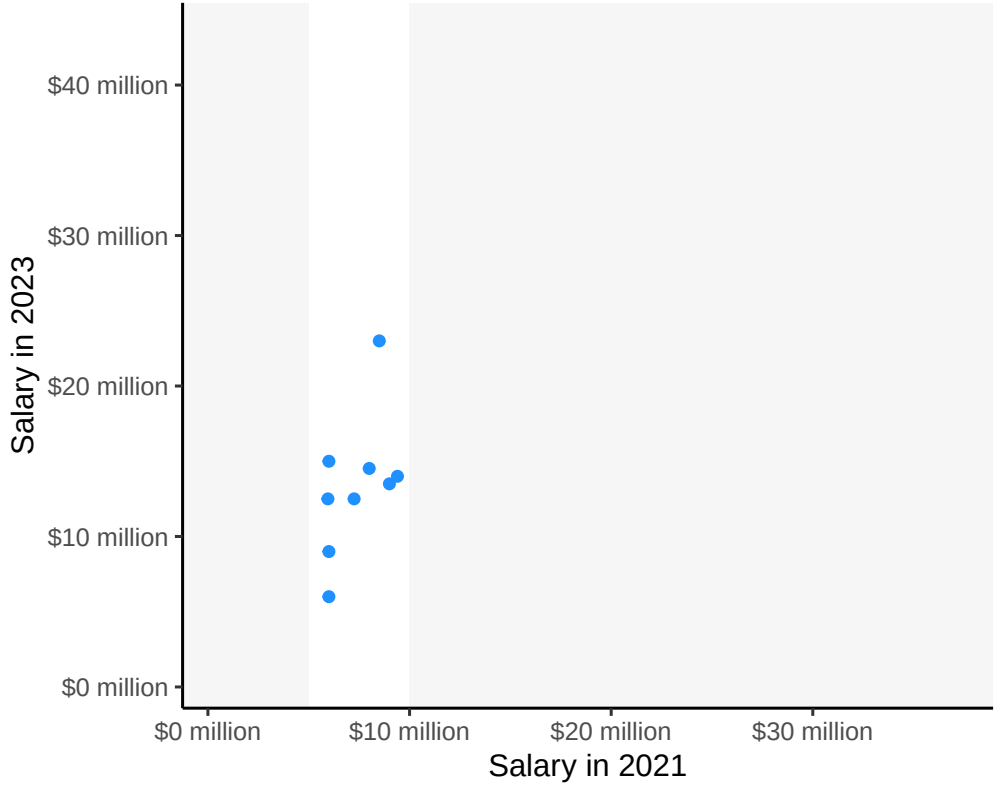

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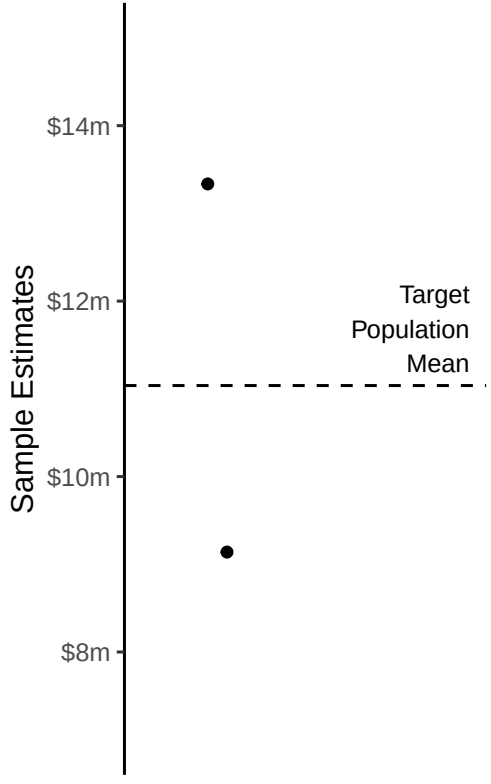

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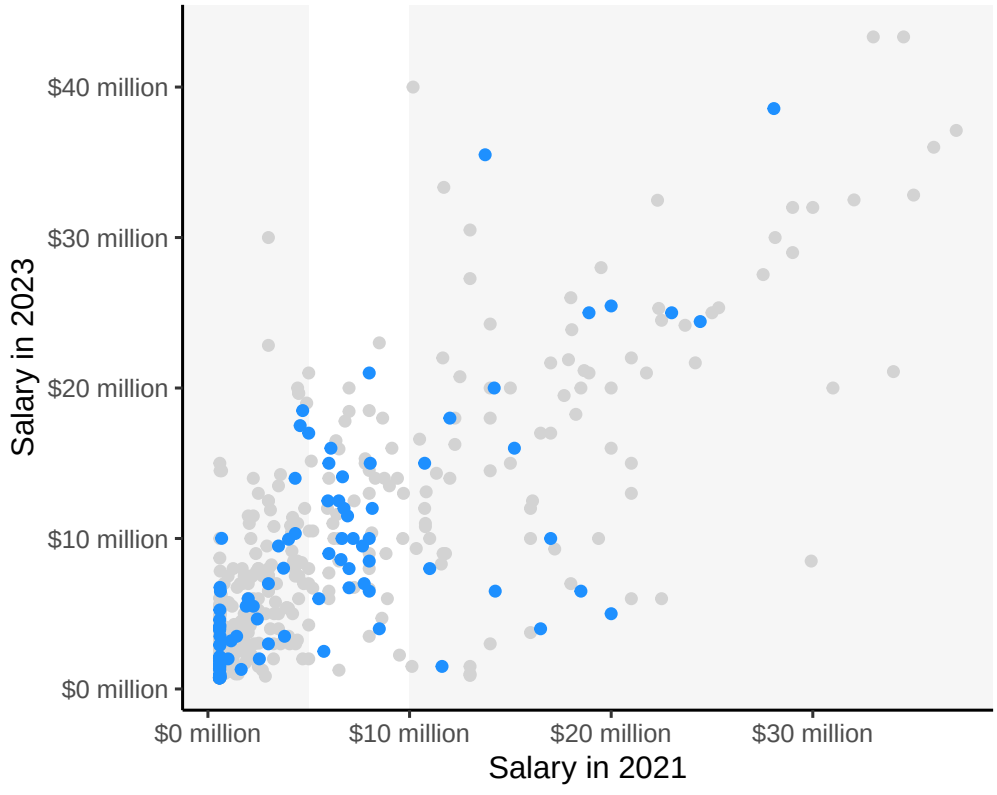

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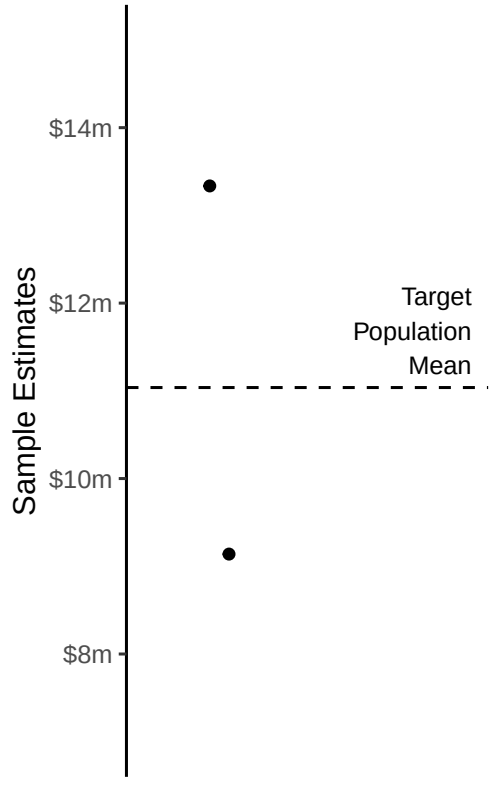

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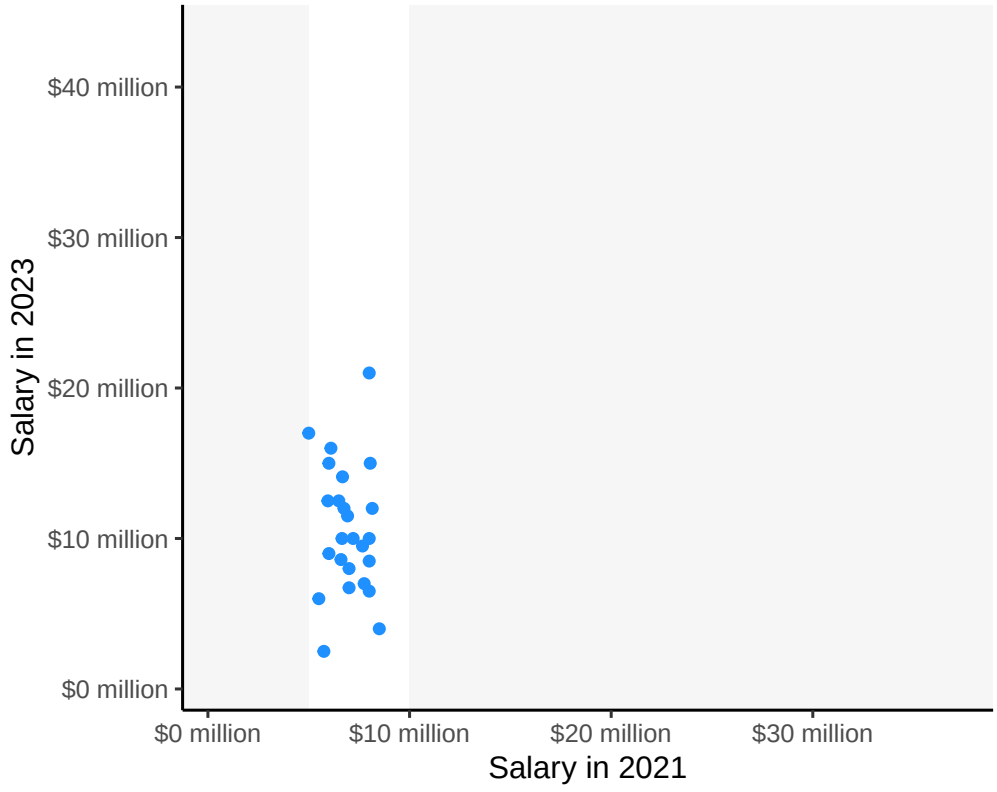

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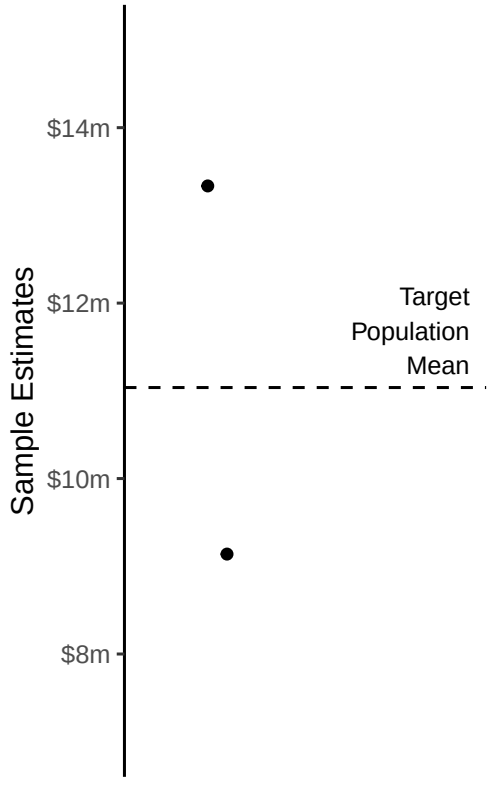

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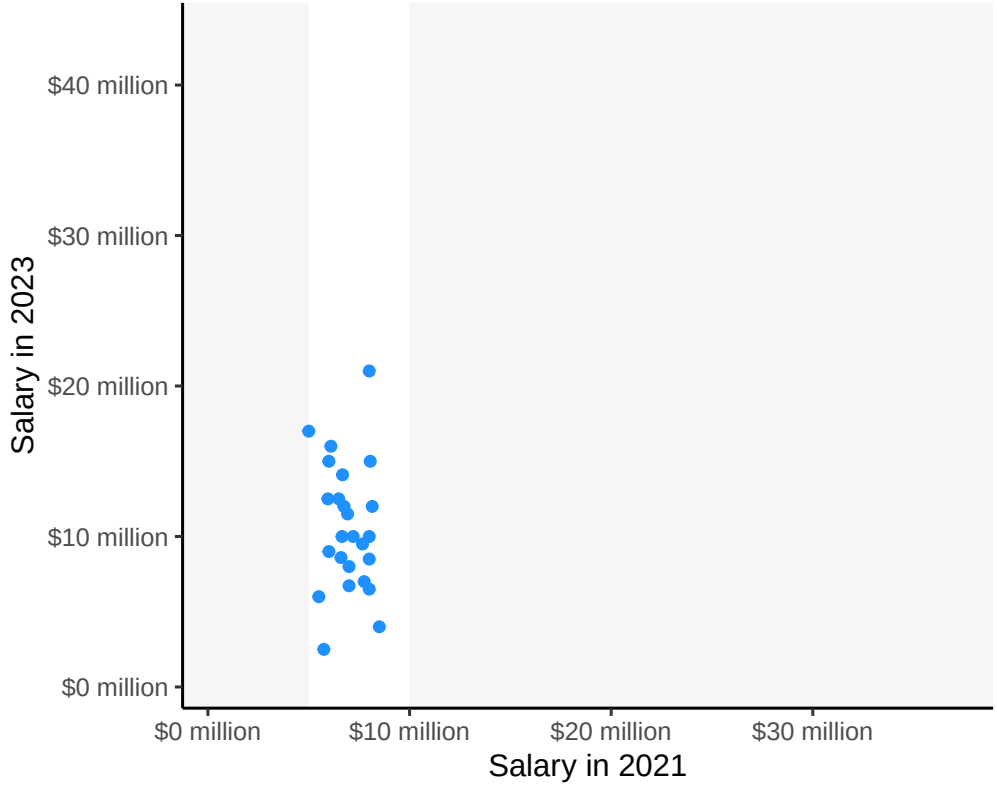

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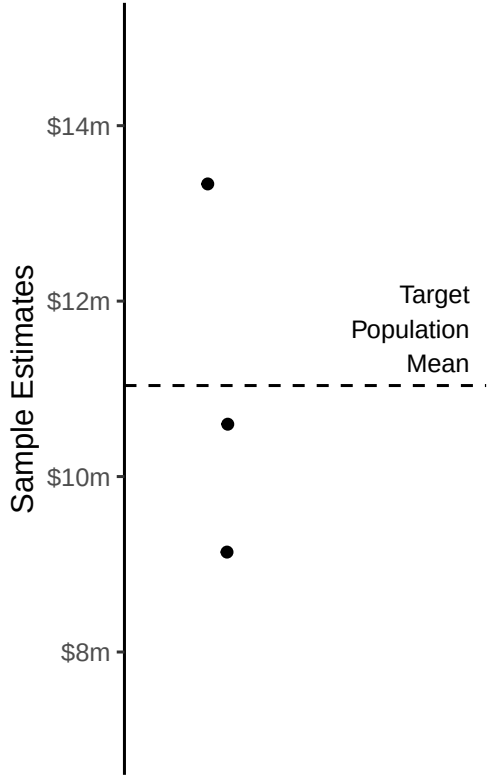

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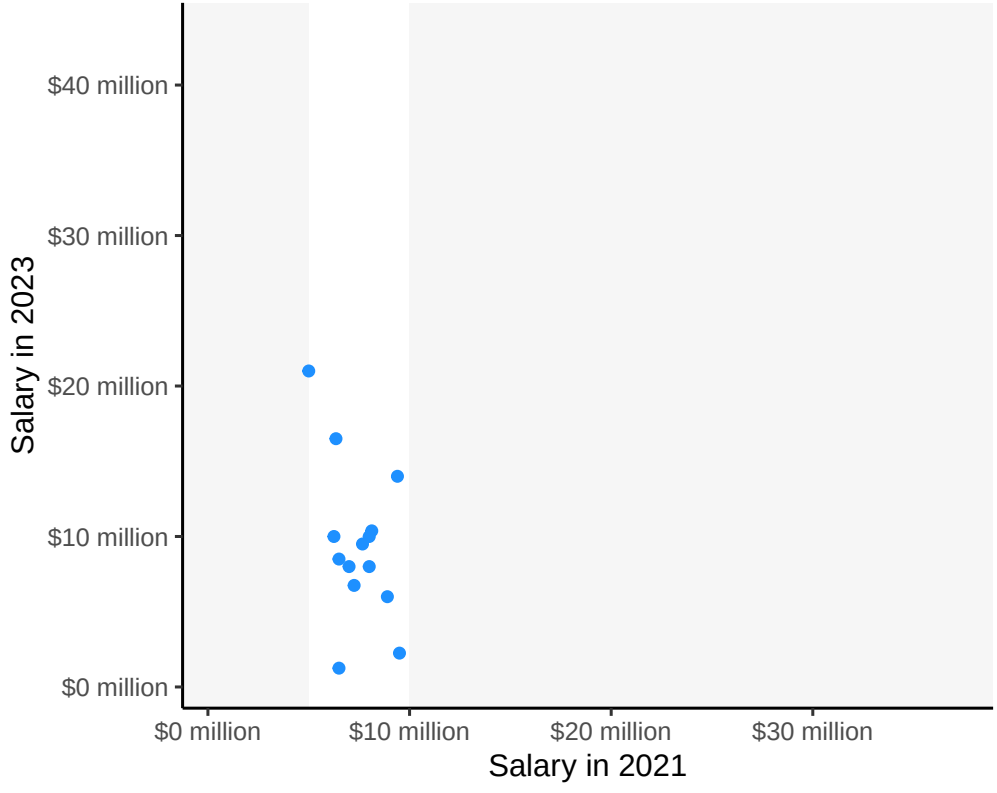

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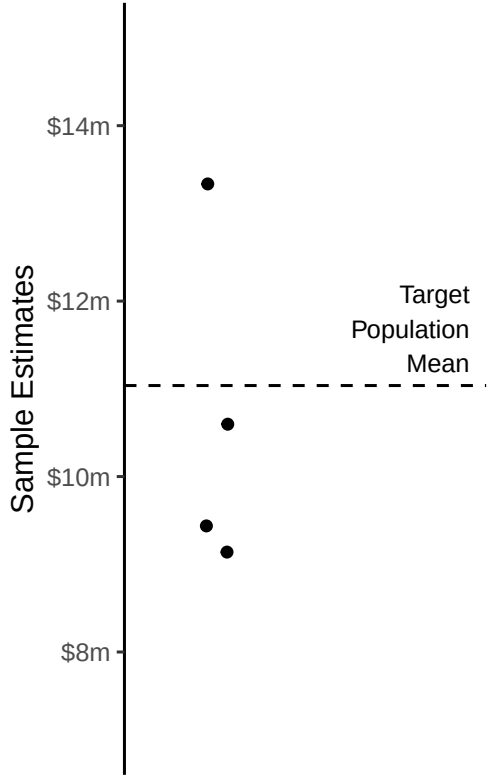

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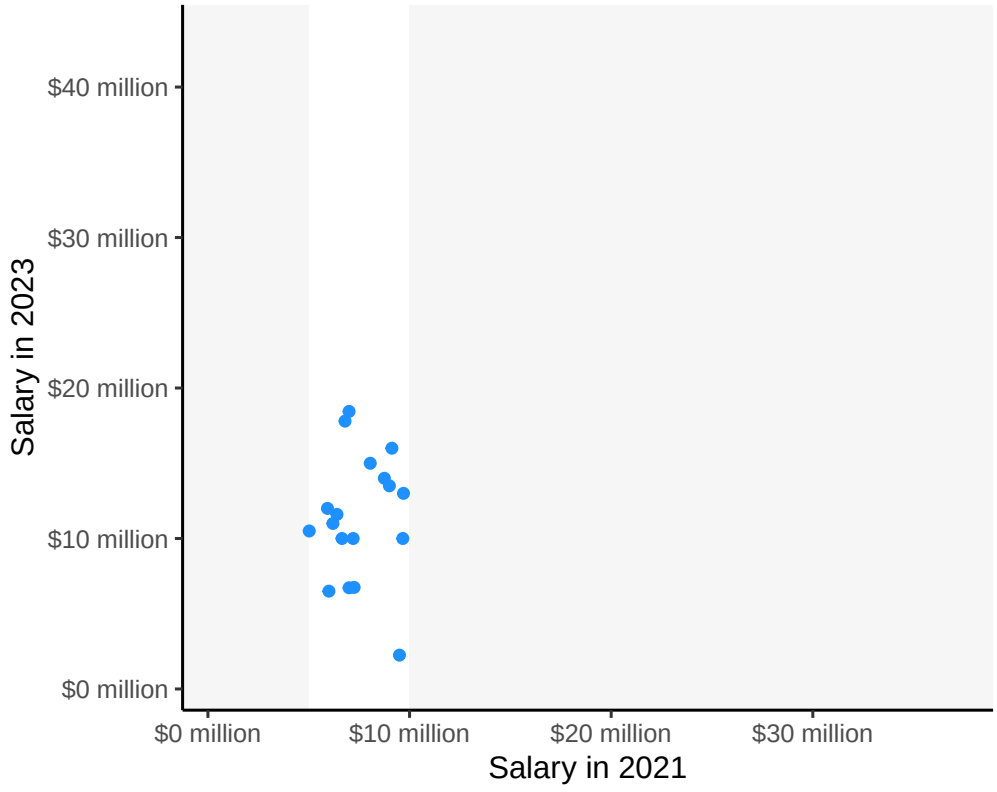

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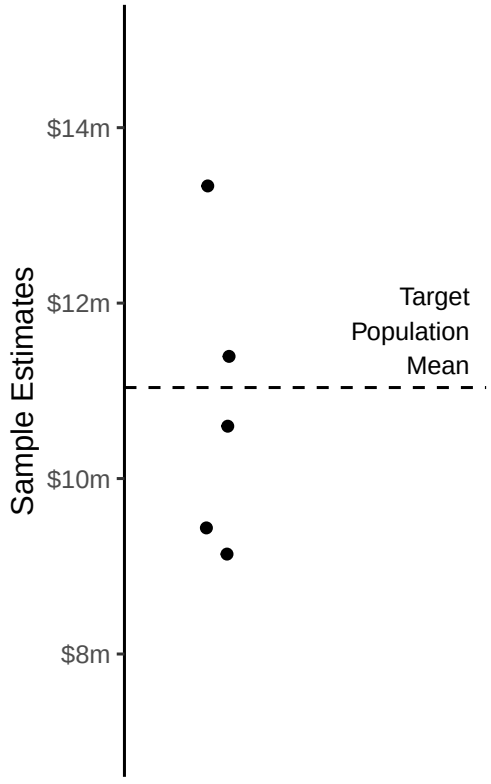

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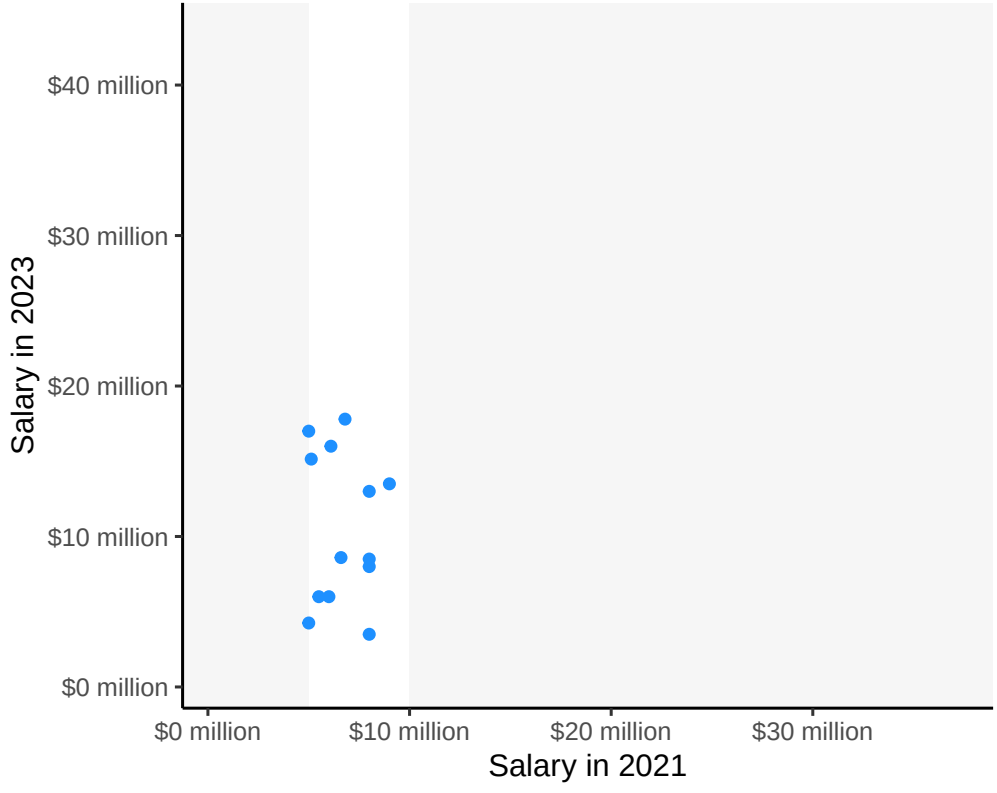

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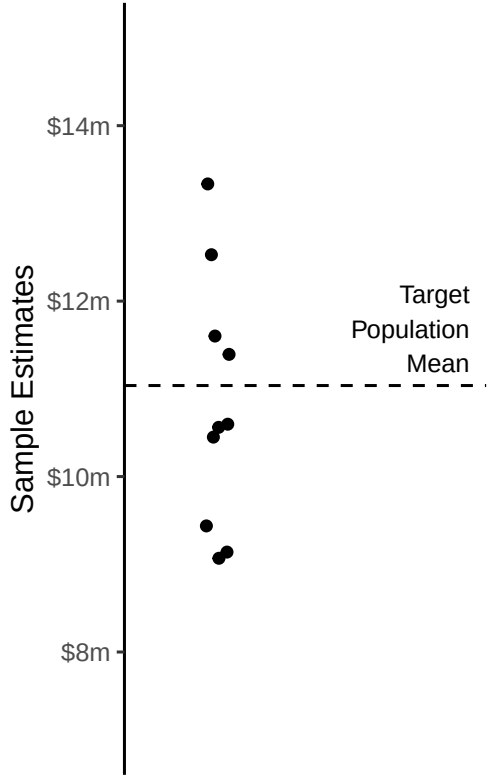

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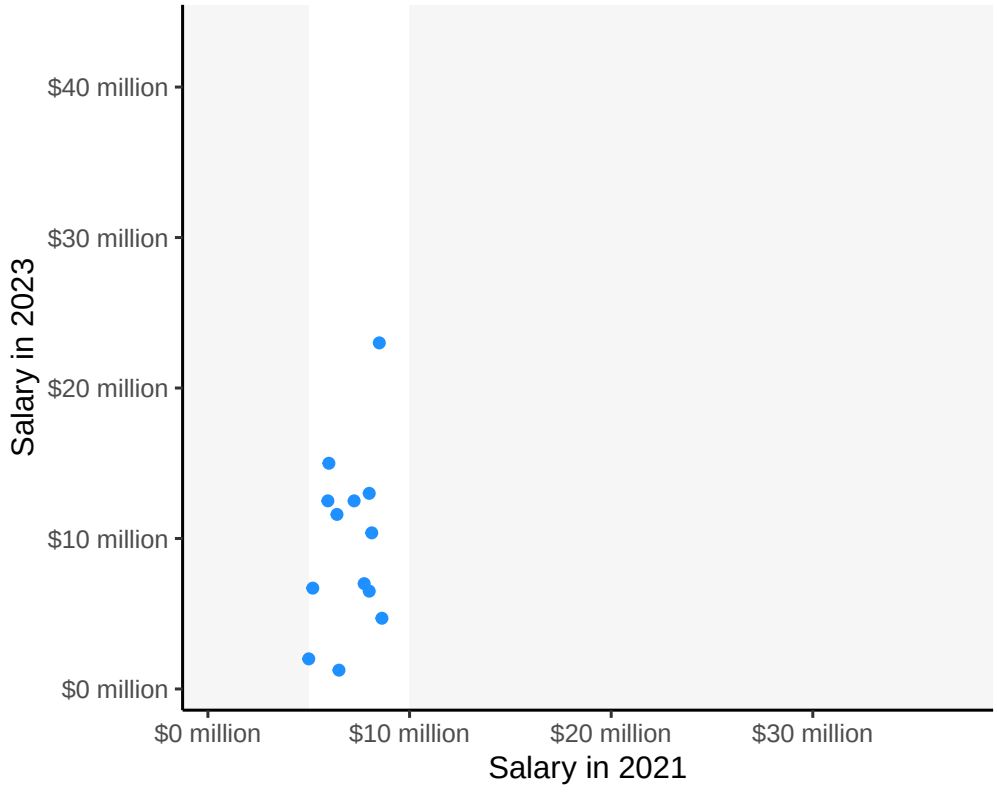

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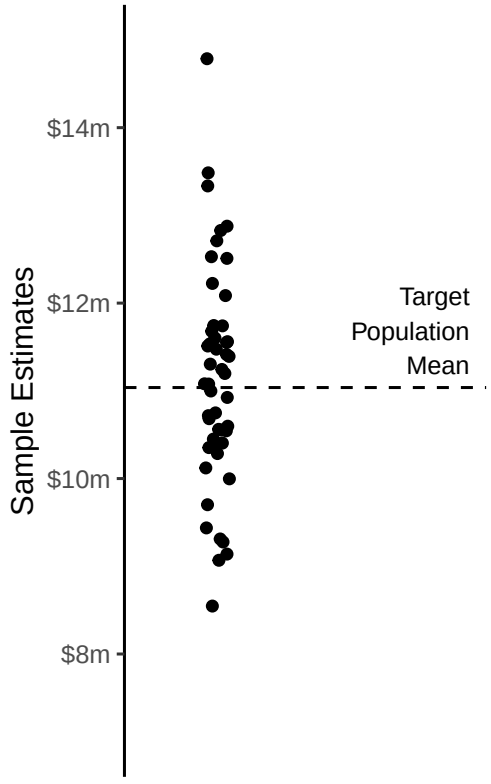

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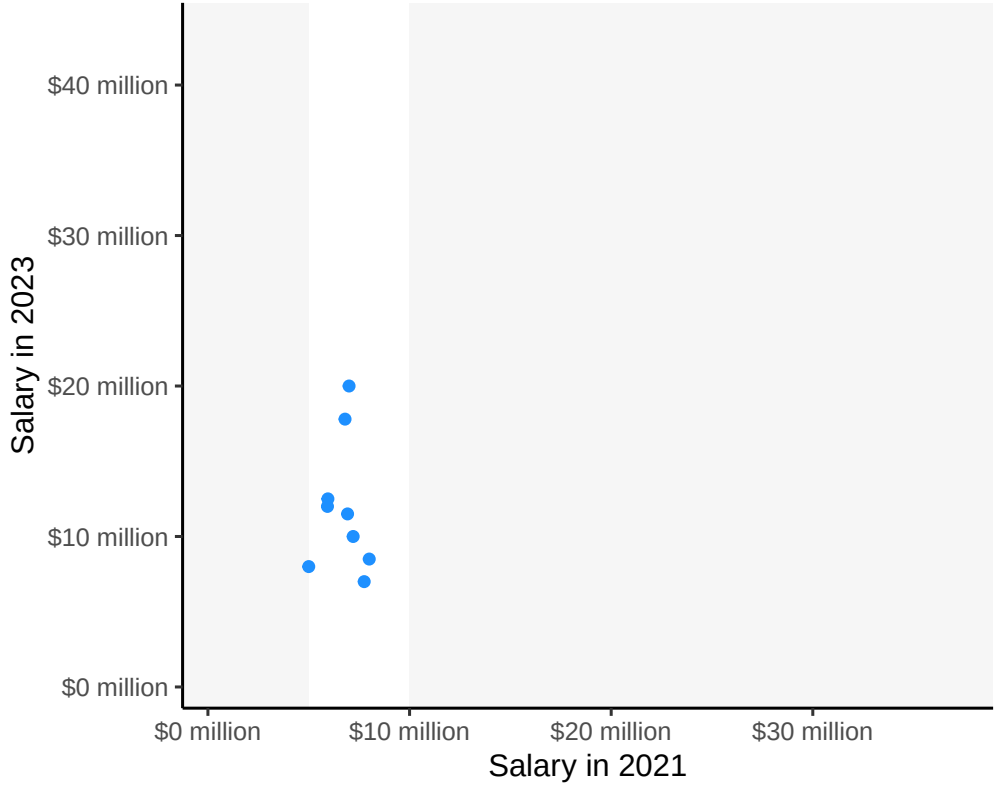

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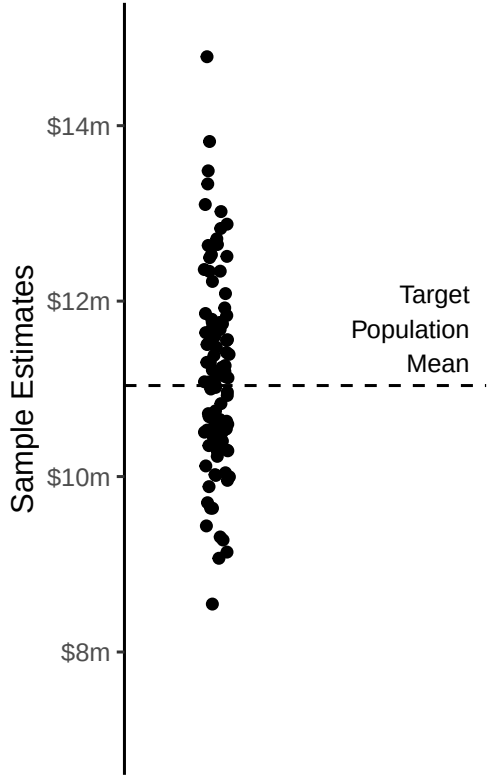
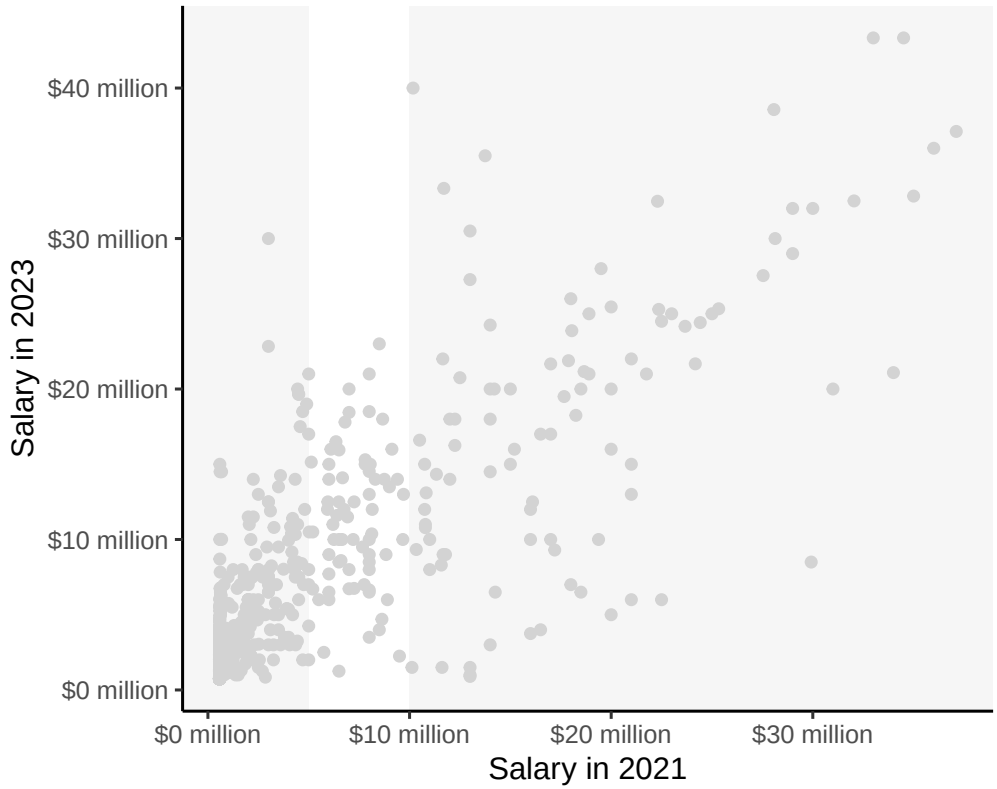


Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

How would you use a model?



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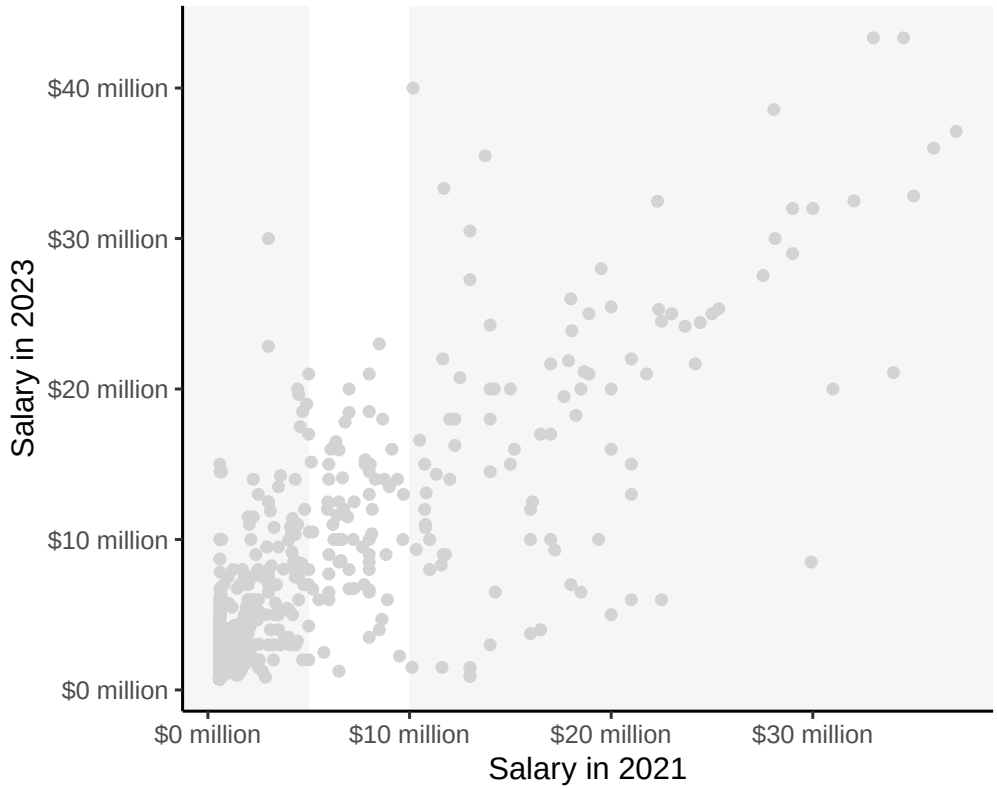

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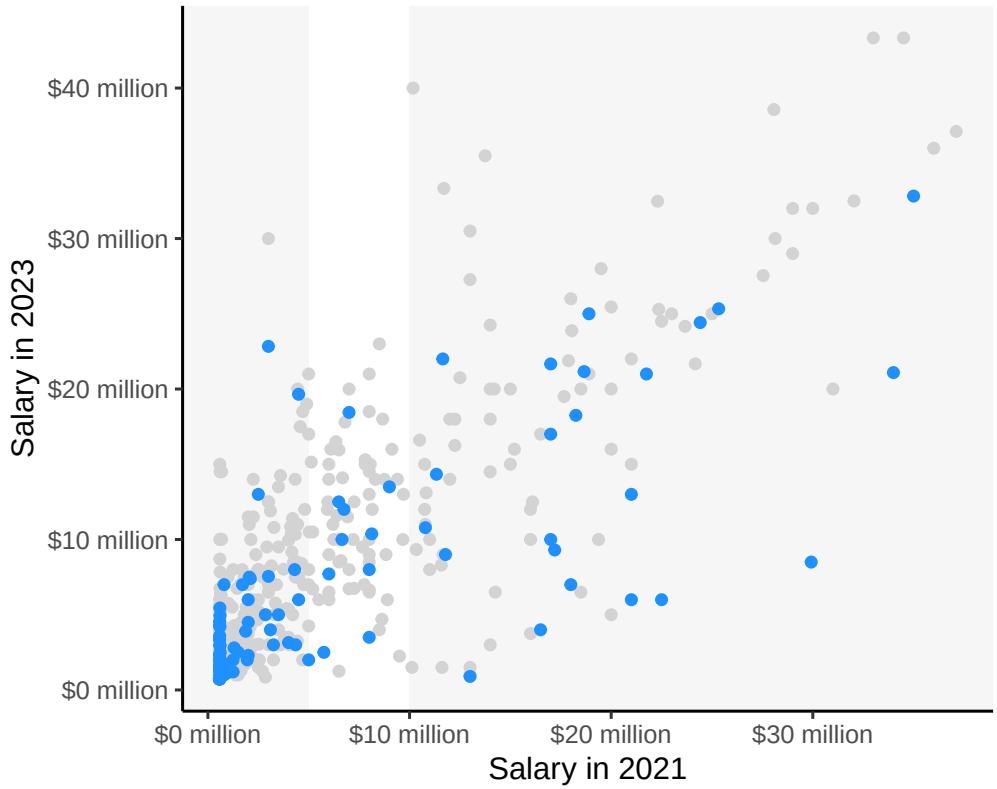

Goal: Estimate a target population mean from a sample

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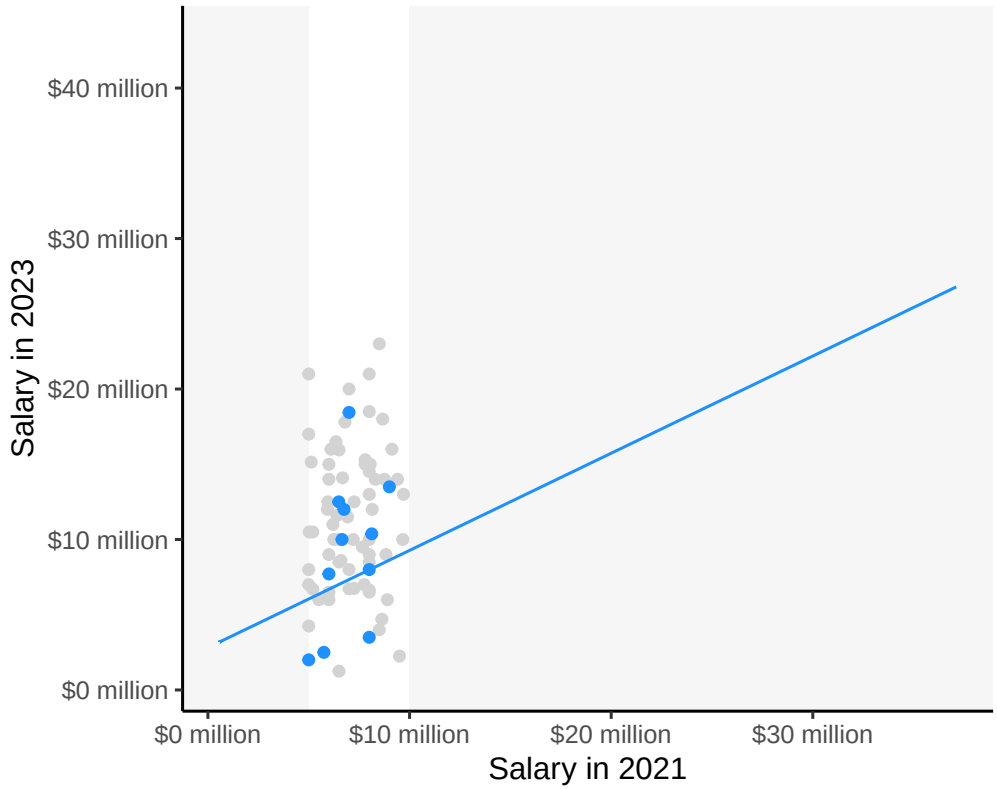
Learn a model

Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

Focus on the target population



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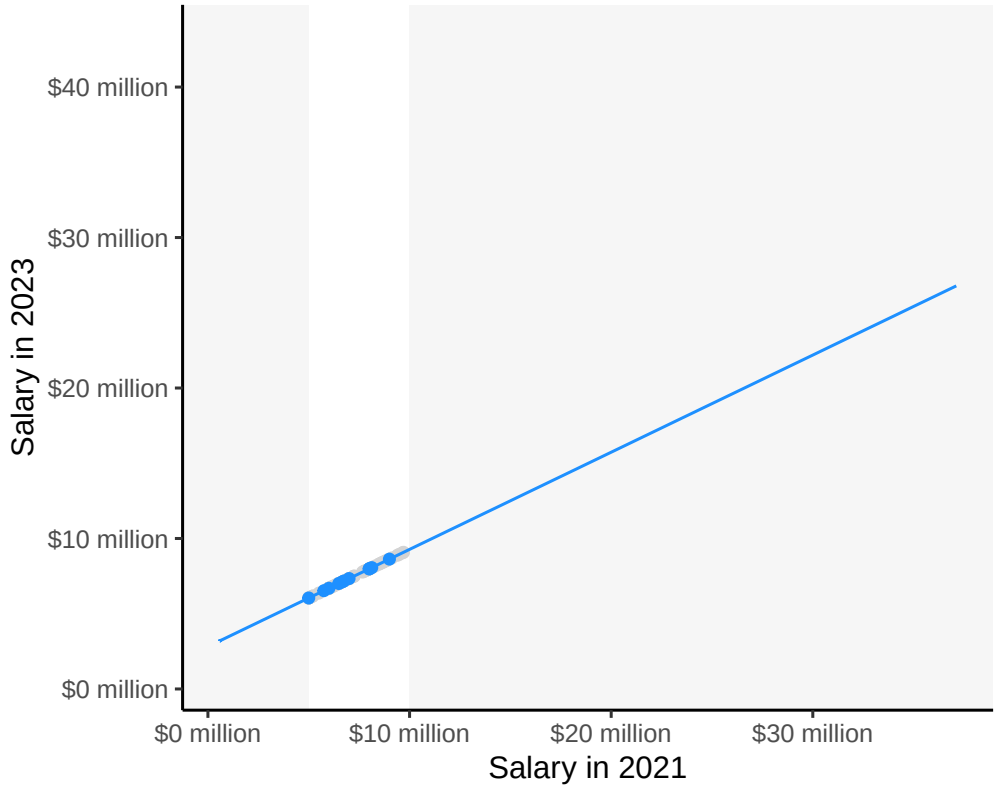

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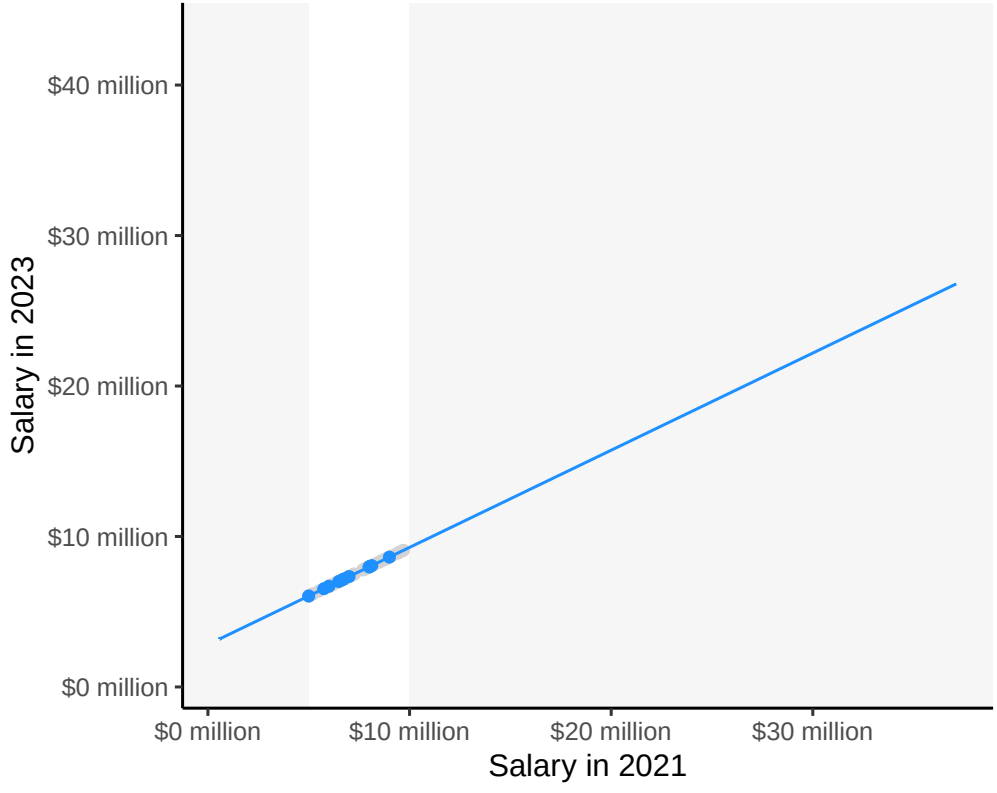

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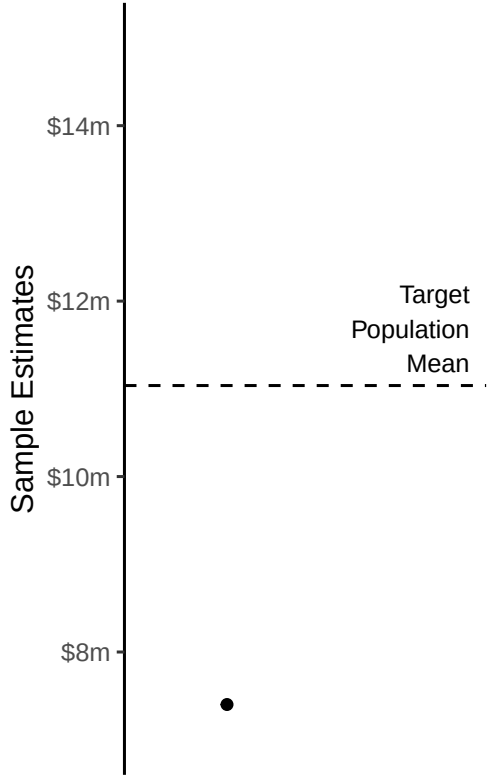

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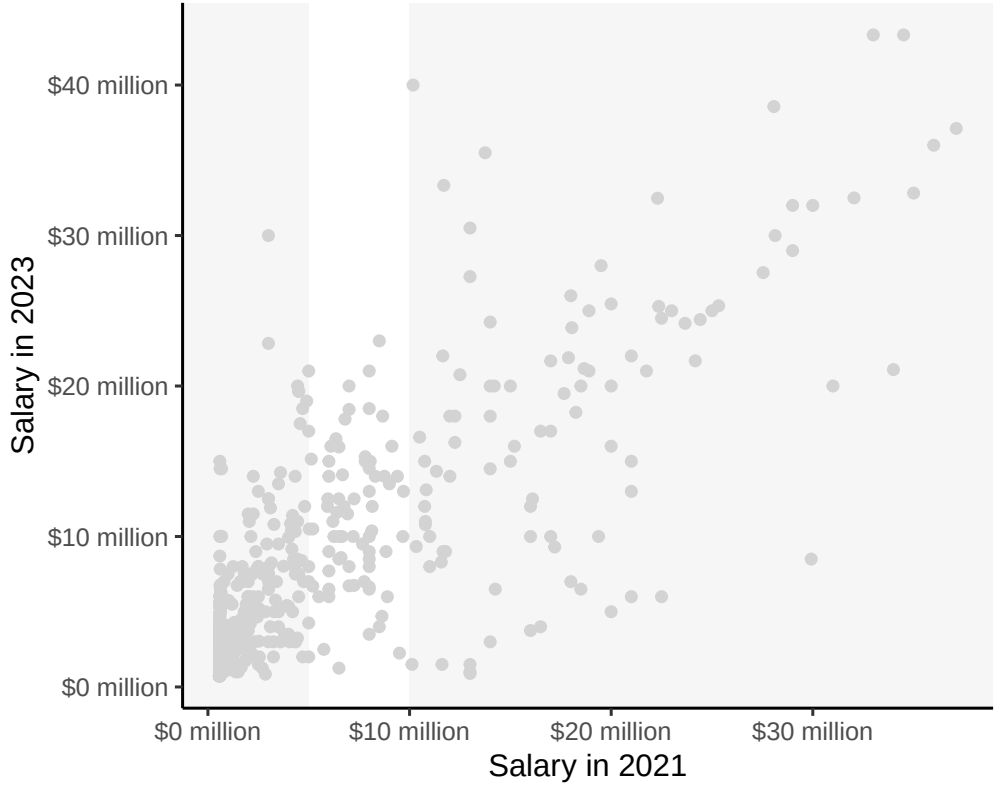

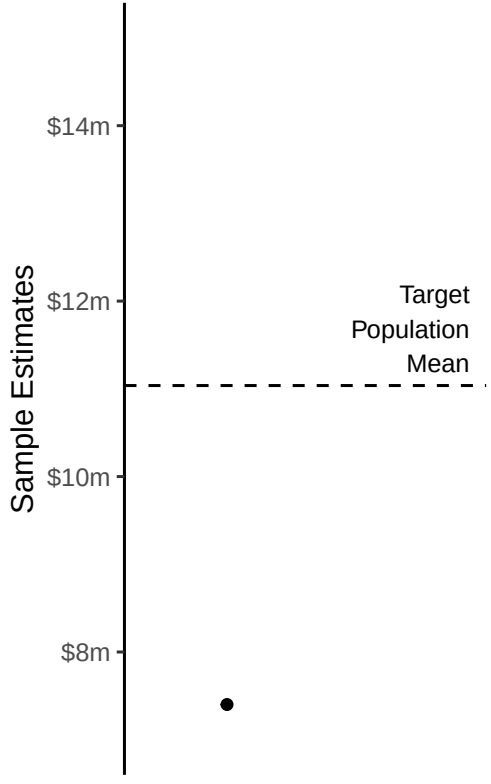

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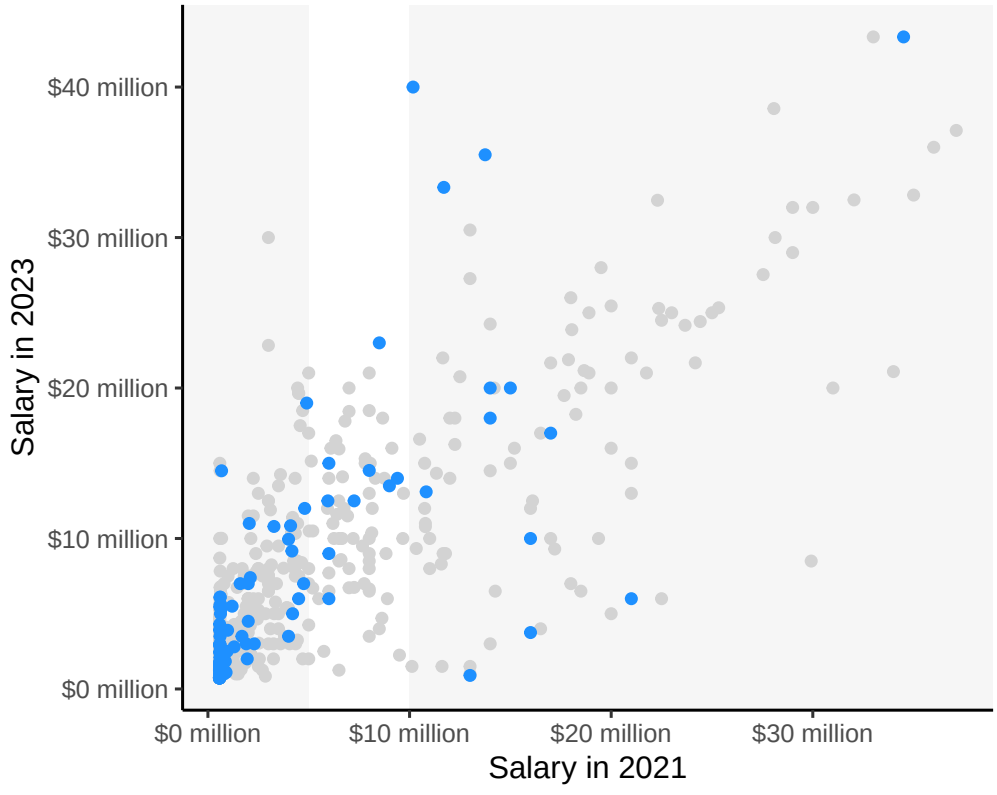

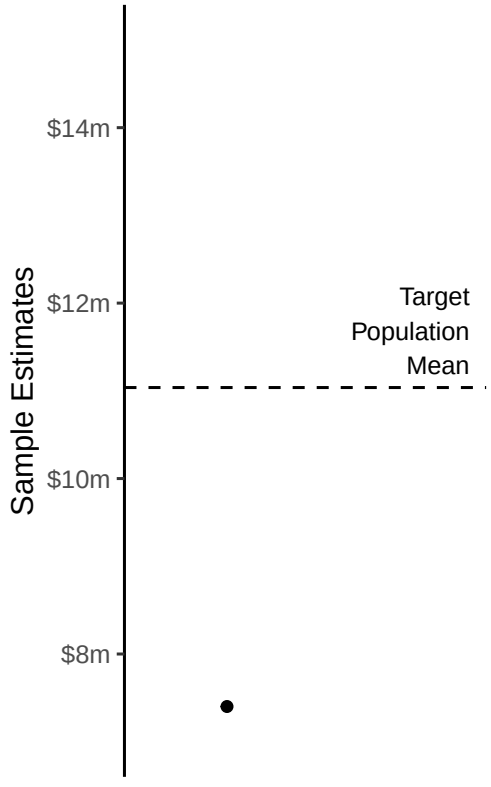

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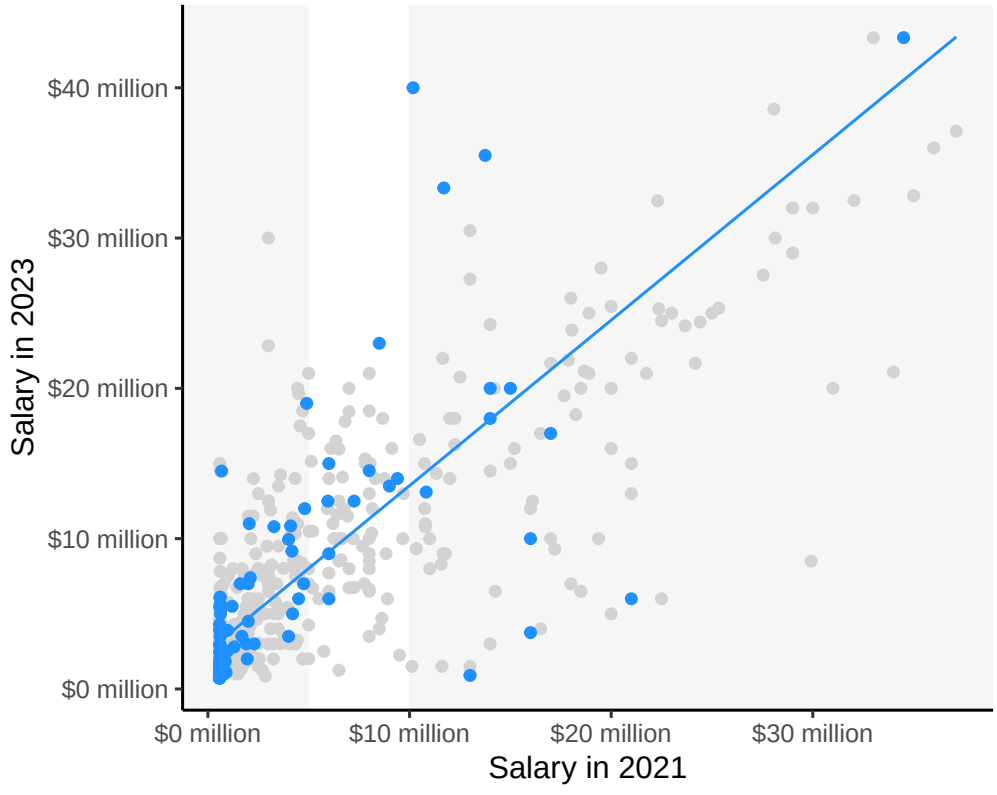

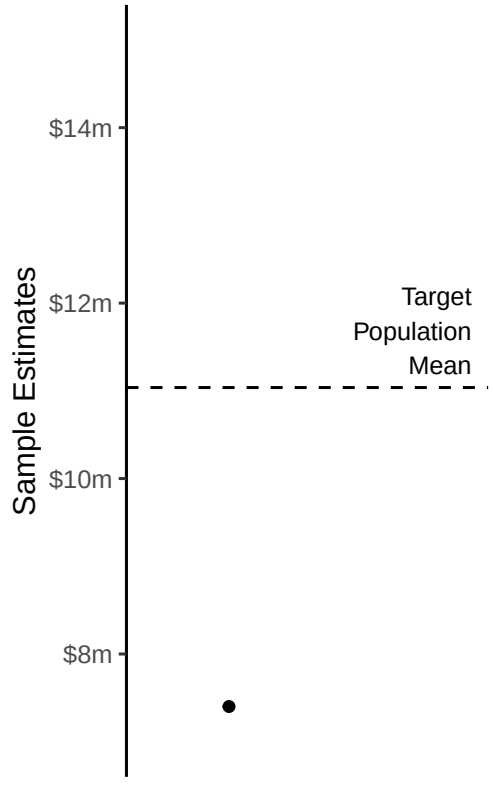

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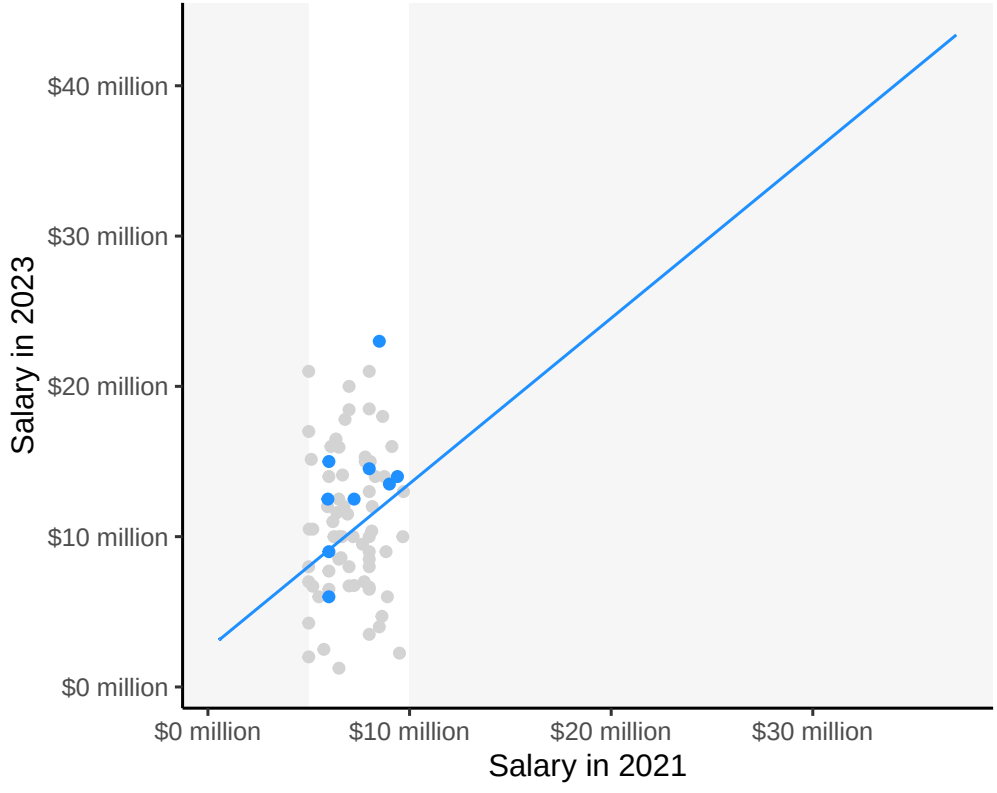

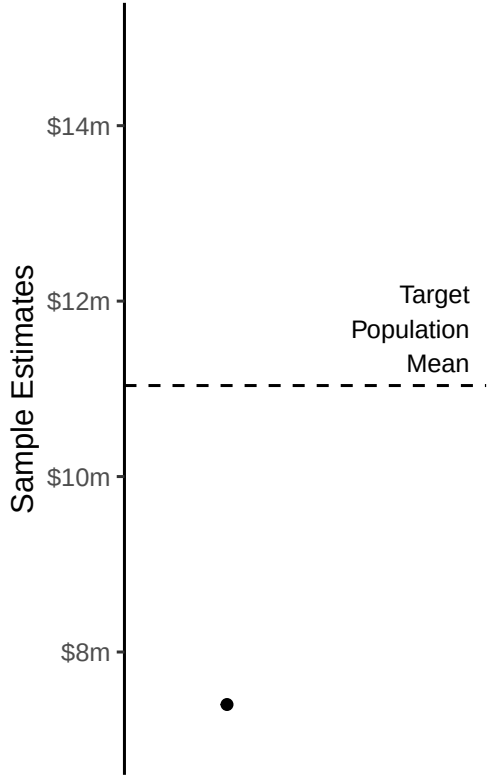

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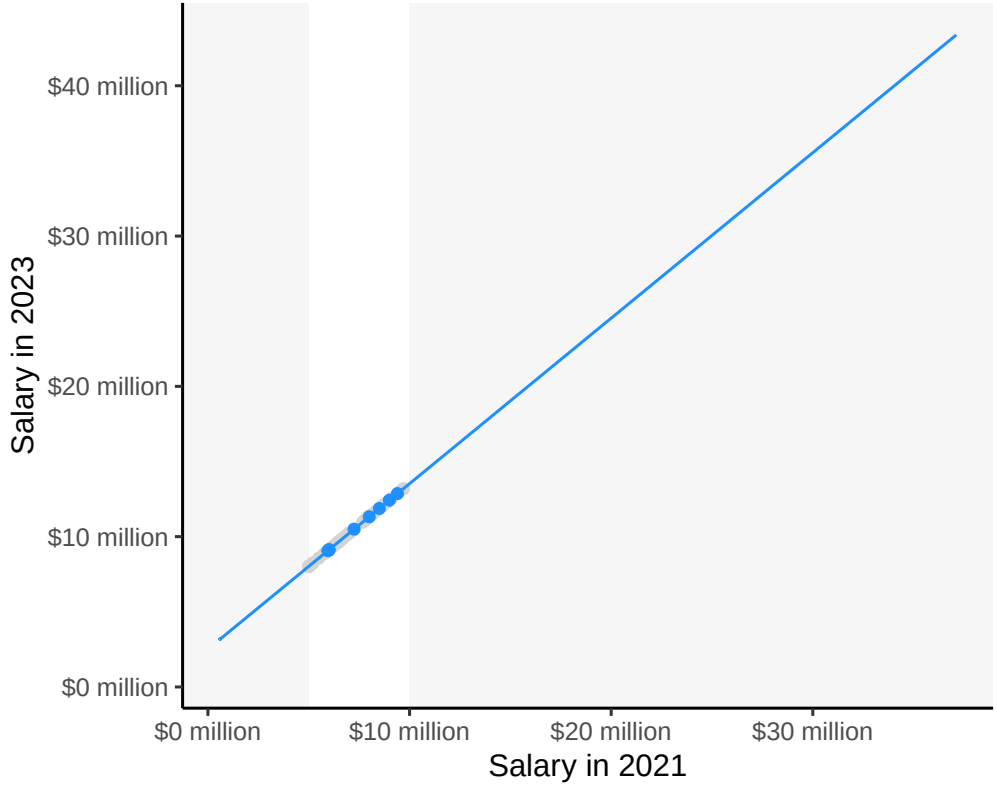

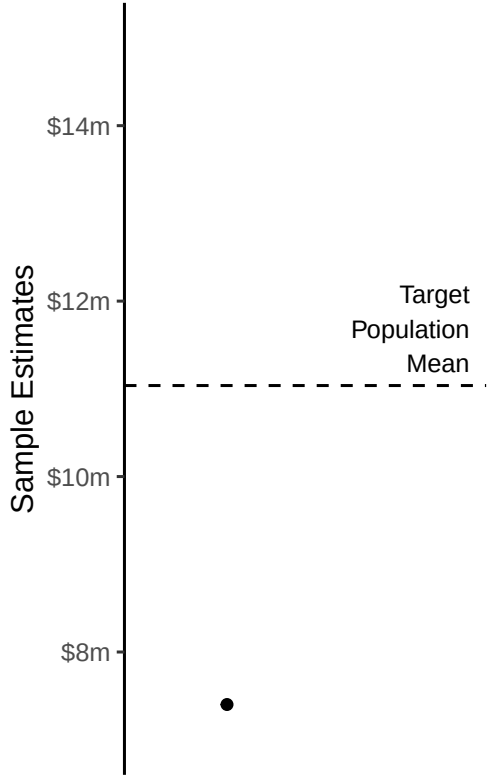

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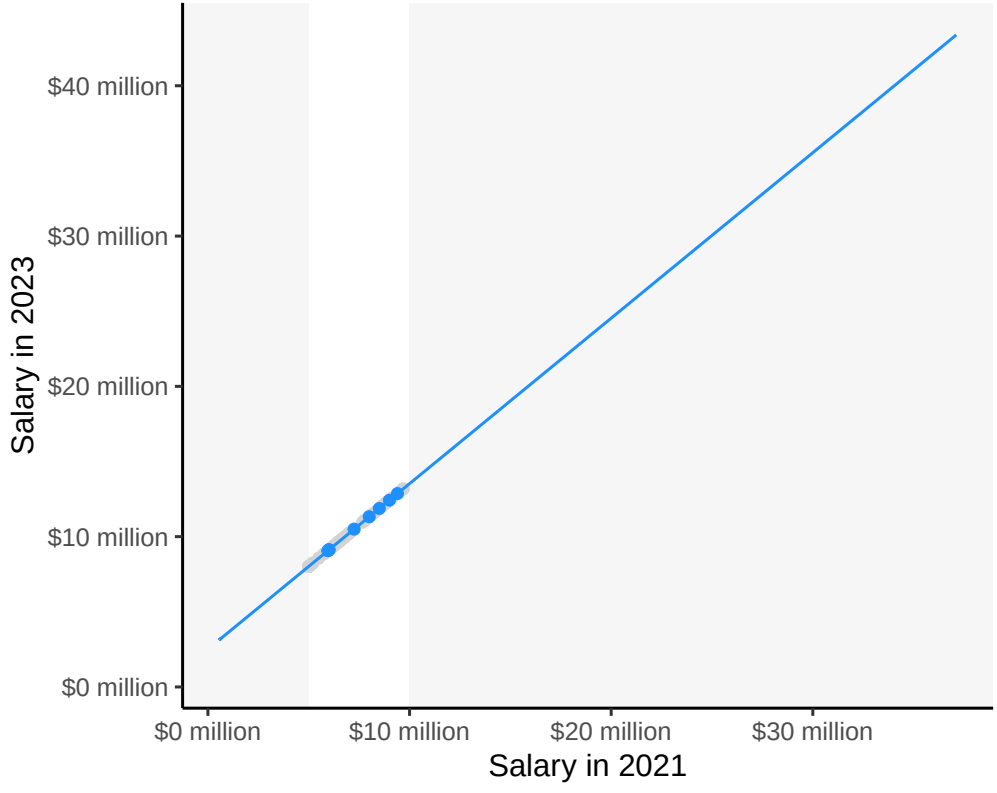

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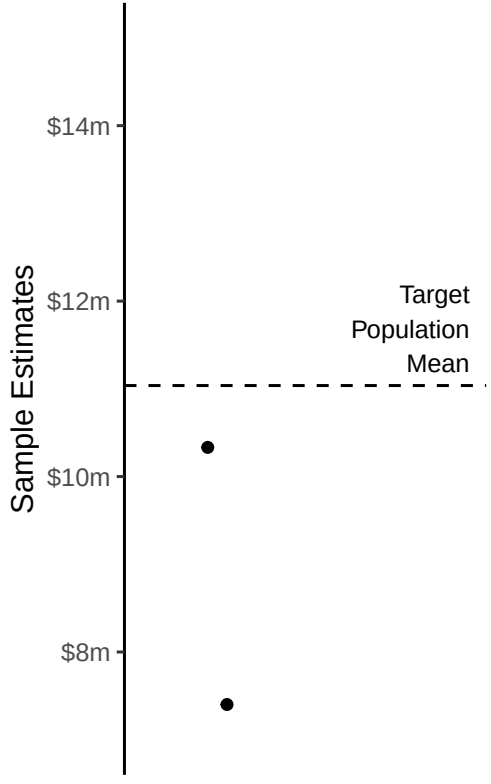

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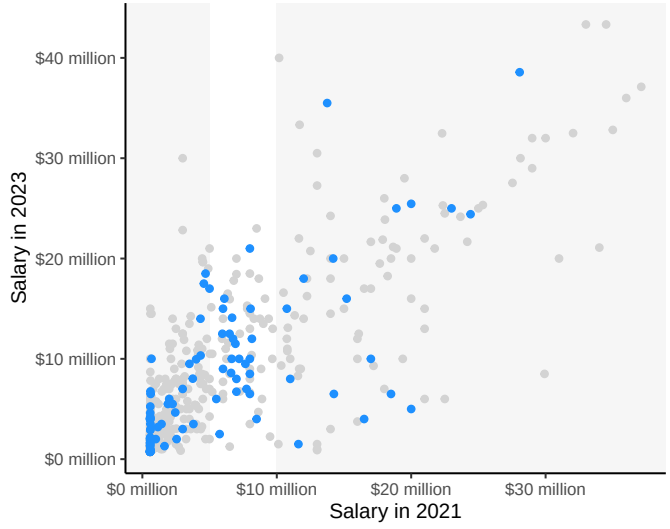
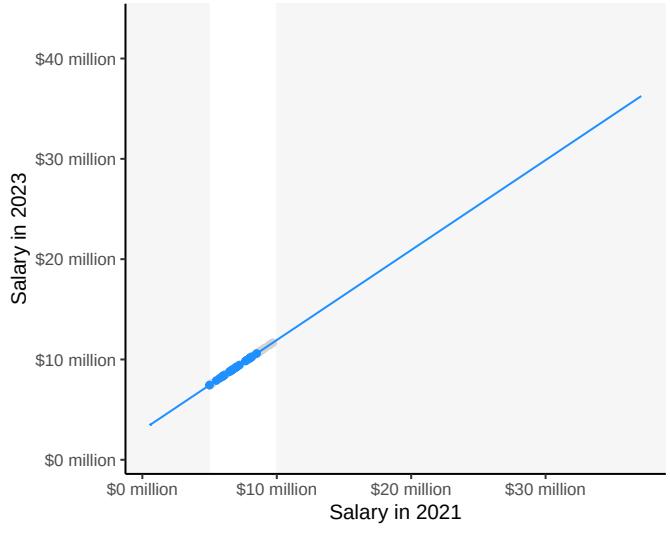
Method: Ordinary Least Squares prediction

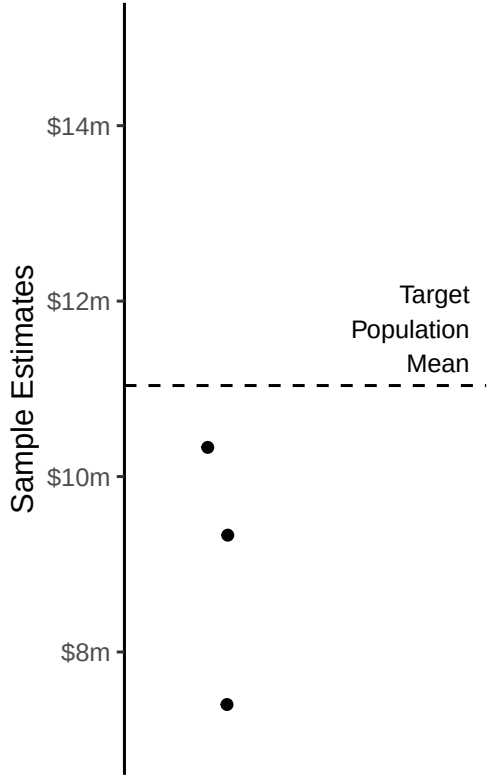
Sample



Learn



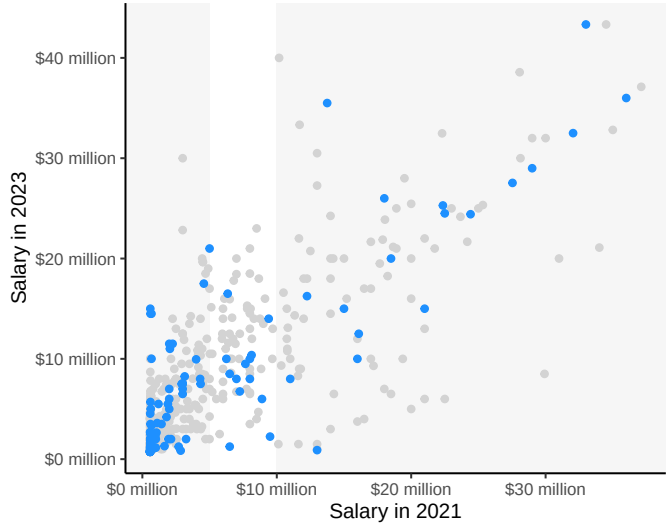
Record



Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

Sample



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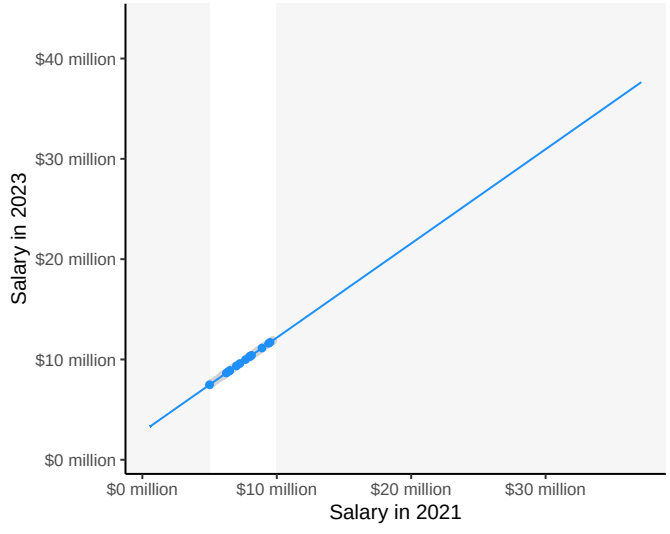

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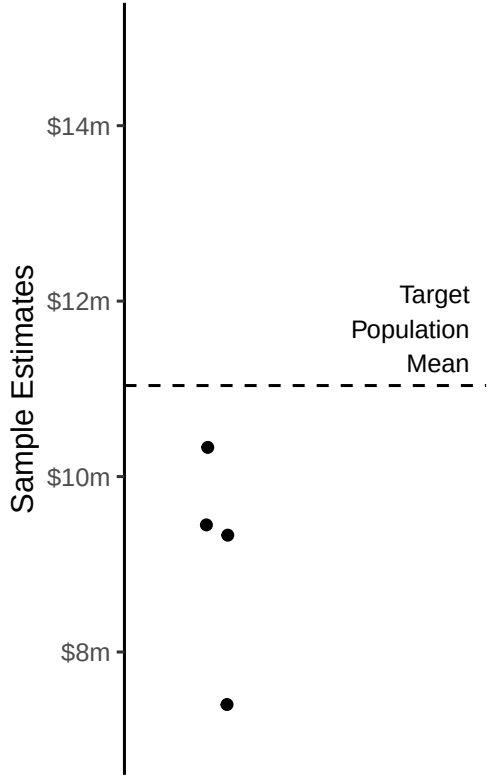
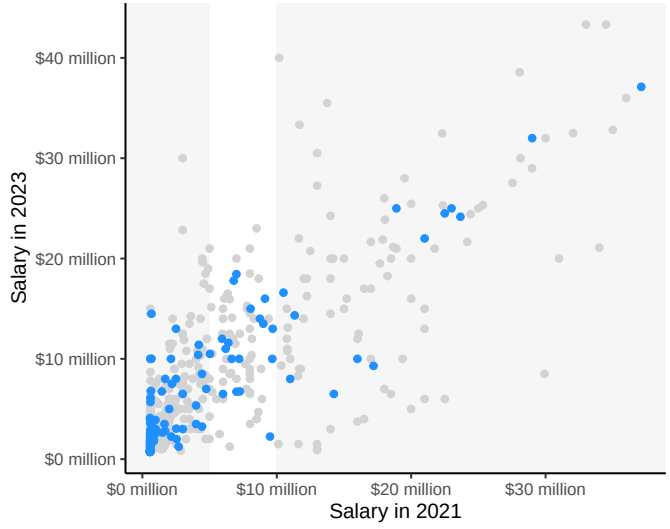


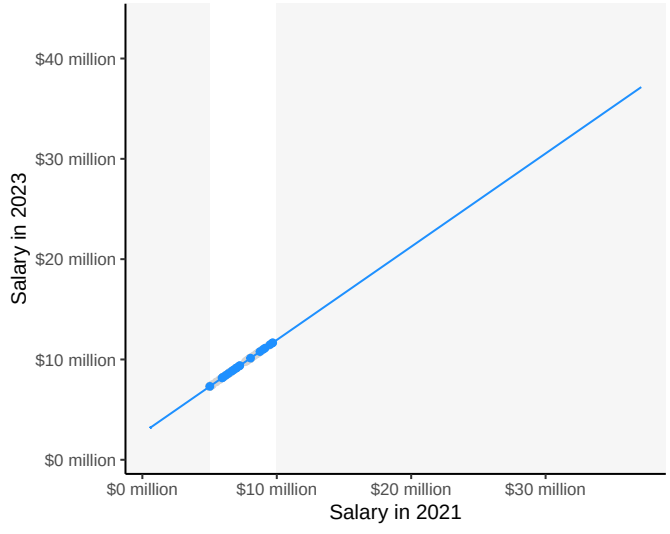
Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

Sample



Learn



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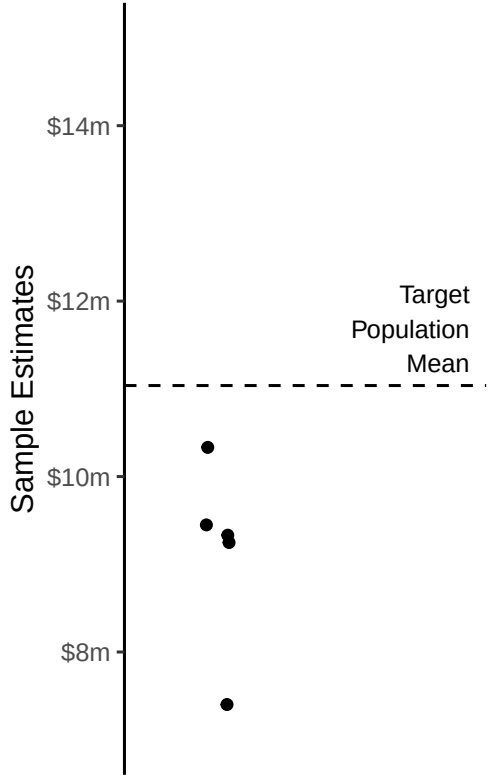
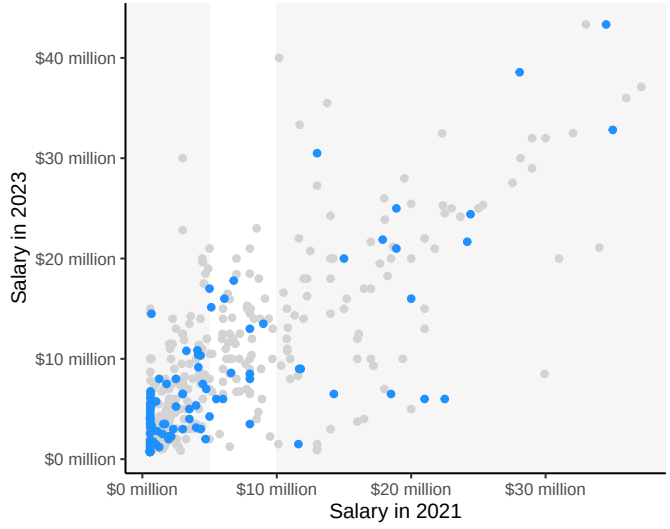


Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

Sample



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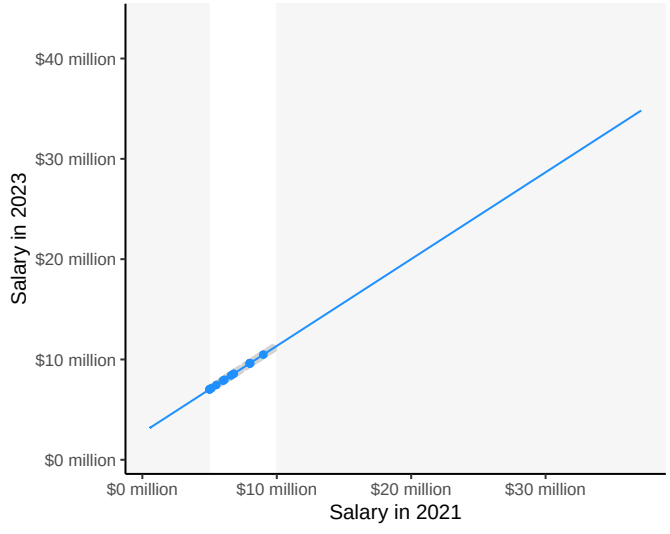

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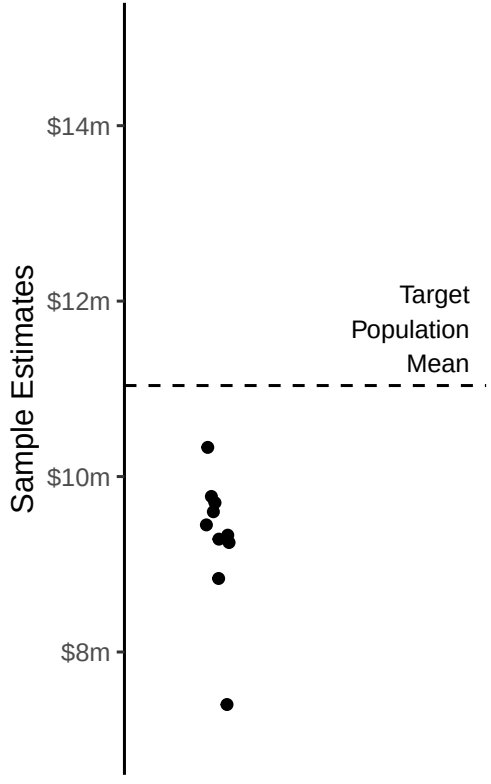
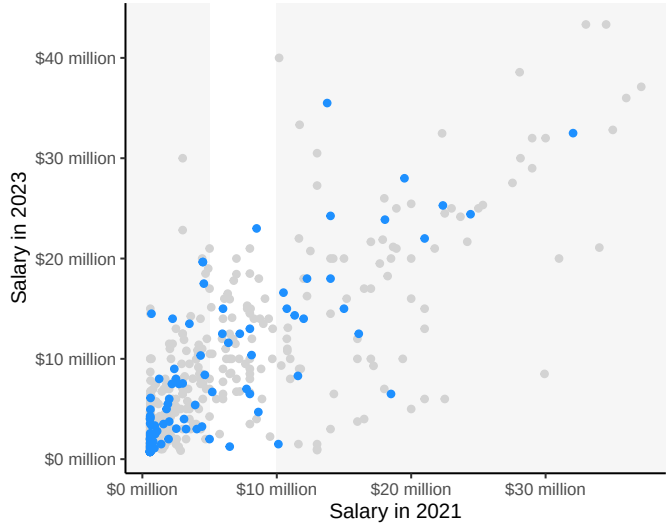


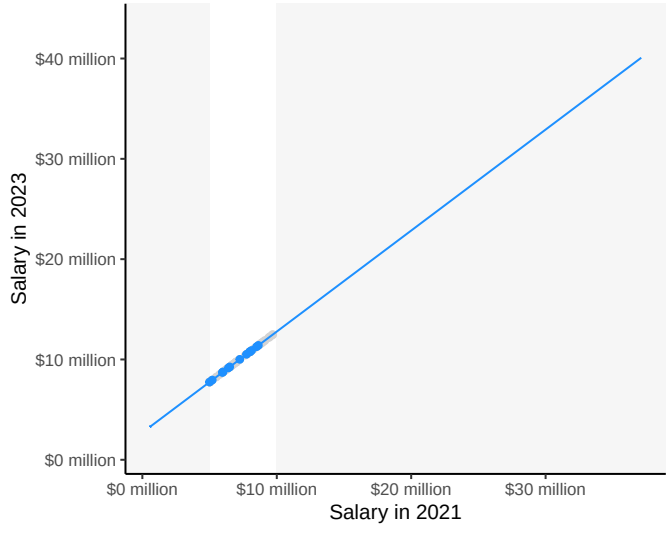
Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

Sample



Learn



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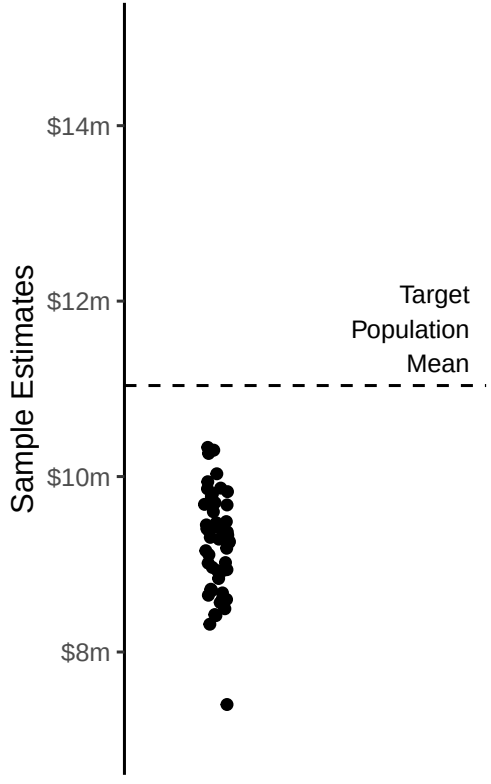
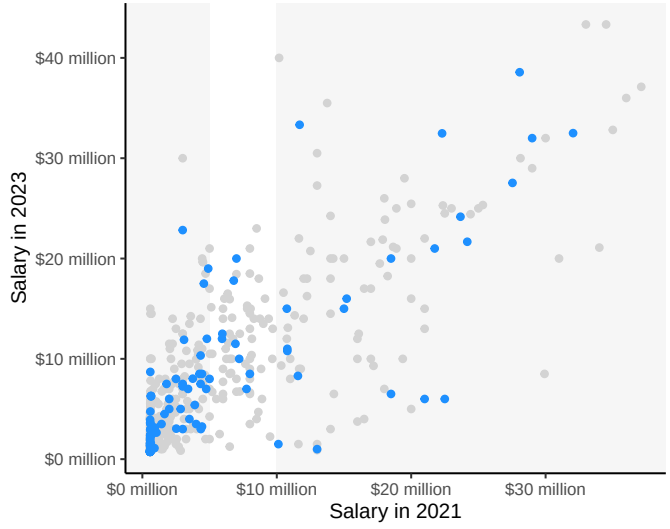


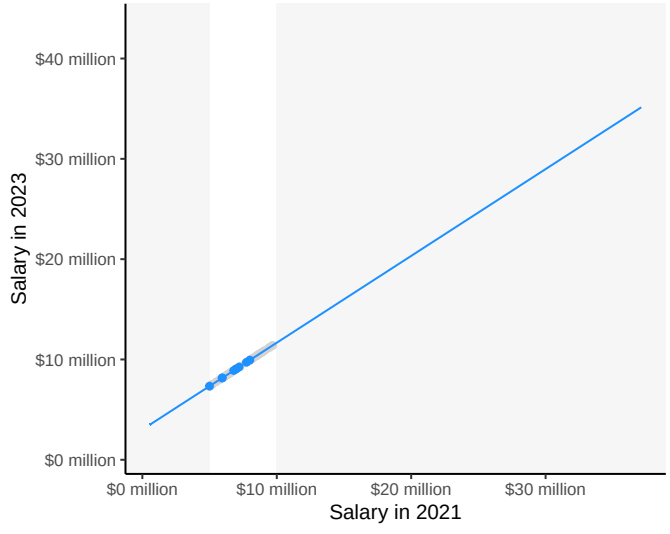
Goal: Estimate a target population mean from a sample

Method: Ordinary Least Squares prediction

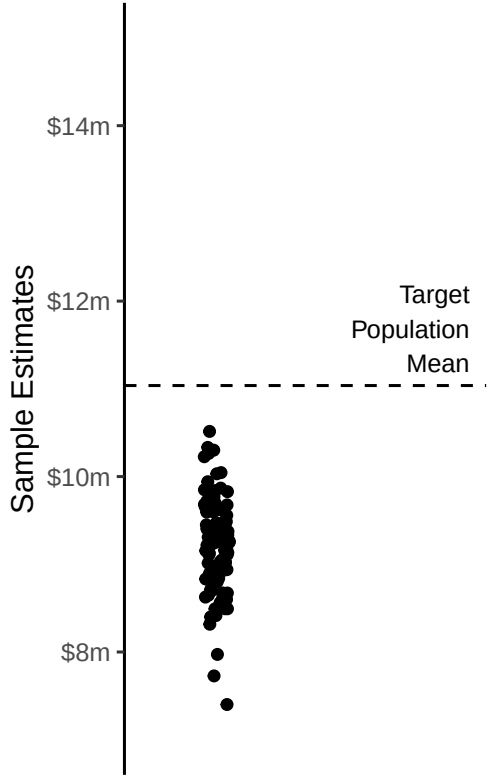
Sample



Learn



Record

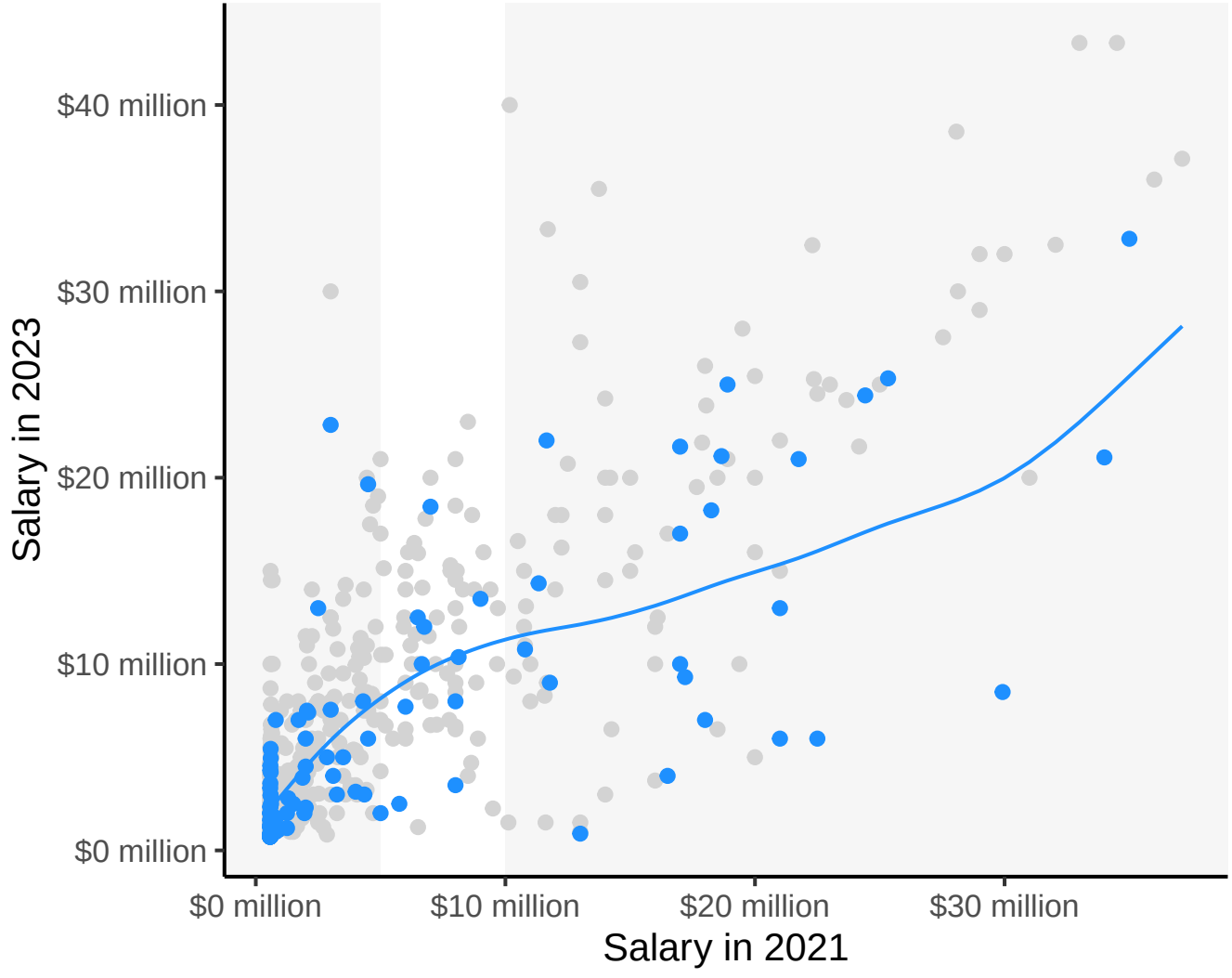


Ordinary Least Squares strategy:

1. Sample from the population
2. Learn a model
3. Record the average prediction in the target subgroup

Goal: Estimate a target population mean from a sample

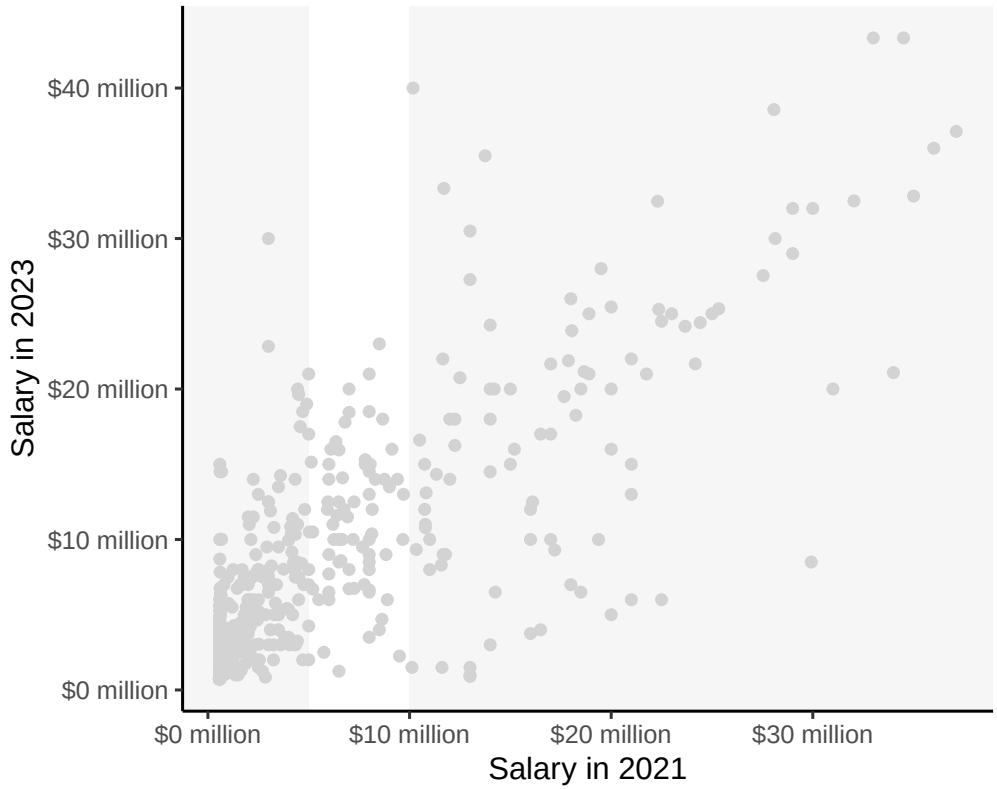
How would you do this with machine learning?



Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

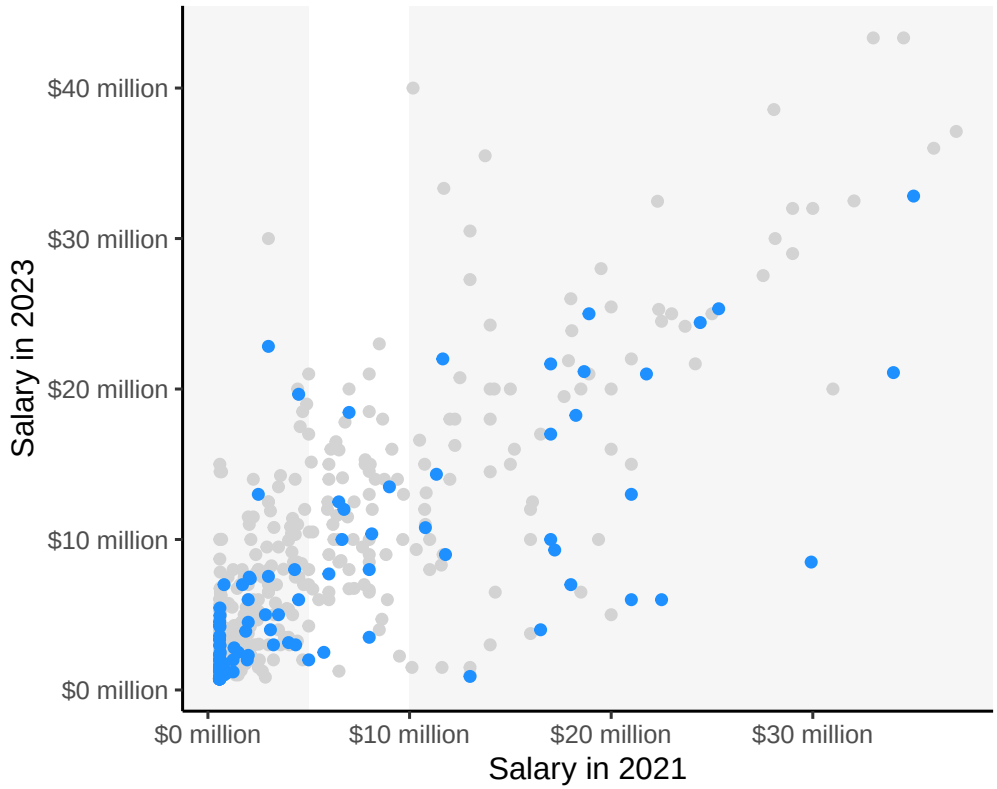
Begin with the population



Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Draw a sample



Goal: Estimate a target population mean from a sample

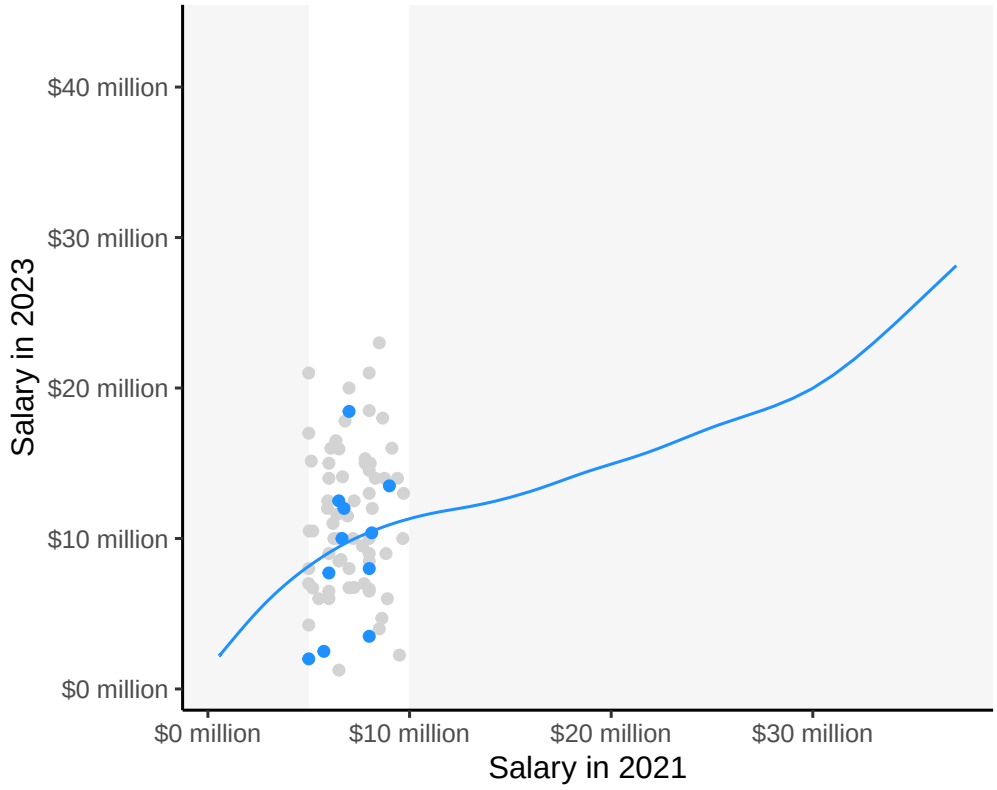
Method: Generalized Additive Model prediction

Learn a model

Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

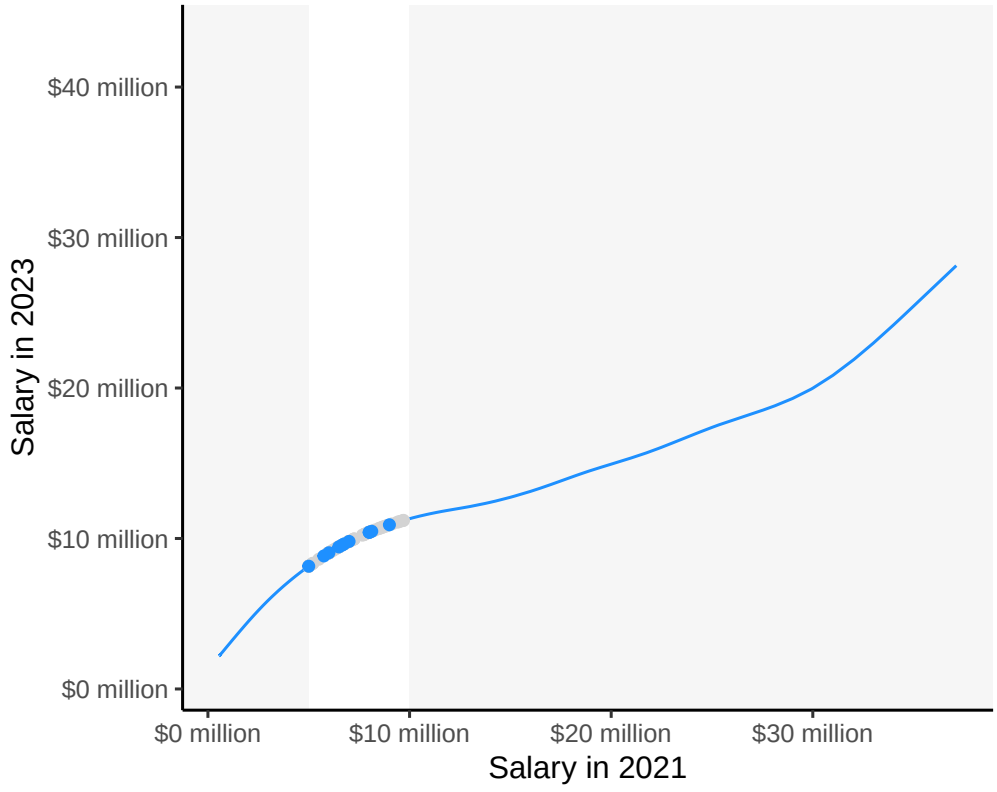
Focus on the target population



Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

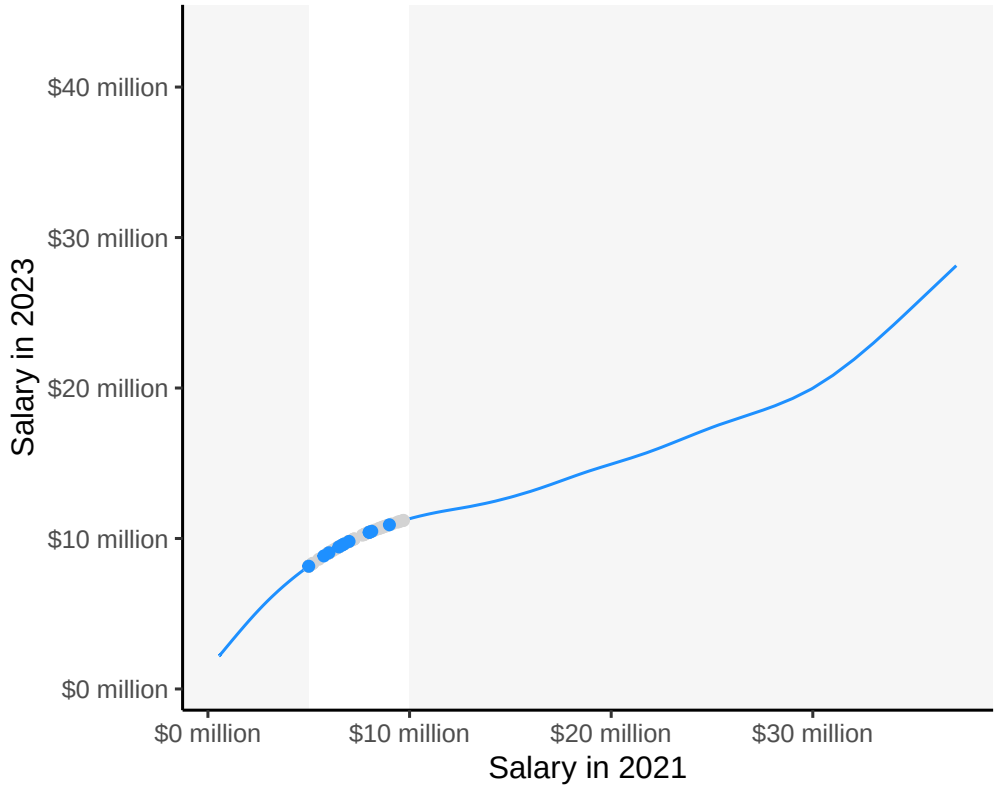
Predict



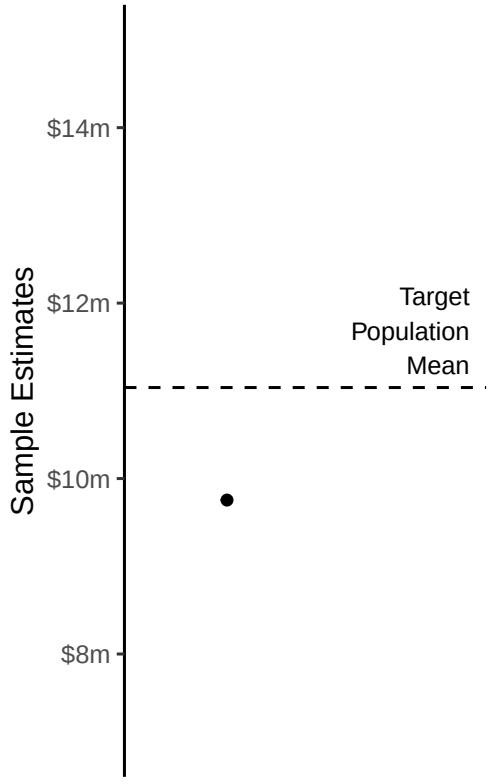
Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Predict



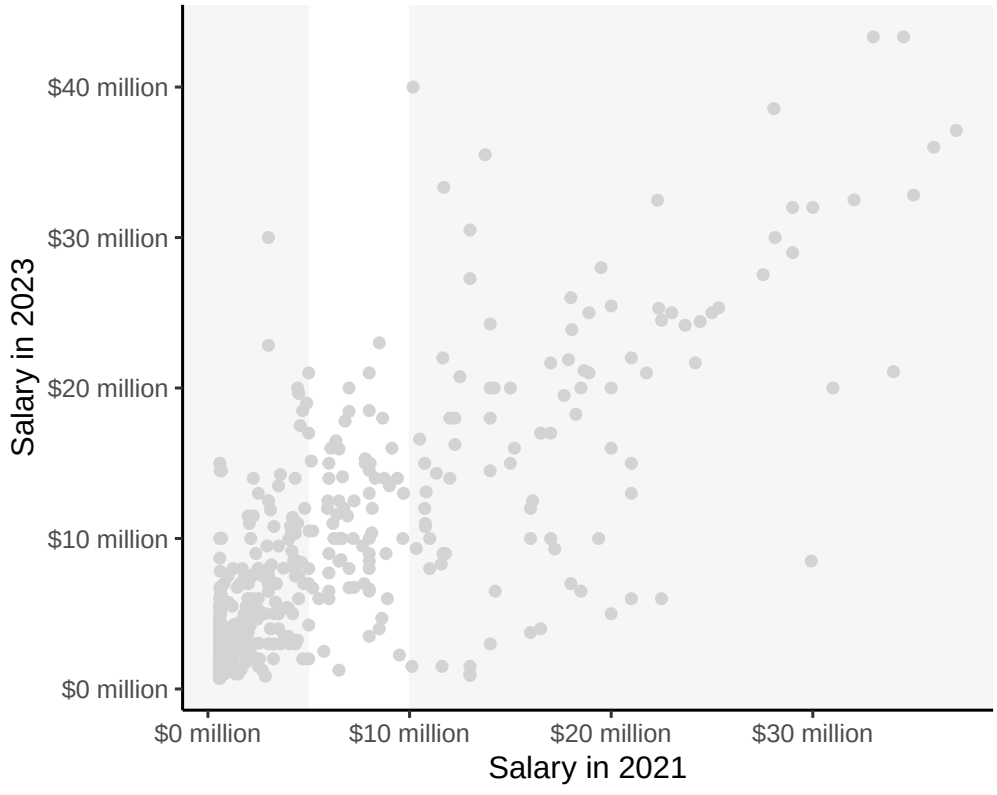
Record the average

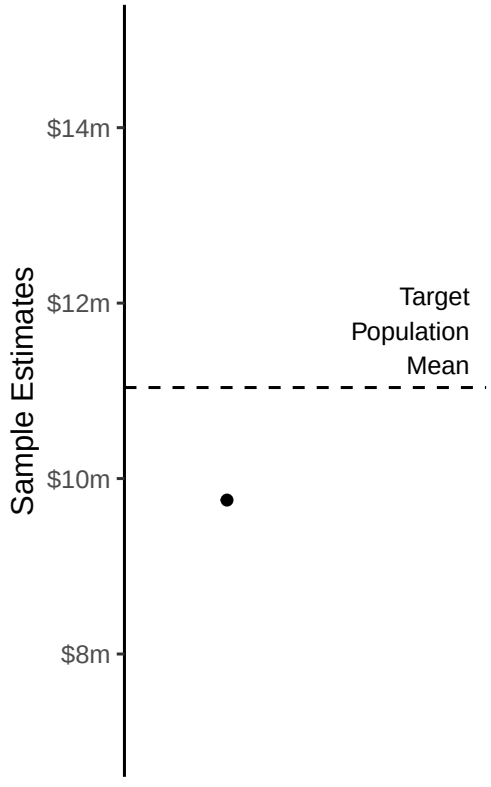


Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Begin with the population

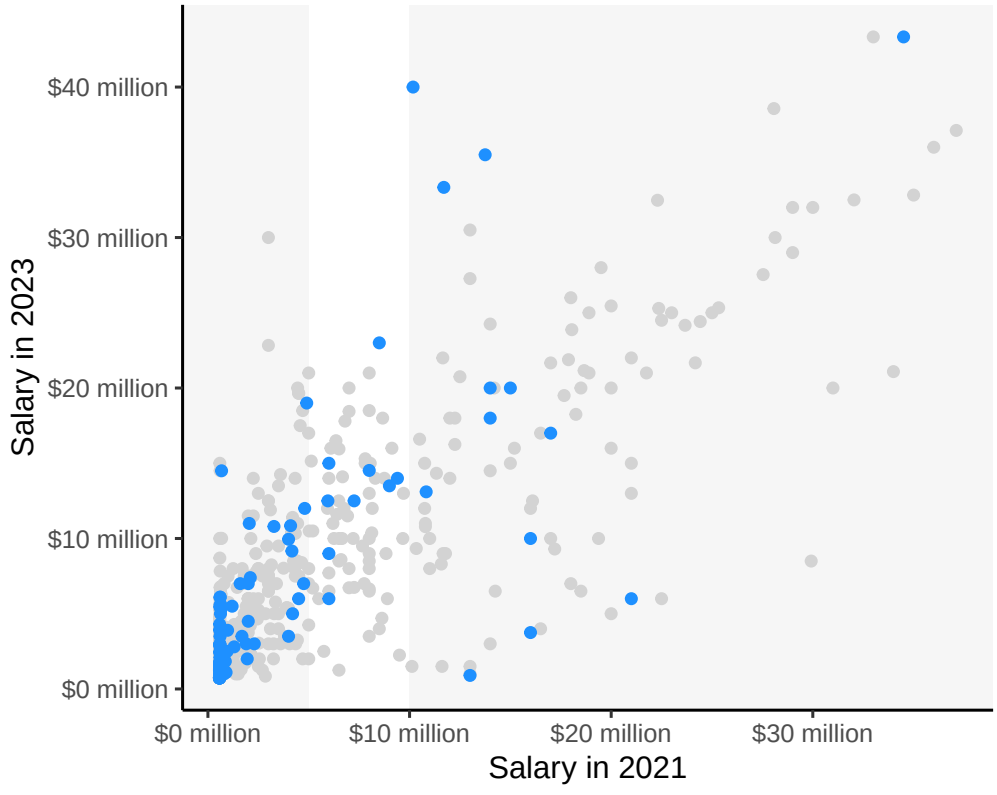


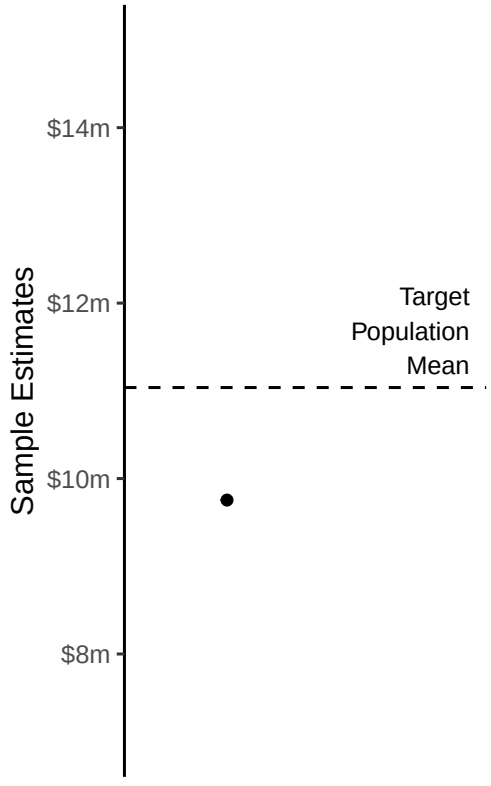


Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Draw a sample

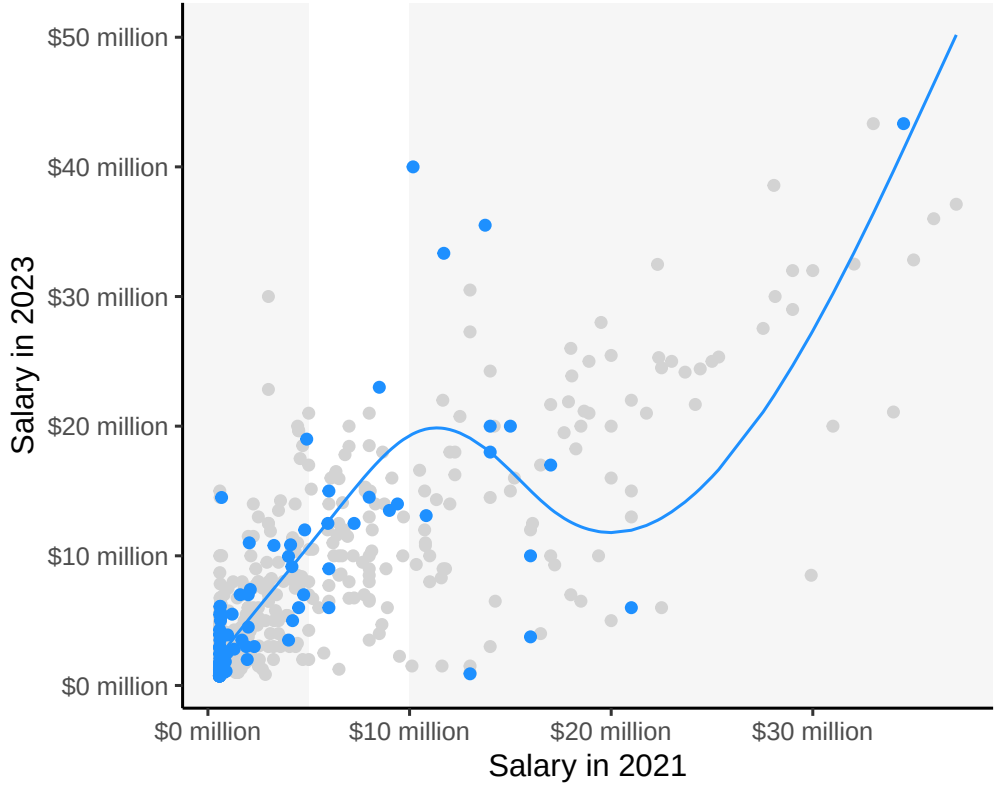


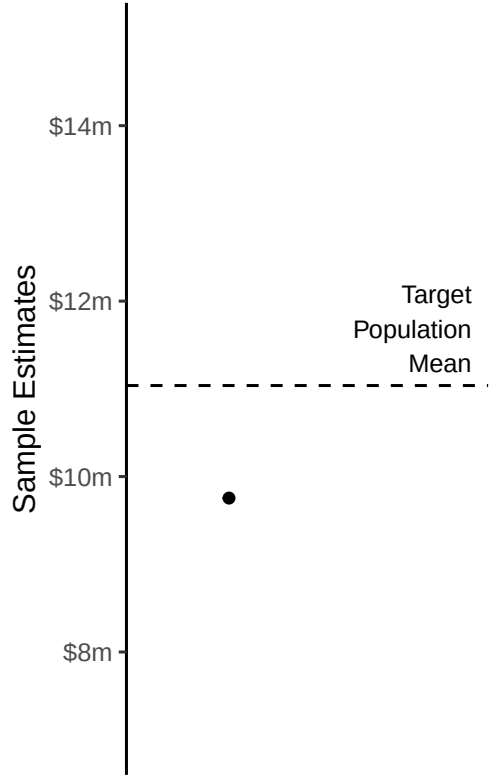


Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Learn a model

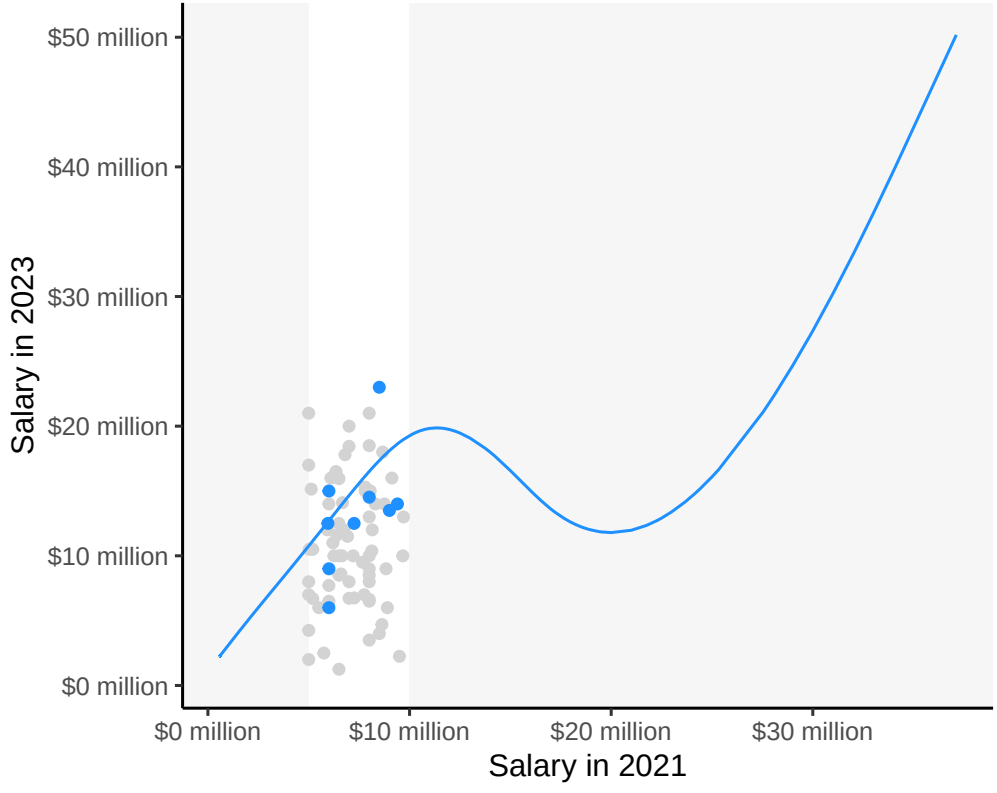


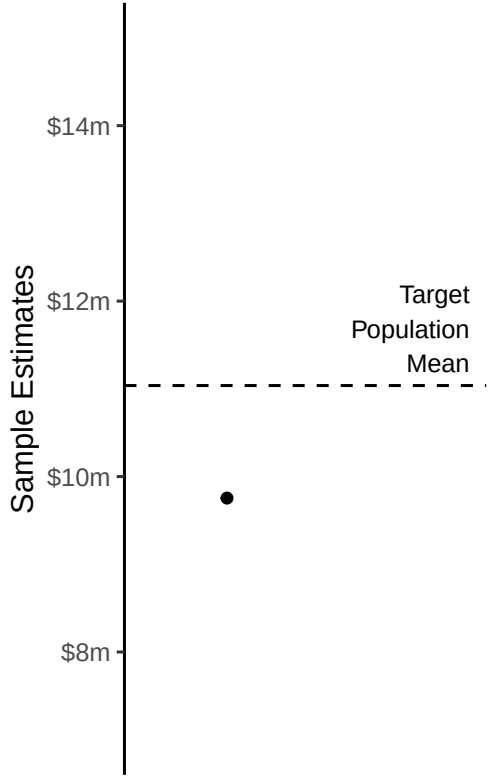


Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Focus on the target population

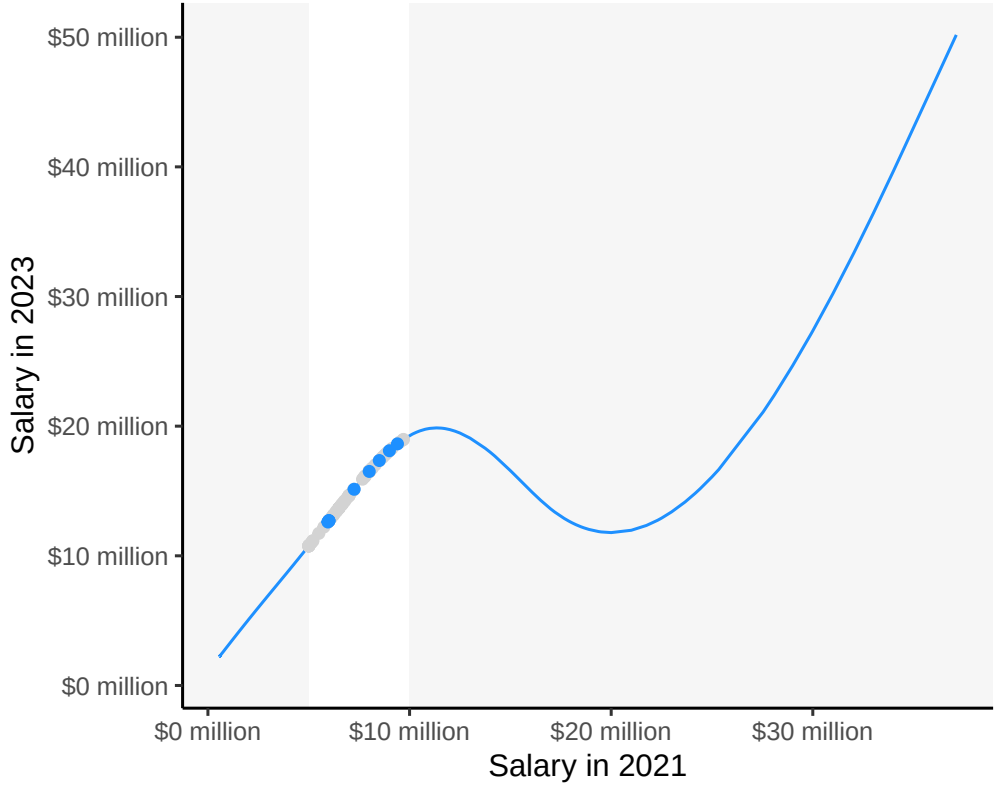


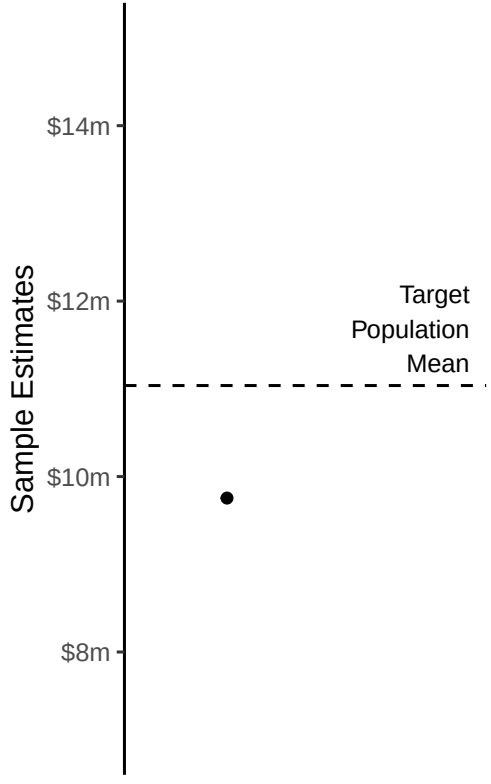


Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Predict

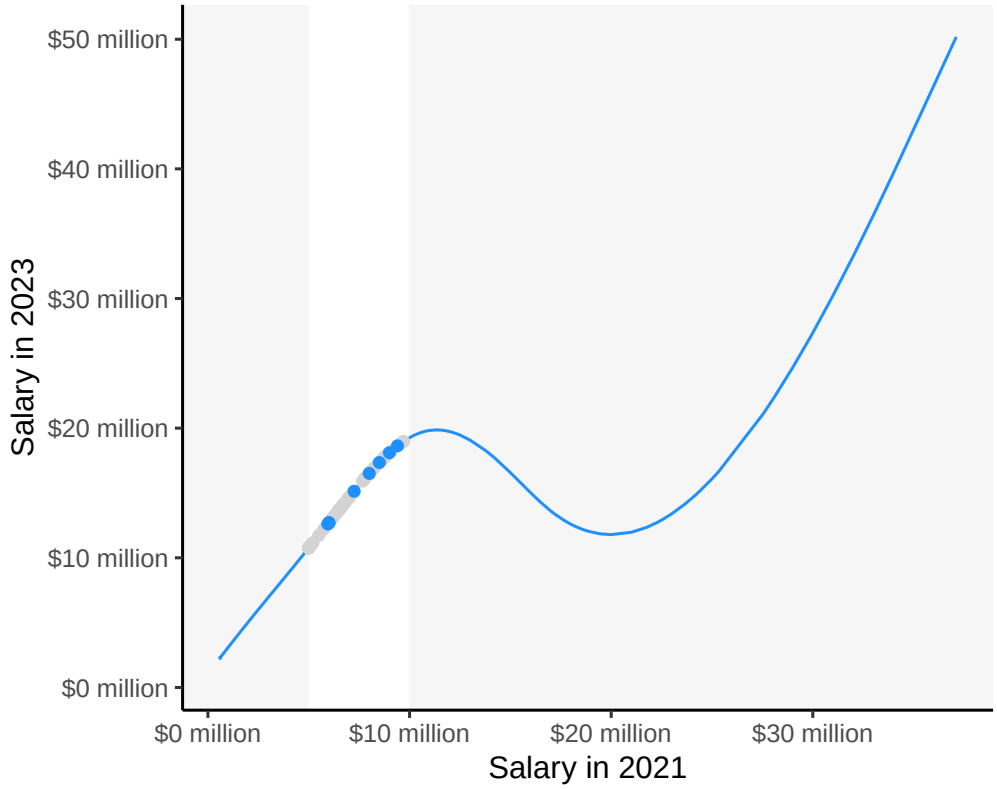




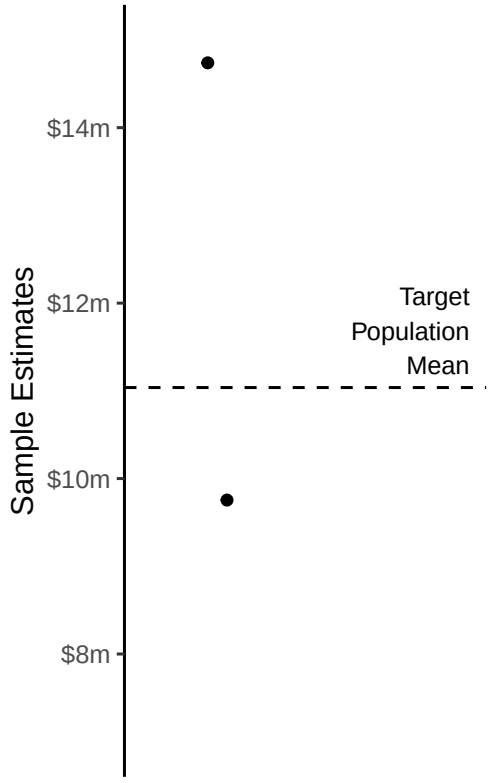
Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Predict



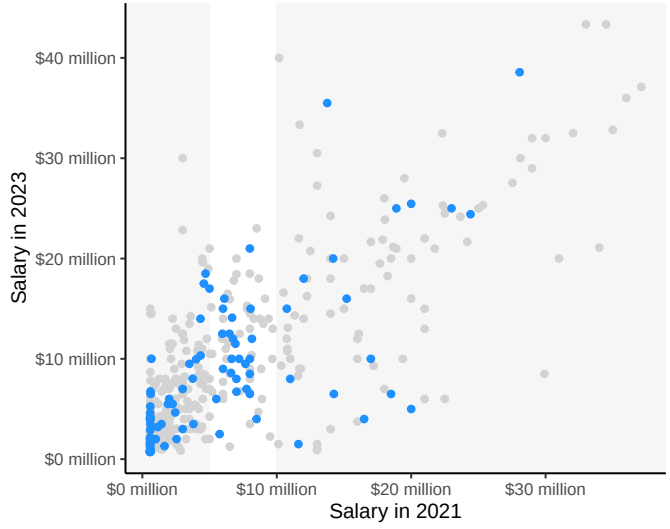
Record the average



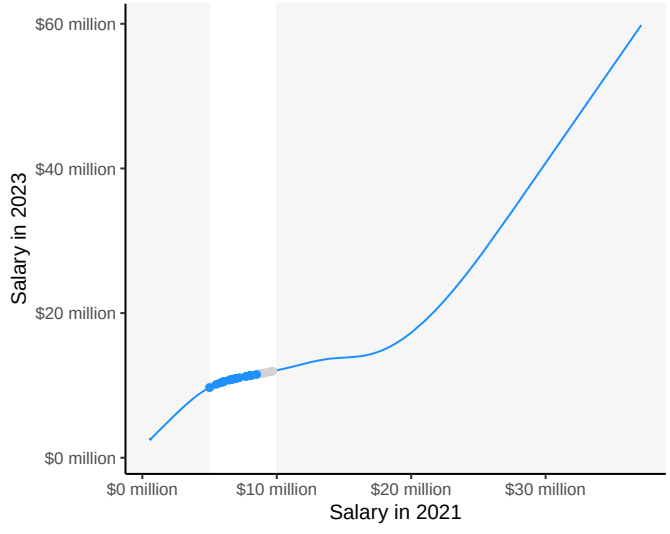
Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

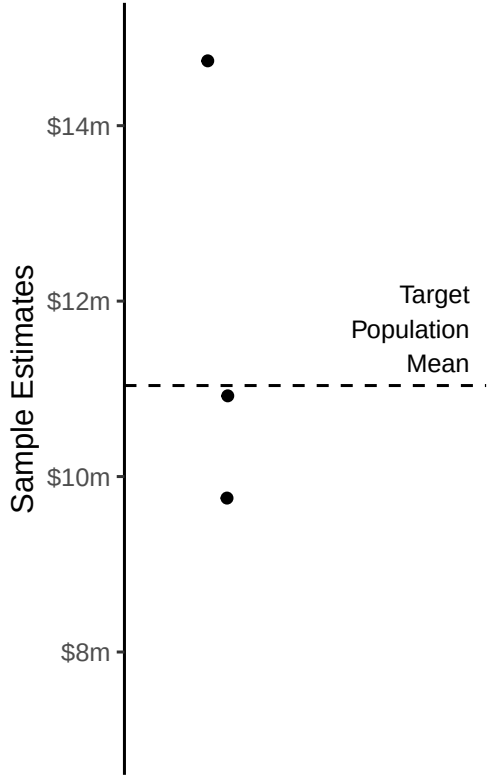
Sample



Learn



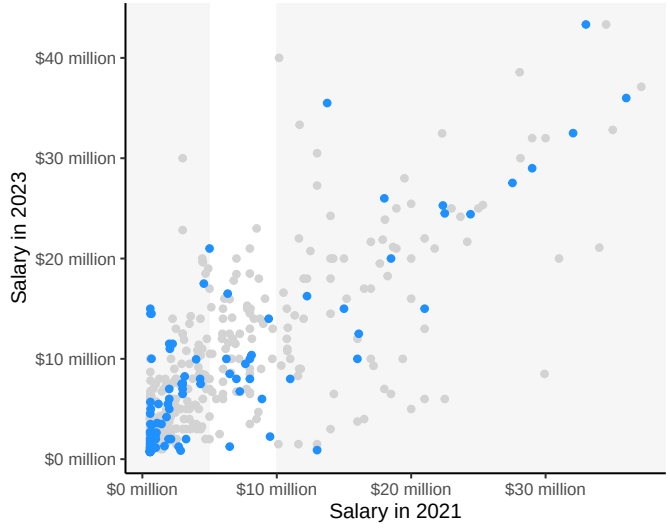
Record



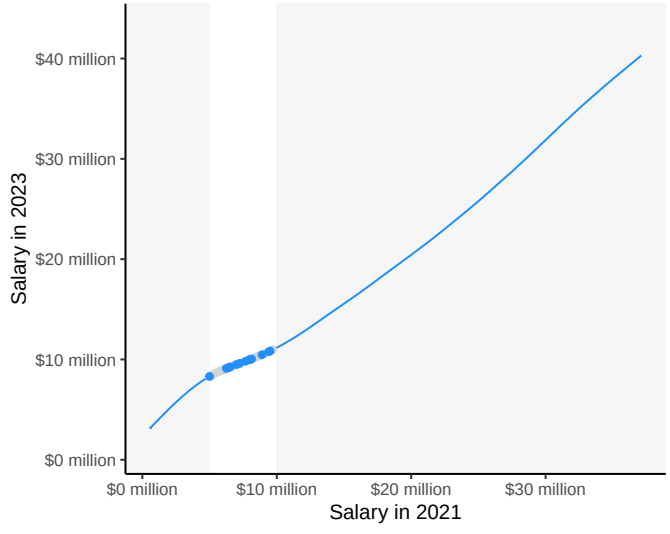
Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

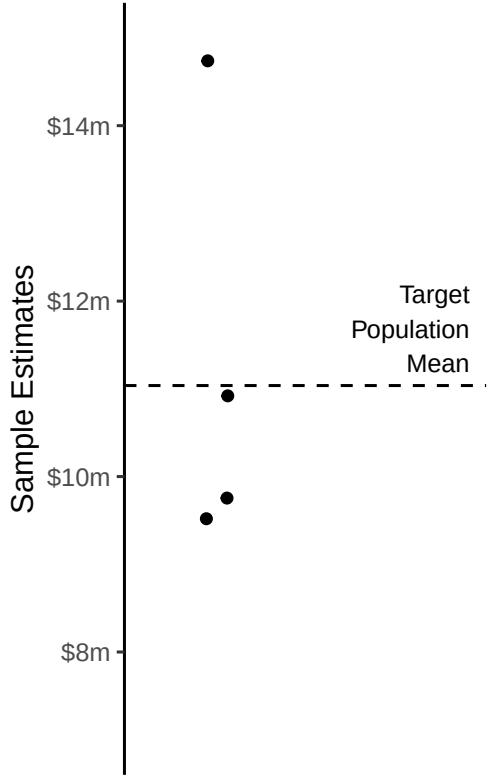
Sample



Learn



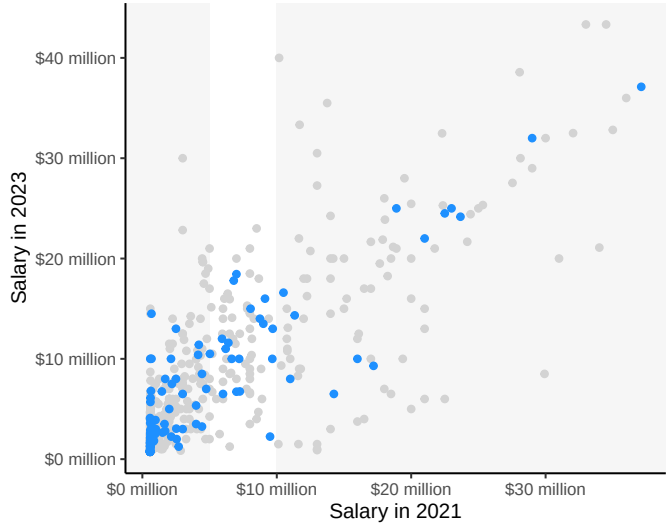
Record



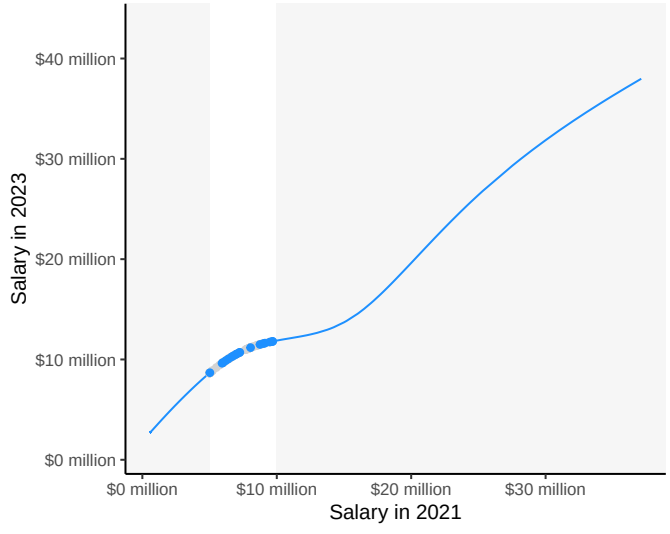
Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Sample



Learn



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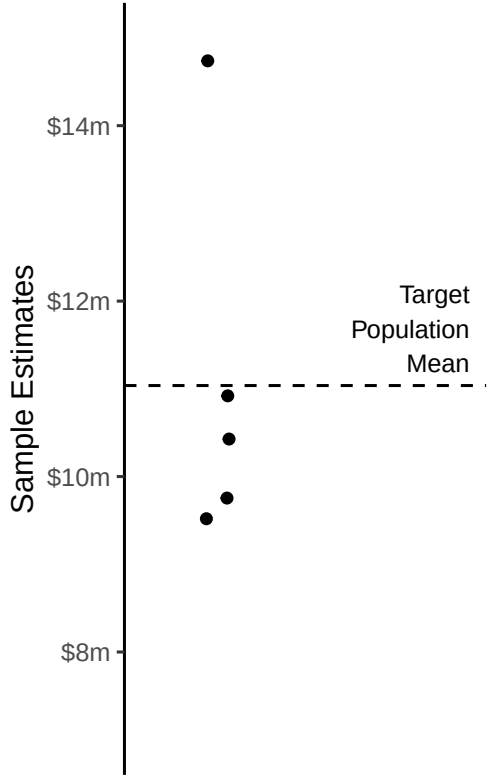
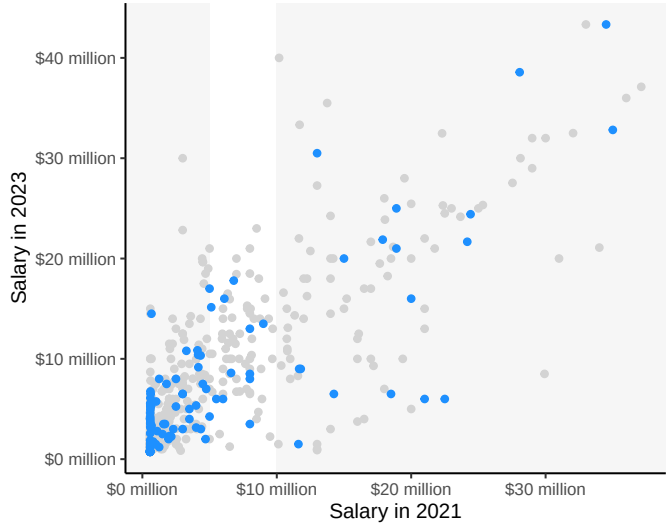


Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Sample



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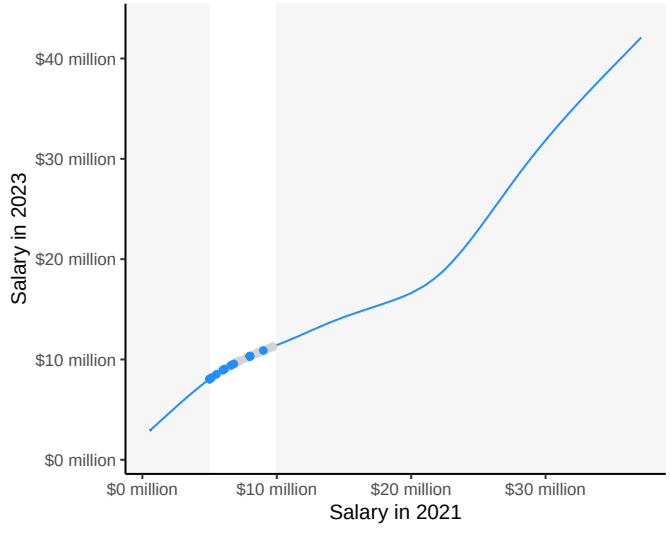
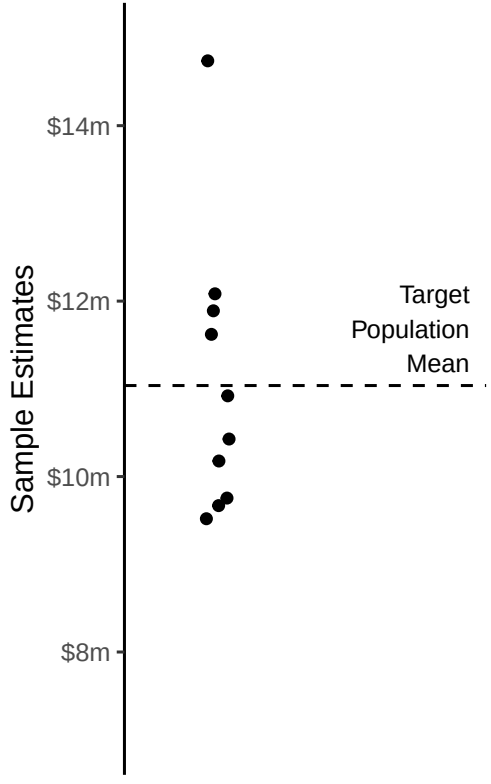


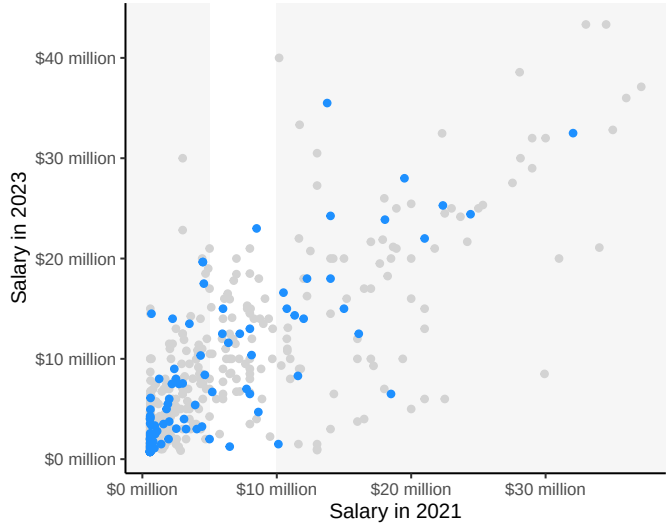
Record



Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Sample



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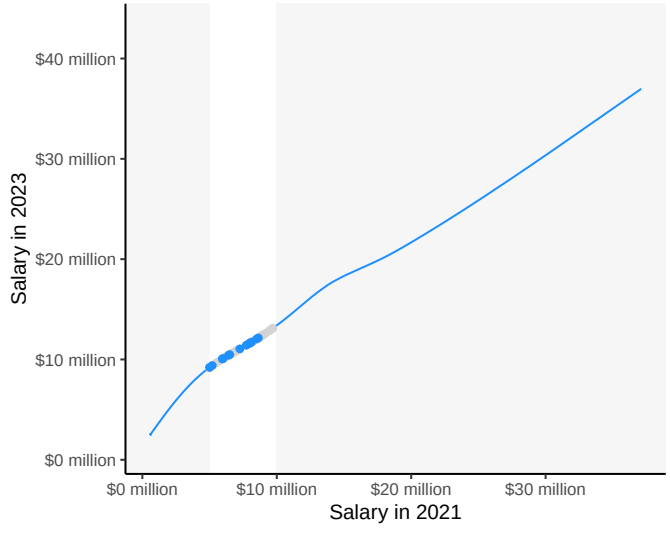

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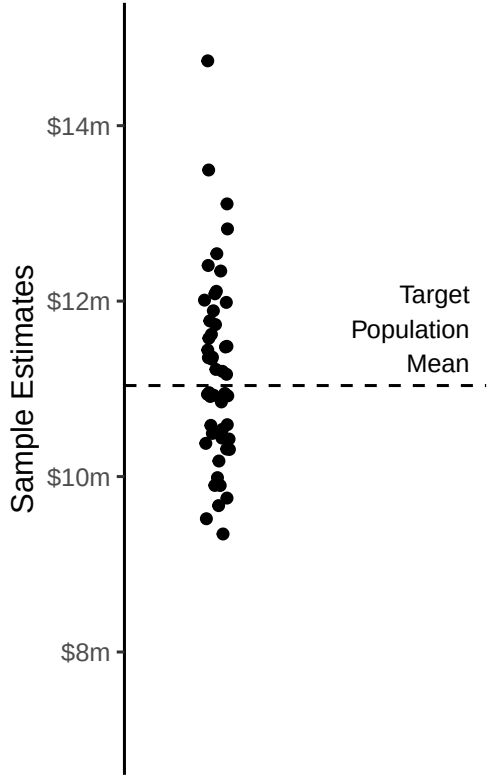
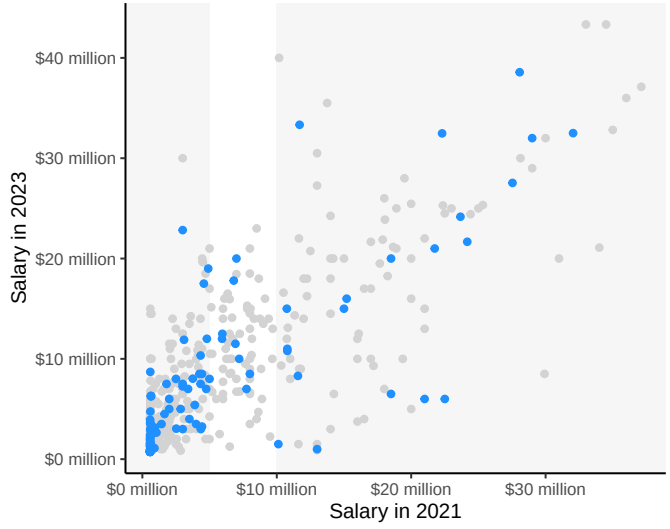


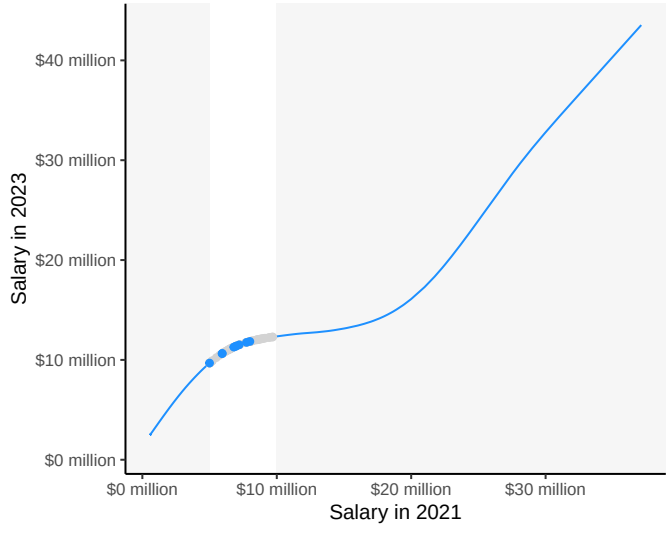
Goal: Estimate a target population mean from a sample

Method: Generalized Additive Model prediction

Sample



Learn



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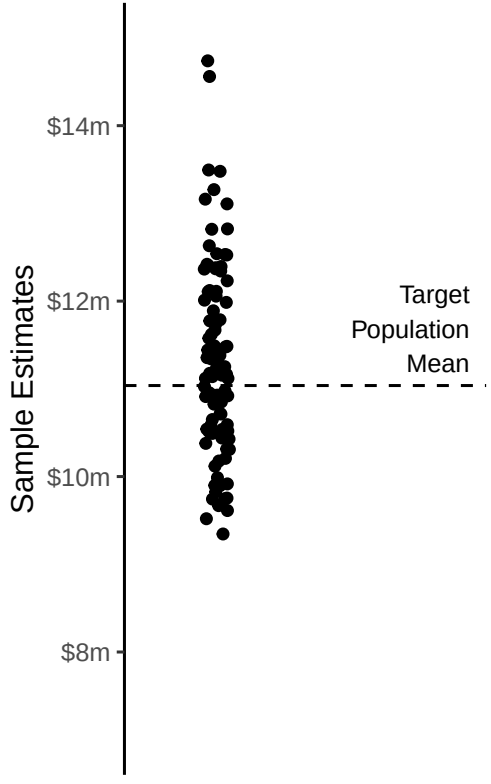
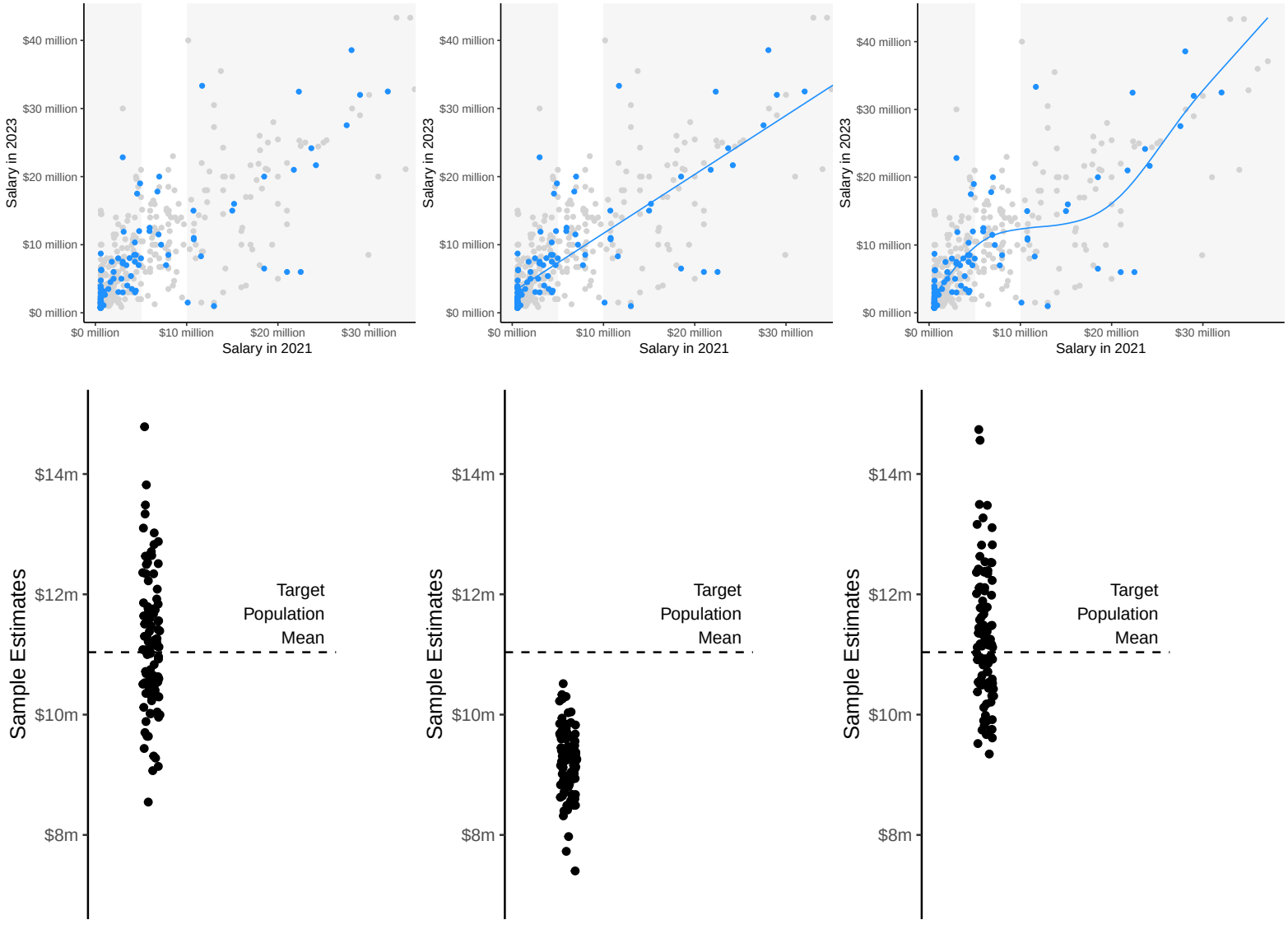
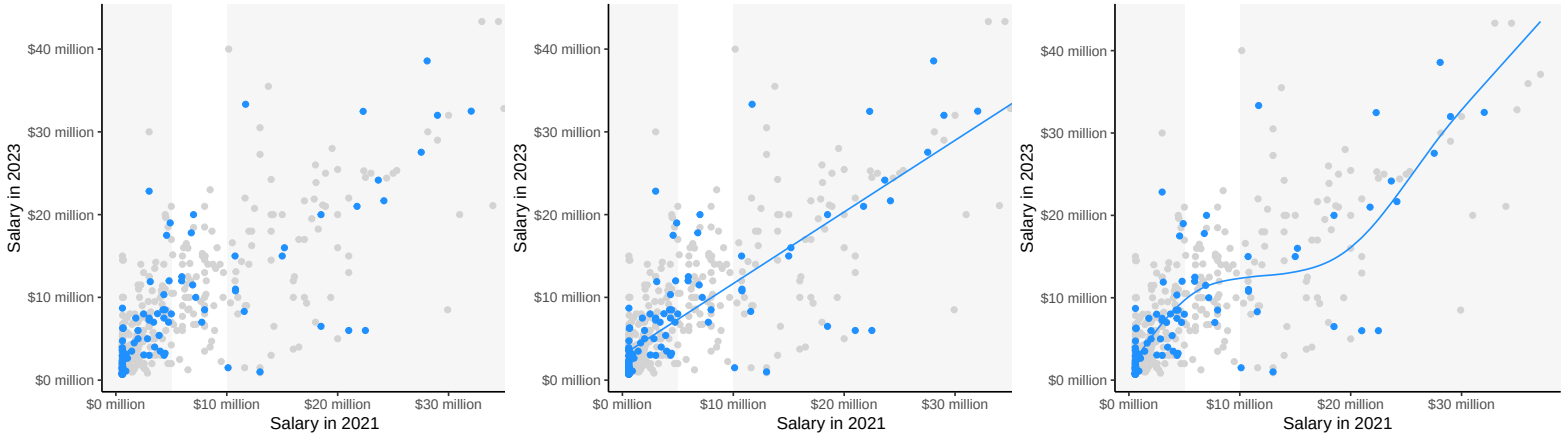
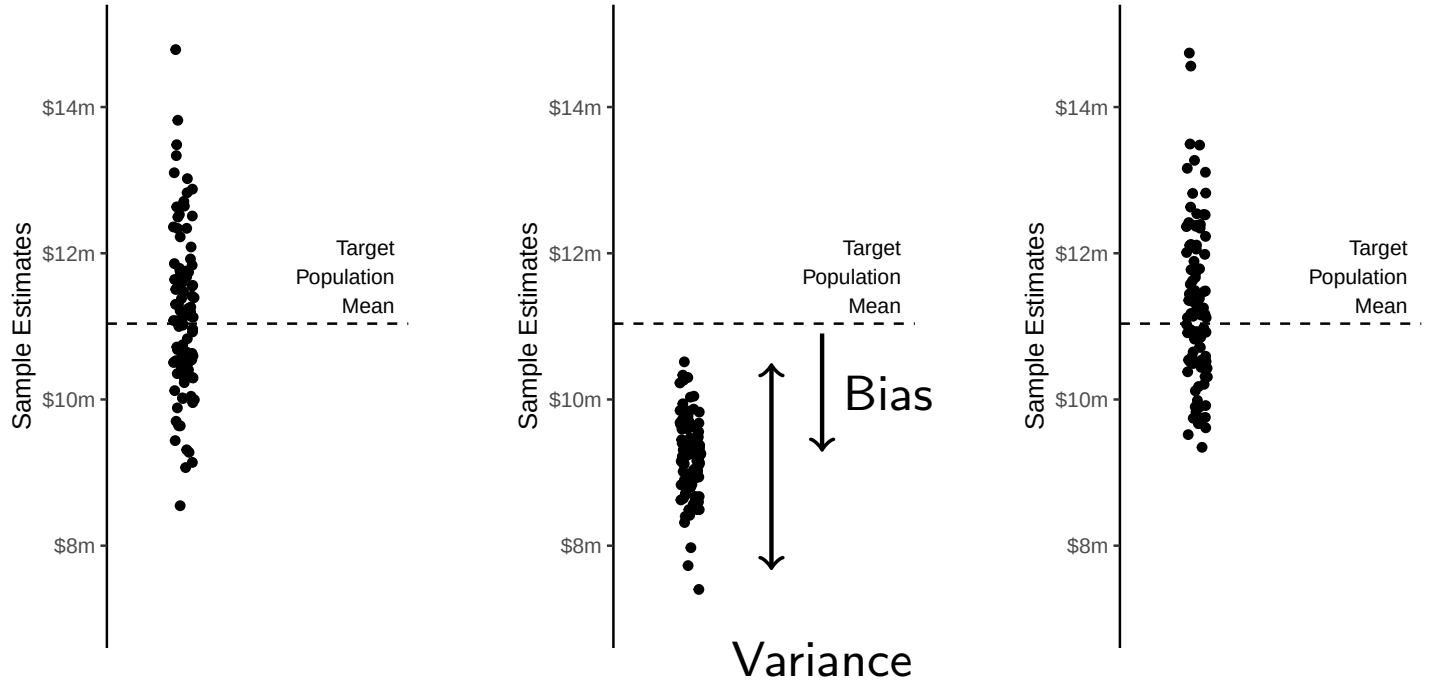


Comparing the estimators

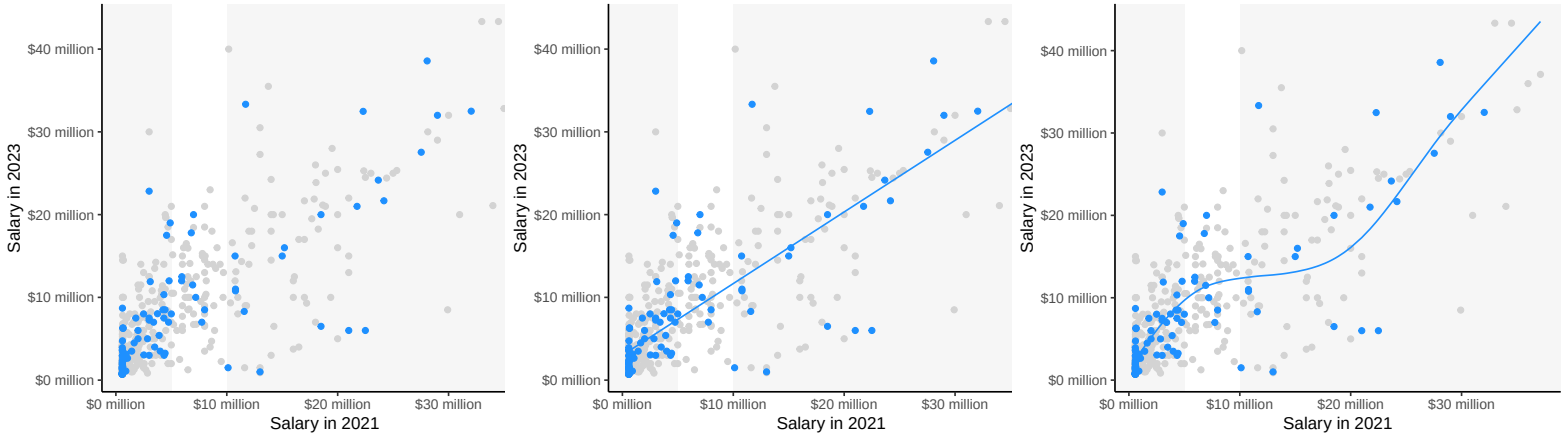


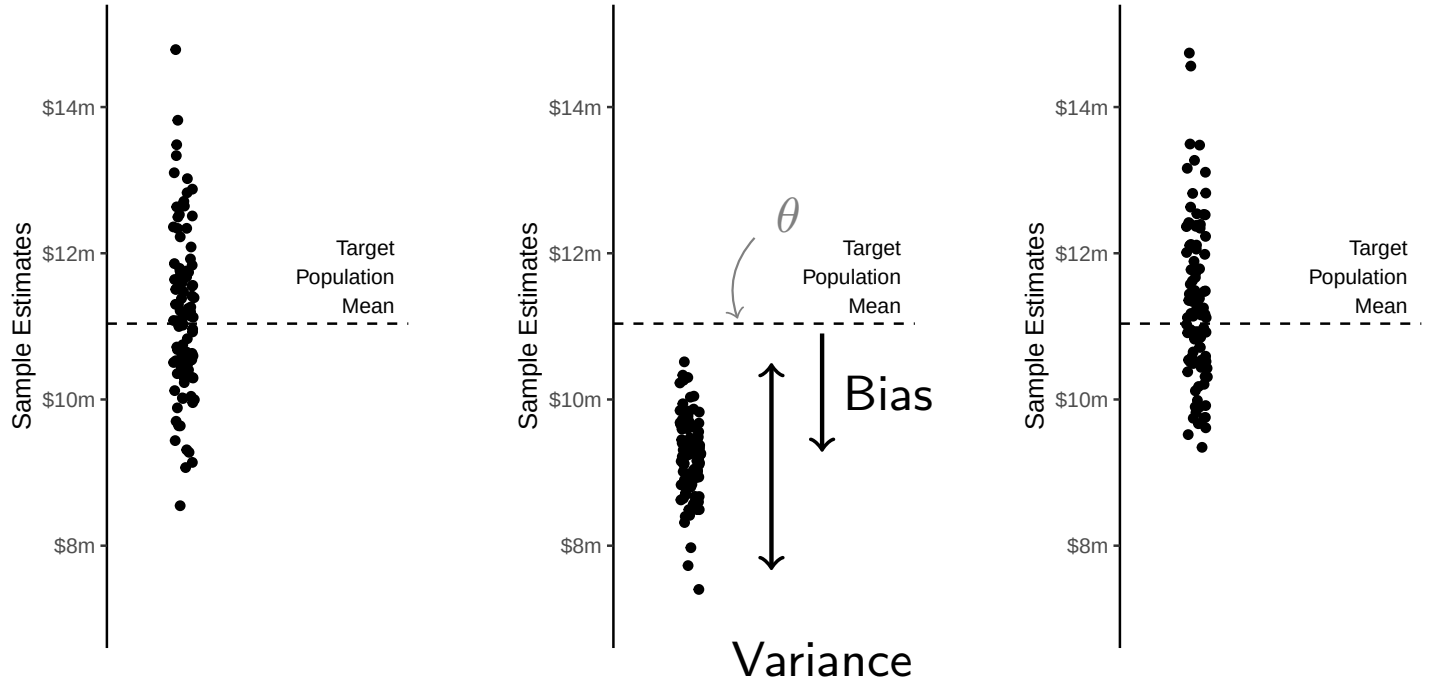
Comparing the estimators



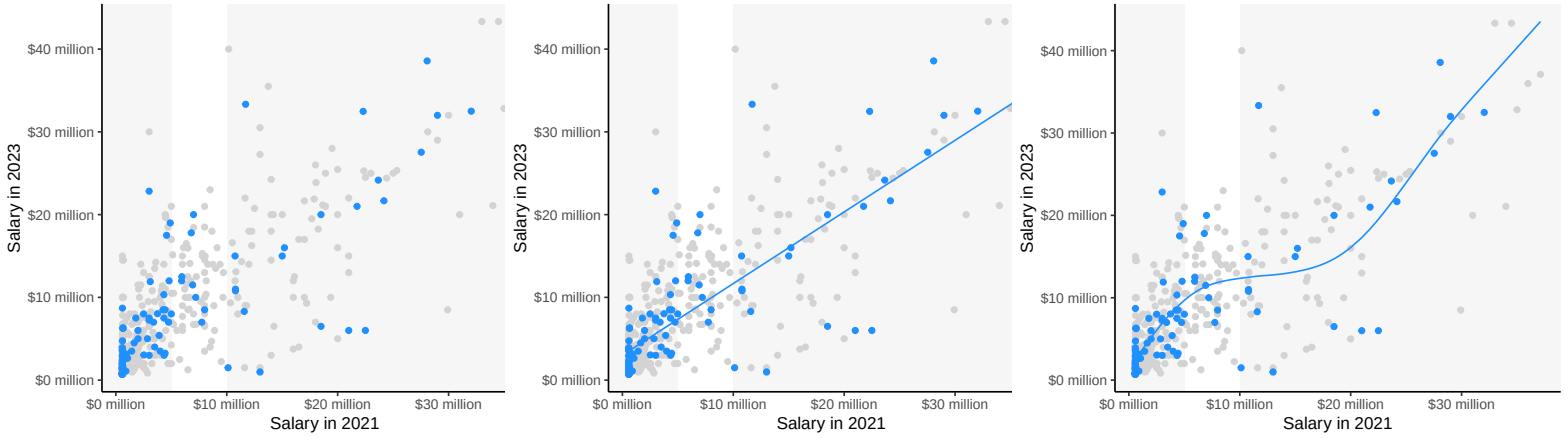


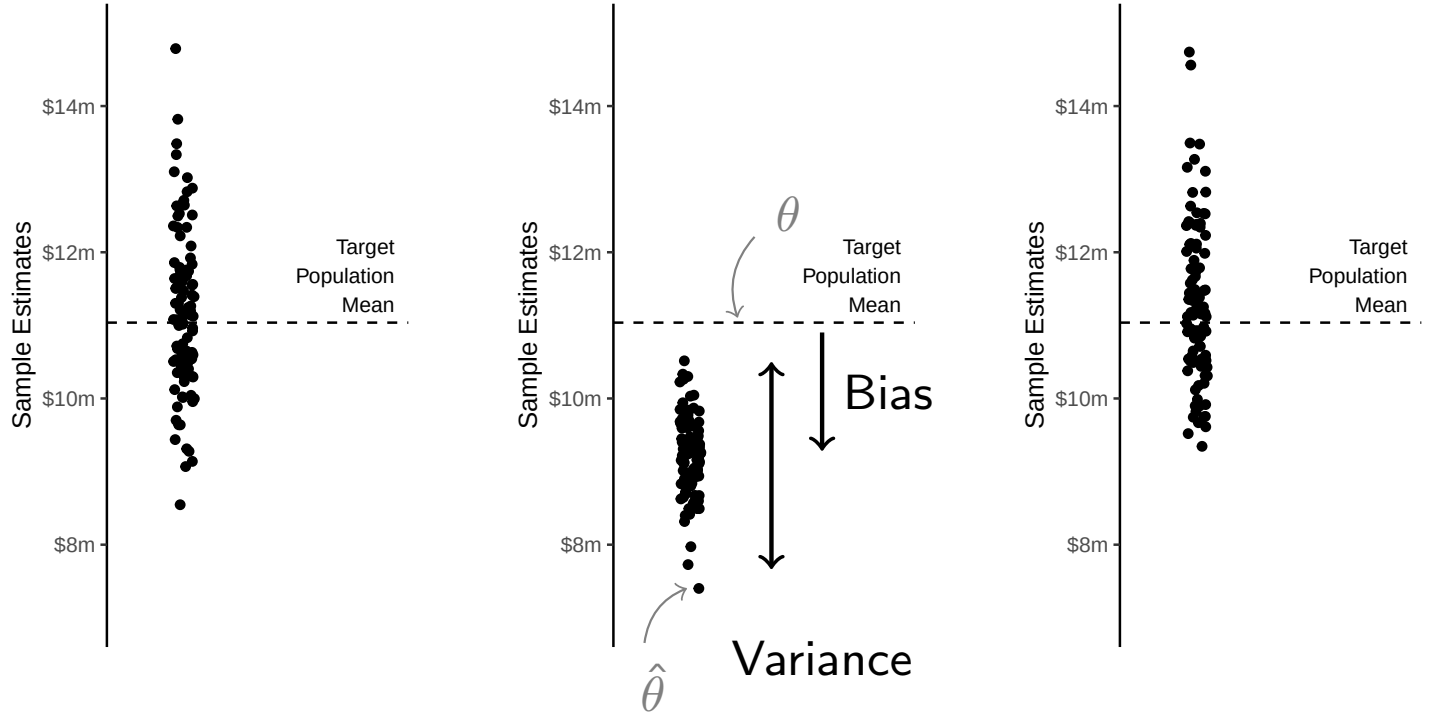
Comparing the estimators



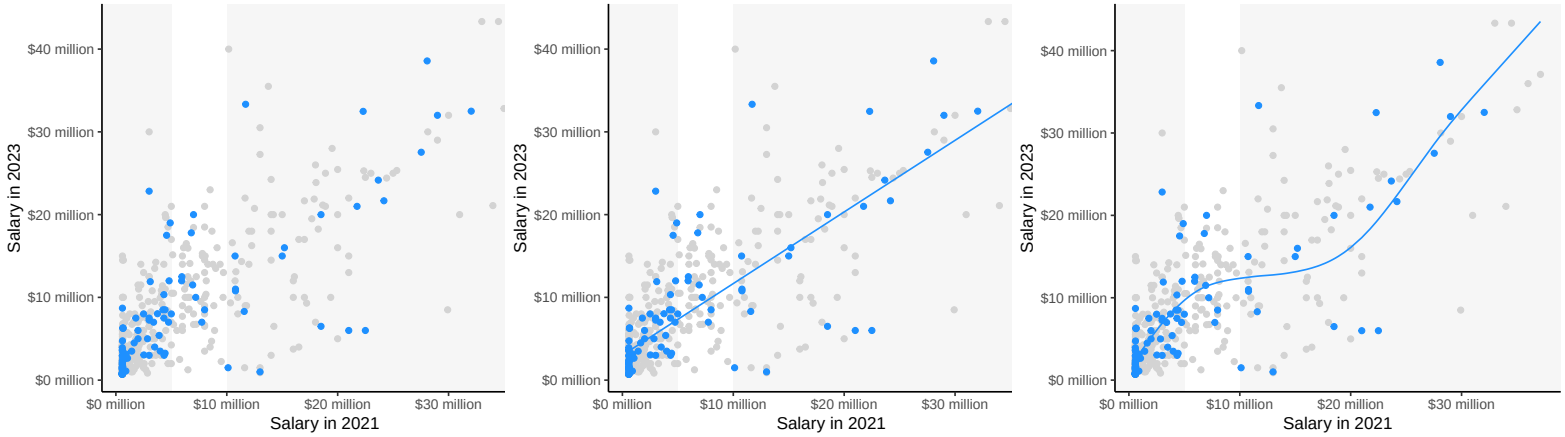


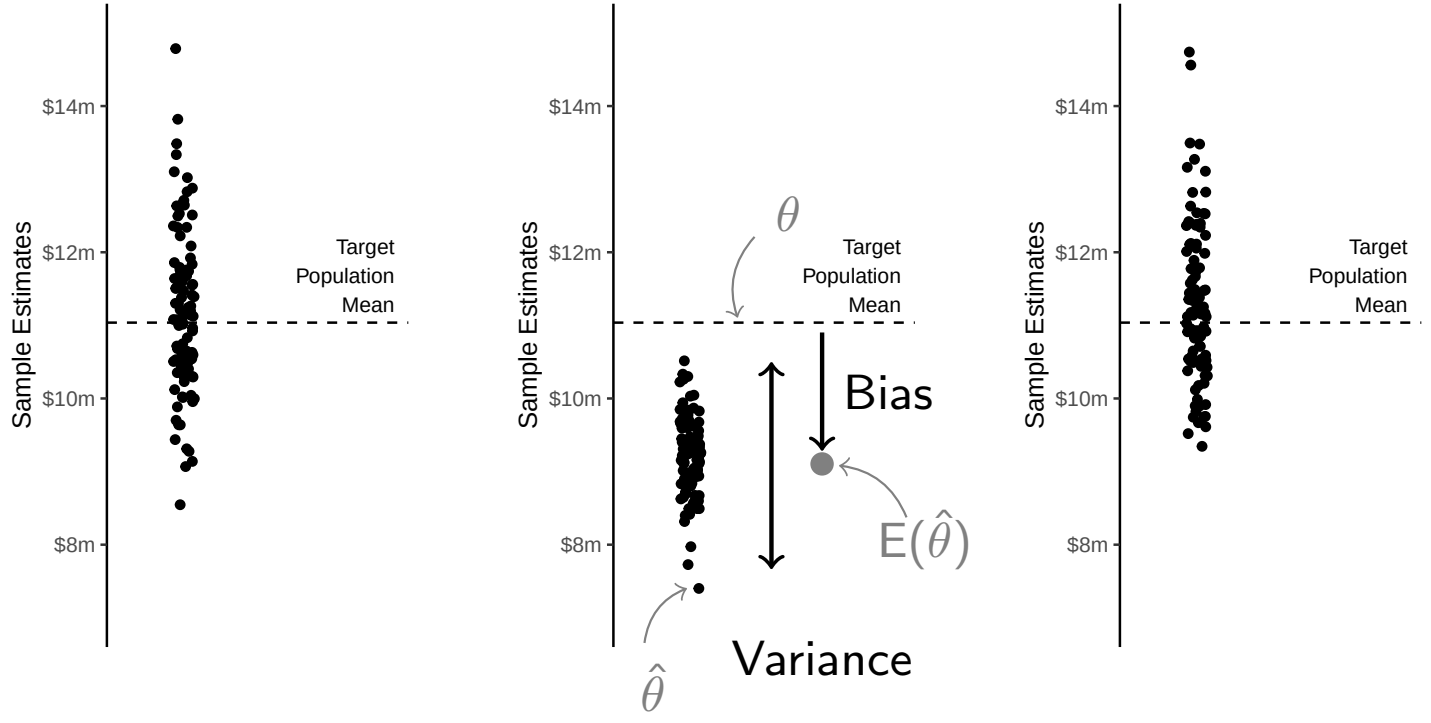
Comparing the estimators





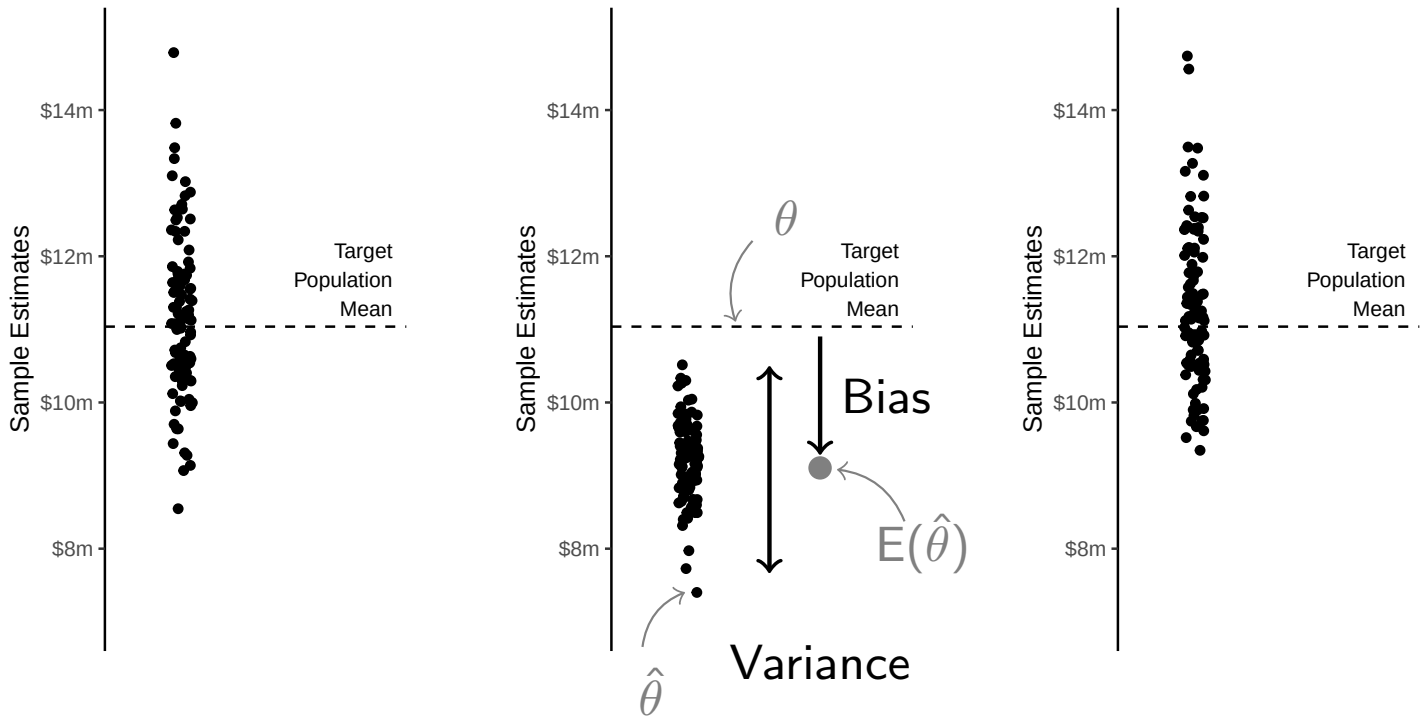
Comparing the estimators





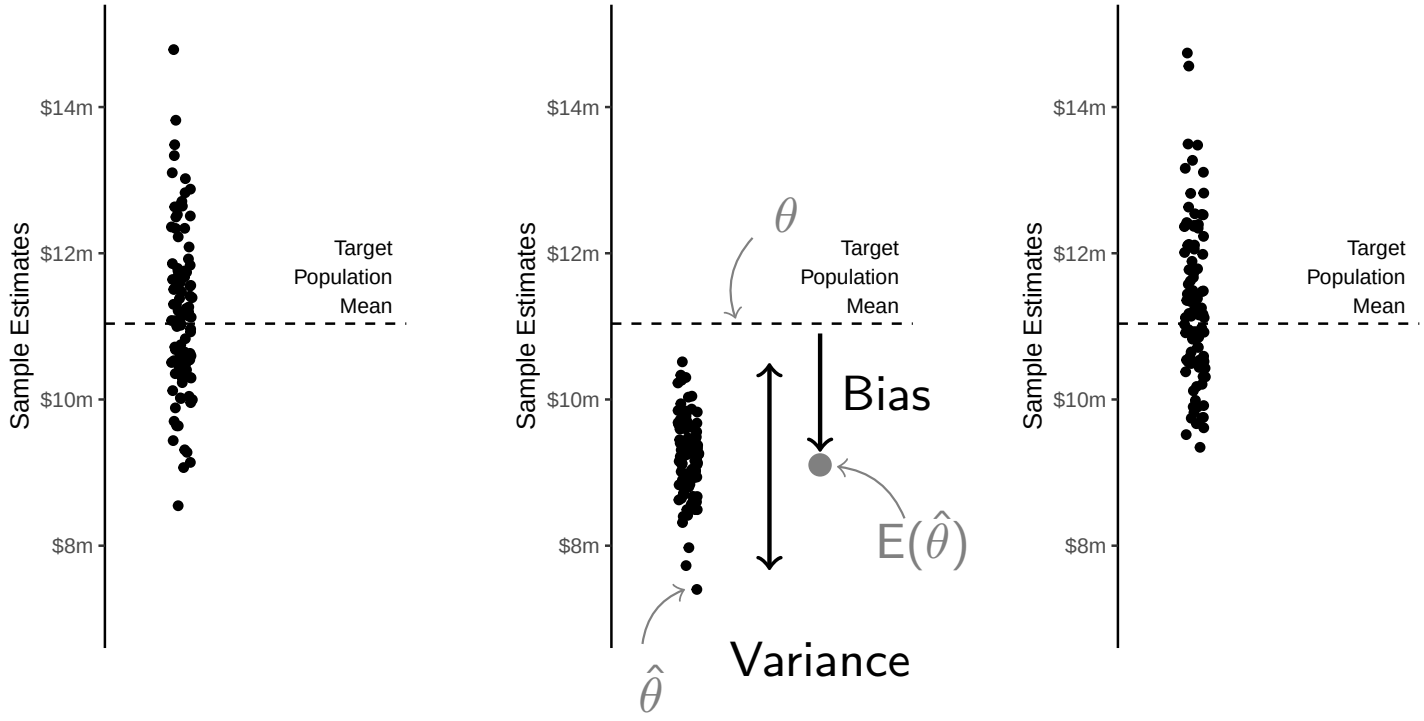
Comparing the estimators

$$\left(\hat{\theta} - \theta\right) = \left(\hat{\theta} - \mathsf{E}\left(\hat{\theta}\right)\right) + \left(\mathsf{E}\left(\hat{\theta}\right) - \theta\right)$$



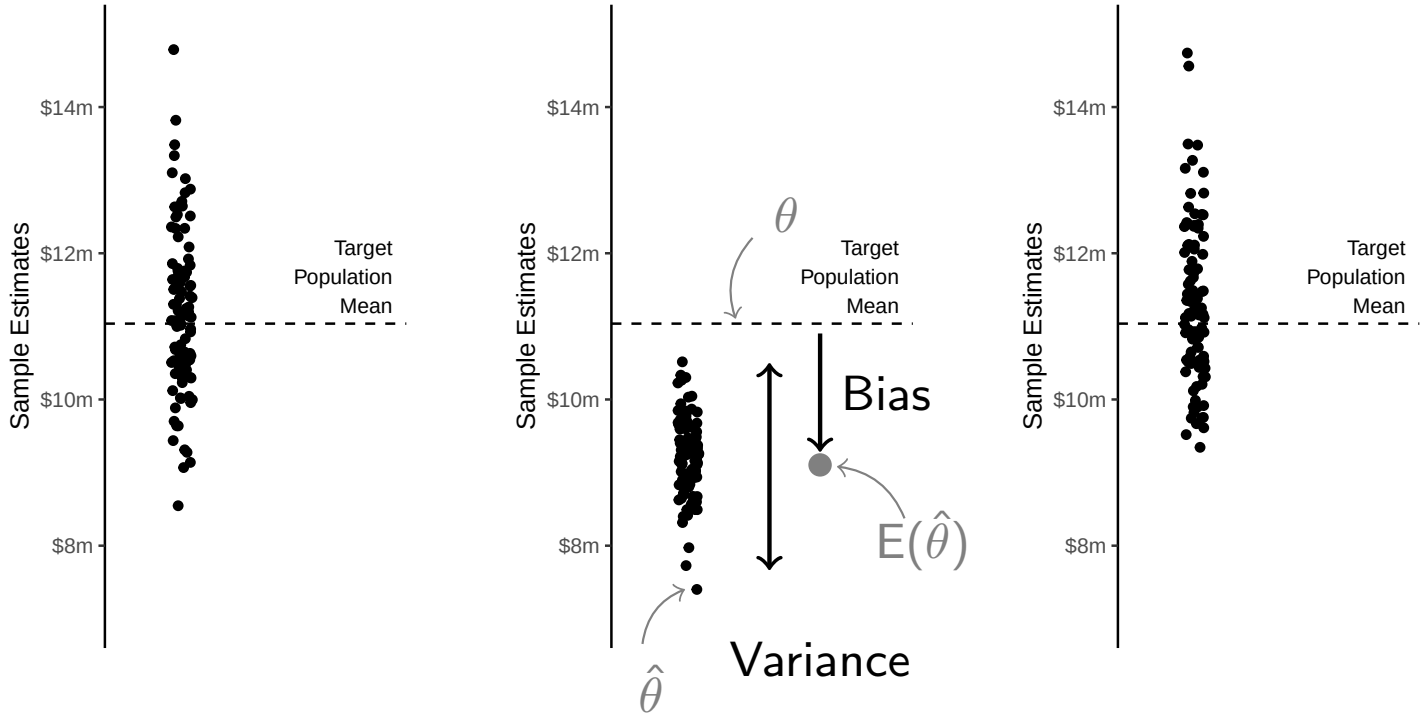
Comparing the estimators

$$\left(\hat{\theta} - \theta\right)^2 = \left(\hat{\theta} - \mathsf{E}\left(\hat{\theta}\right)\right)^2 + \left(\mathsf{E}\left(\hat{\theta}\right) - \theta\right)^2 + 2\left(\hat{\theta} - \mathsf{E}\left(\hat{\theta}\right)\right)\left(\mathsf{E}\left(\hat{\theta}\right) - \theta\right)$$



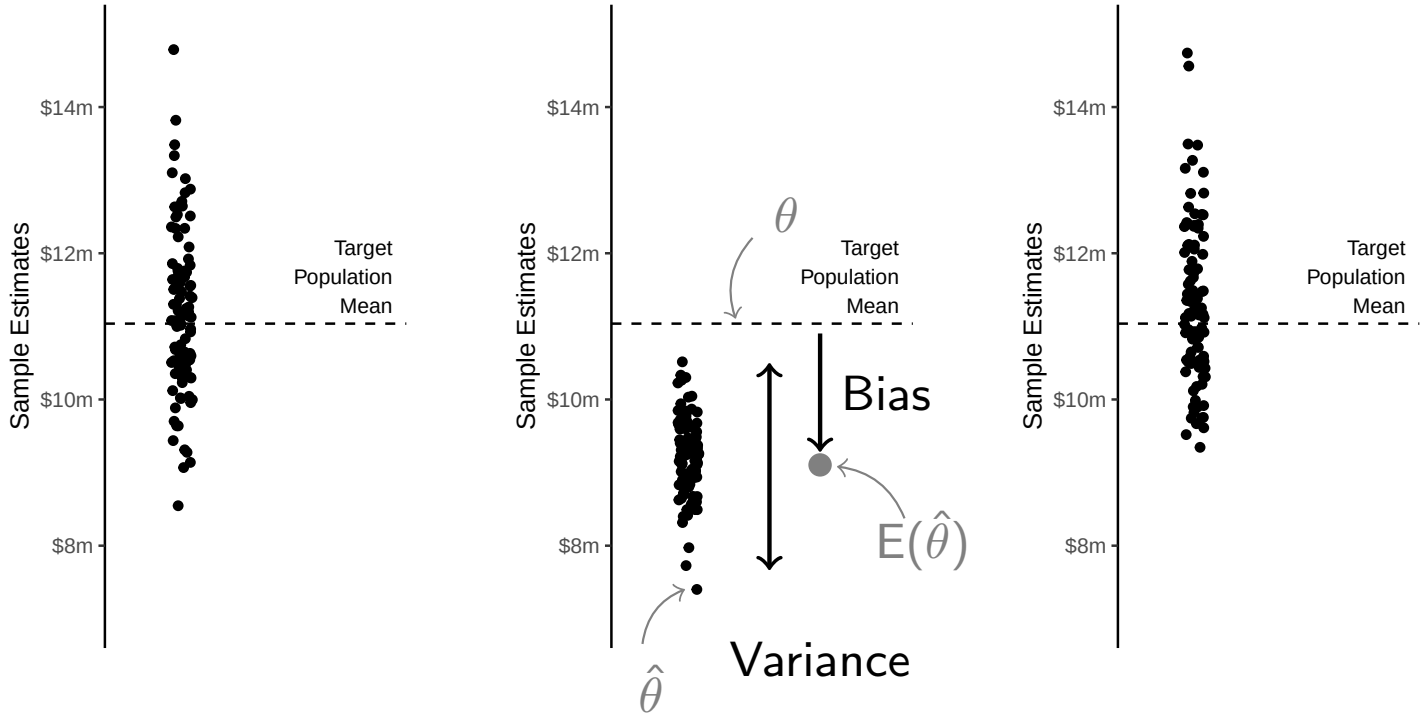
Comparing the estimators

$$\mathrm{E}\left[\left(\hat{\theta}-\theta\right)^2\right] = \mathrm{E}\left[\left(\hat{\theta}-\mathrm{E}\left(\hat{\theta}\right)\right)^2\right] + \mathrm{E}\left[\left(\mathrm{E}\left(\hat{\theta}\right)-\theta\right)^2\right] + 2\mathrm{E}\left[\left(\hat{\theta}-\mathrm{E}\left(\hat{\theta}\right)\right)\left(\mathrm{E}\left(\hat{\theta}\right)-\theta\right)\right]$$



Comparing the estimators

$$\mathrm{E}\left[\left(\hat{\theta}-\theta\right)^2\right] = \mathrm{E}\left[\left(\hat{\theta}-\mathrm{E}\left(\hat{\theta}\right)\right)^2\right] + \mathrm{E}\left[\left(\mathrm{E}\left(\hat{\theta}\right)-\theta\right)^2\right] + \cancel{2\mathrm{E}\left[\left(\hat{\theta}-\mathrm{E}\left(\hat{\theta}\right)\right)\left(\mathrm{E}\left(\hat{\theta}\right)-\theta\right)\right]} = 0$$



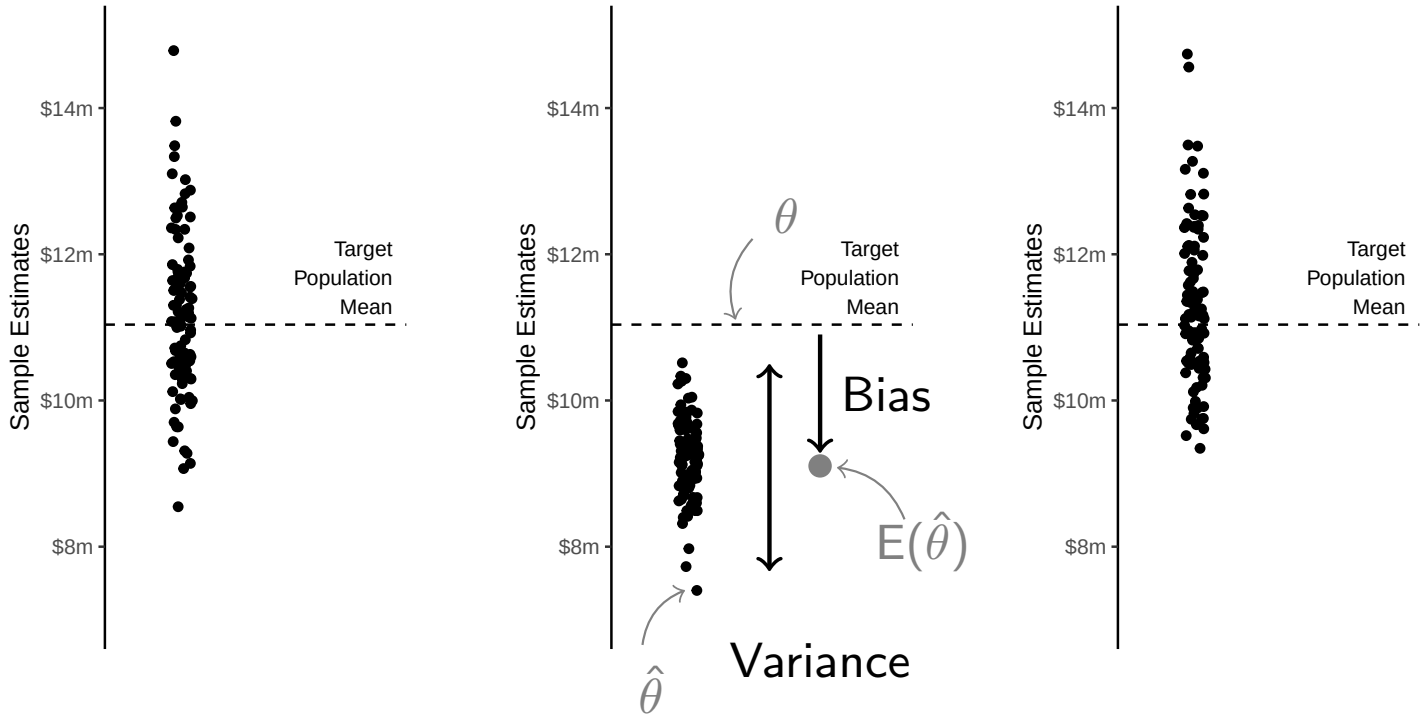
Comparing the estimators

$$\mathrm{E}\left[\left(\hat{\theta}-\theta\right)^2\right] = \mathrm{E}\left[\left(\hat{\theta}-\mathrm{E}\left(\hat{\theta}\right)\right)^2\right] + \mathrm{E}\left[\left(\mathrm{E}\left(\hat{\theta}\right)-\theta\right)^2\right]$$

Mean Squared Error

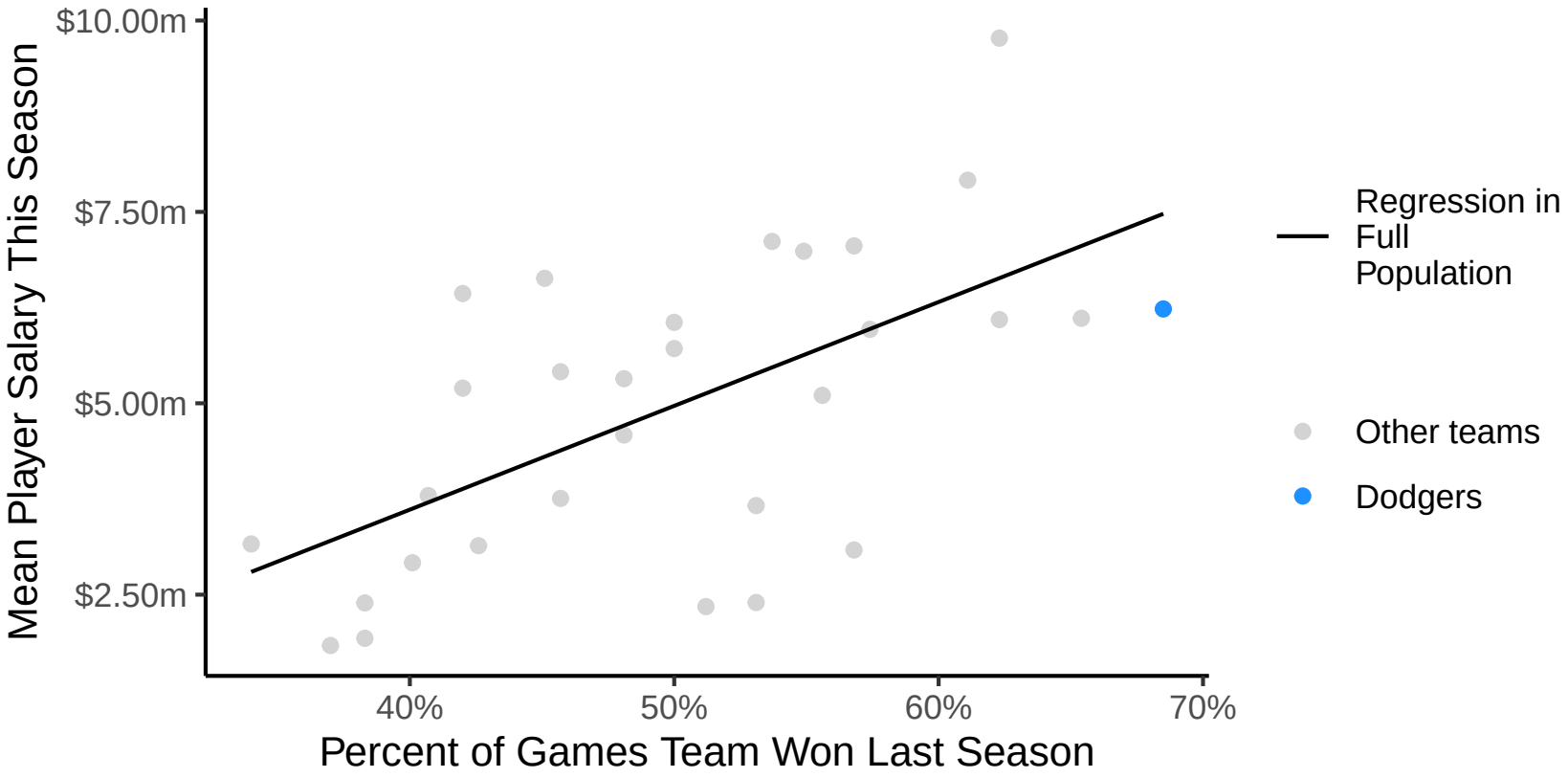
Variance

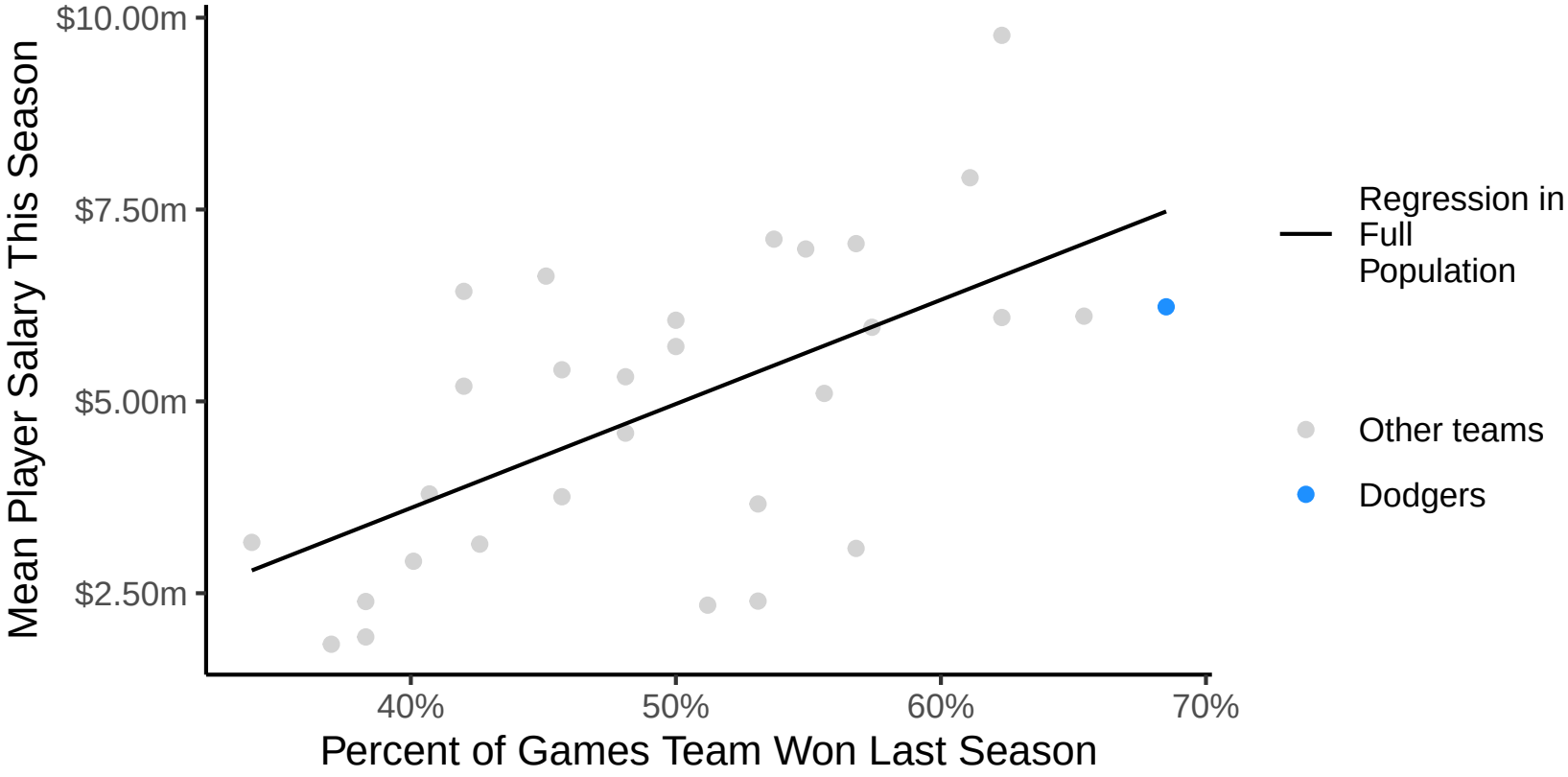
Bias^2



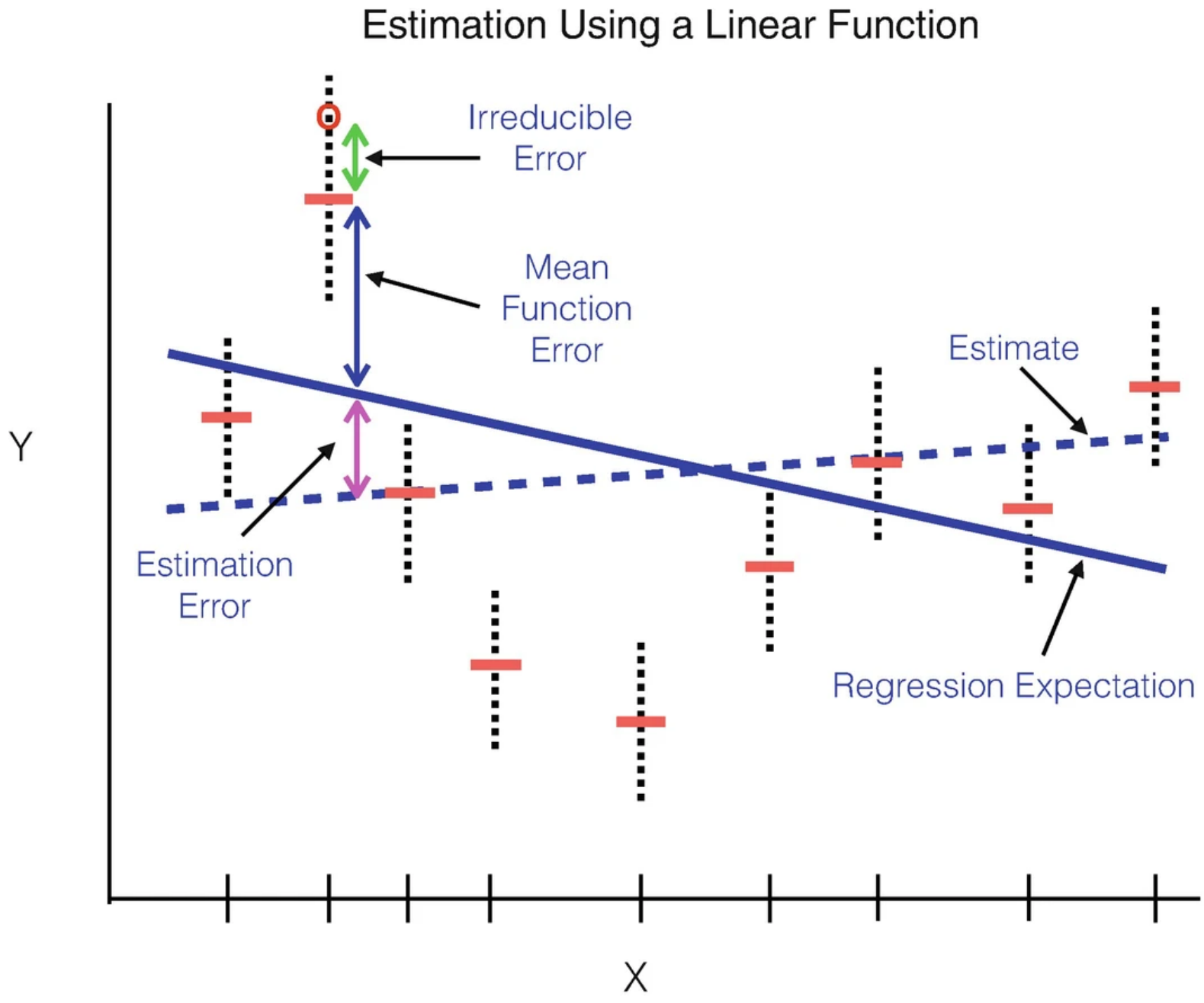
working with imperfect models

Drawing on Berk 2020.
Statistical Learning from a Regression Perspective


$10.00m
$7.50m
$5.00m
$2.50m
Mean Player Salary This Season
40%
50%
60%
70%
Percent of Games Team Won Last Season
Regression in Full Population
Other teams
Dodgers



The model is wrong. Why might we still use it?


Estimation Using a Linear Function
Irreducible Error
Mean Function Error
Estimate
Estimation Error
Regression Expectation
Y
X

Learning goals for today

By the end of class, you will be able to

- use statistical learning to estimate when data are sparse
- work with models that are "wrong"