# ANOMALY DETECTION IN THE PRODUCER PRICE INDEX

Bureau of Labor Statistics

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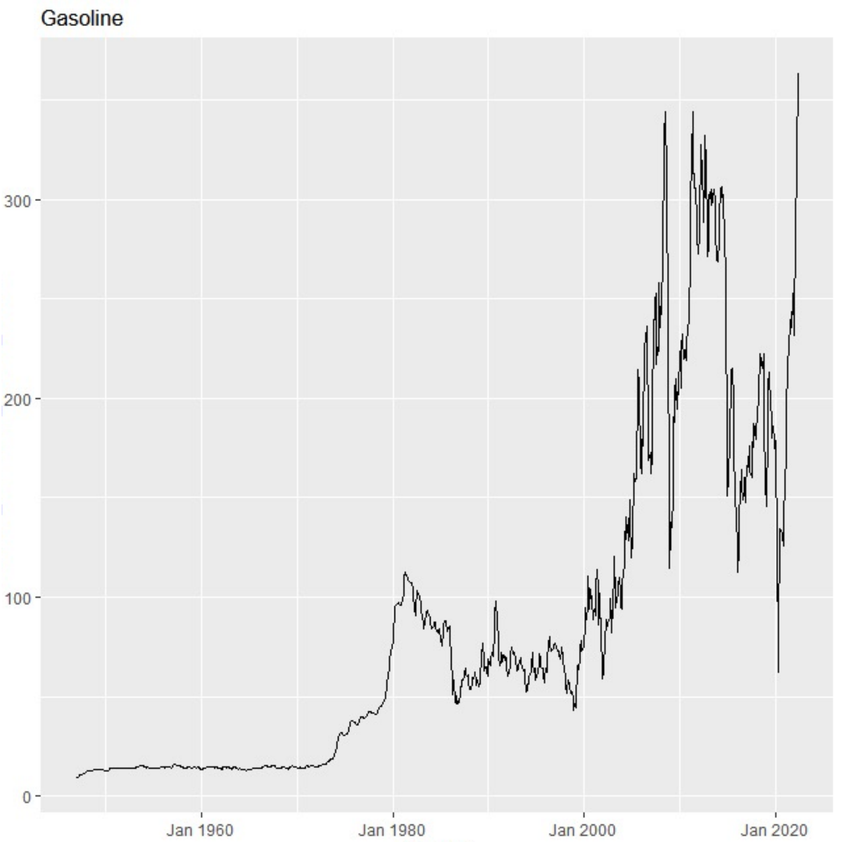
# Problem Statement

Q: How do we detect meaningful change in time series data, including the Producer Price Index (PPI)?

A: With the creation of a new system, the Differential Error Algorithm, which uses machine learning to capture underlying trends in index movement and detect which indexes are most in need of review.

# Background: PPI

- Family of indexes
- Cover wide array of industries and commodities
- Measure average change in selling prices over time
- Data are structured by month
- “Time series”



# Background: Price Notes Algorithm (PNA)

- Current system for anomaly detection
- Price note = explanation of unexpected index behavior
- Based on two variables:
    - Year-over-year change
    - Month-over-month change

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Price Note Algorithm Visualization

*red = no price note required, green = price note required

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# Project Motivation

- Is there a way to improve/supplement PNA with machine learning and other data science tools?
- PNA limitations to address:
    - Fixed
    - Narrow
    - Binary
- What change is **meaningful?**

# Project Outcome: Differential Error Algorithm

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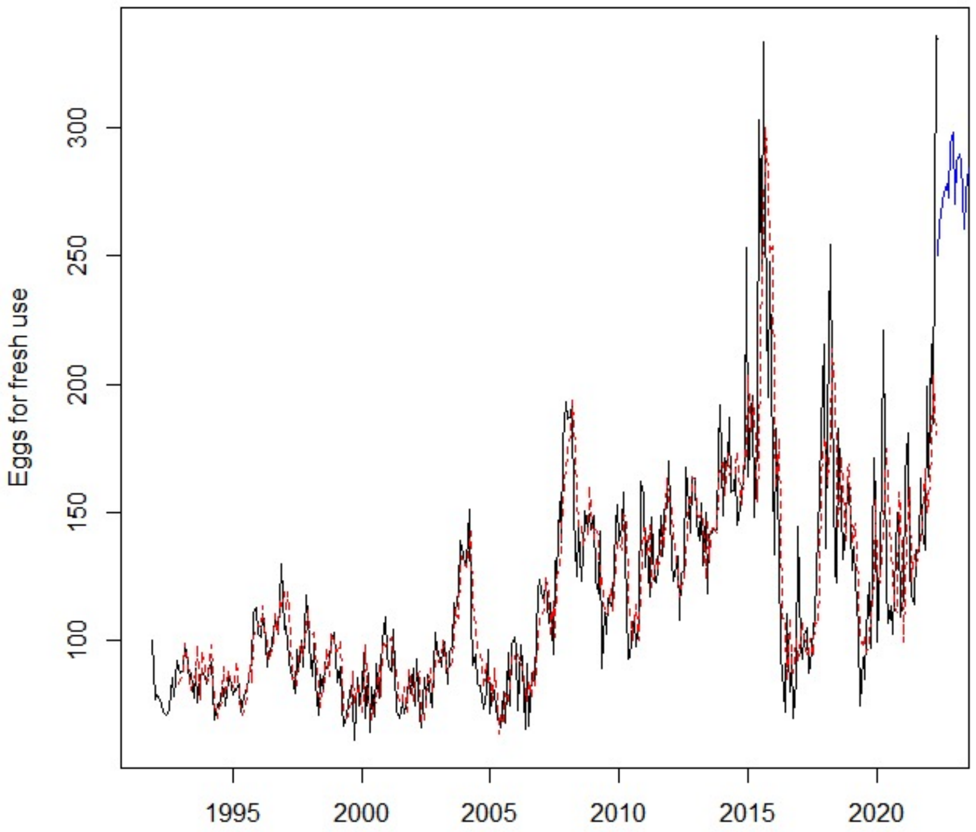
# How it works

- Use time series models to forecast “expected” index value for comparison month
- Compute error between expected index value and actual index value
- Weight according to relative importance
- Rank by “error score”
- Let’s see an example!
  - Eggs for fresh use in May 2022

# Step 1: time series models

- Train 3 models on data through April
  - Holt-Winters, ARIMA, NNETAR
- Project models by one month to forecast a value for May
- Result: 3 predictions of index value for May

# Holt-Winters

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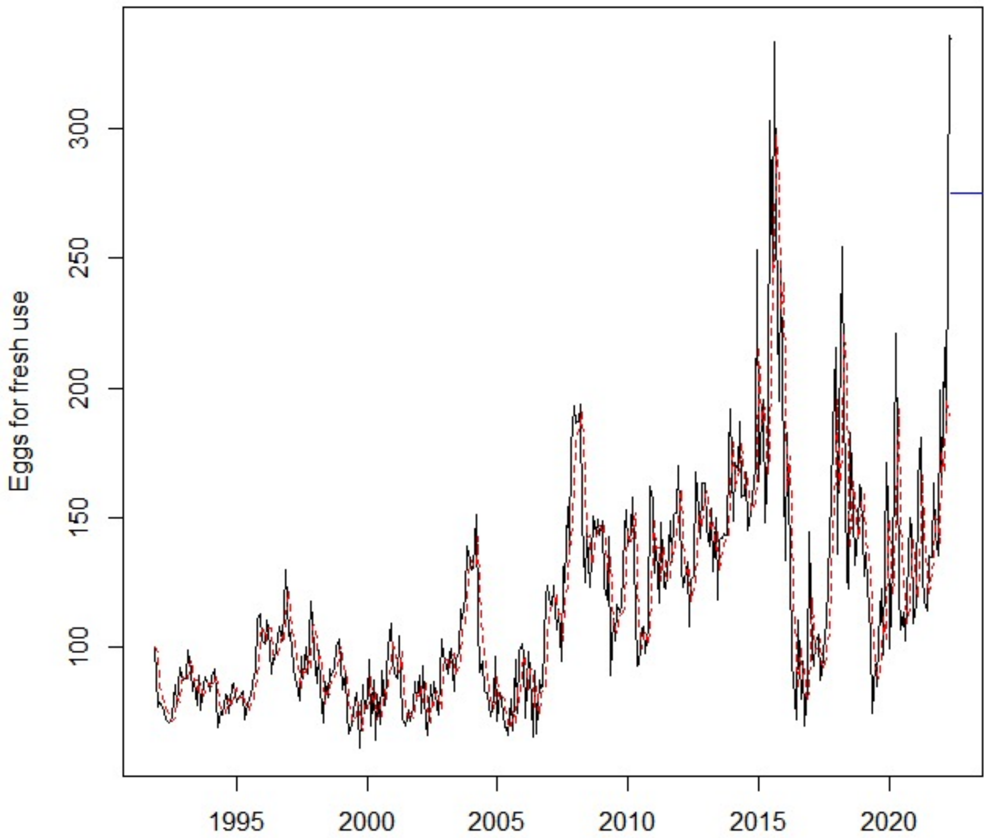
# ARIMA

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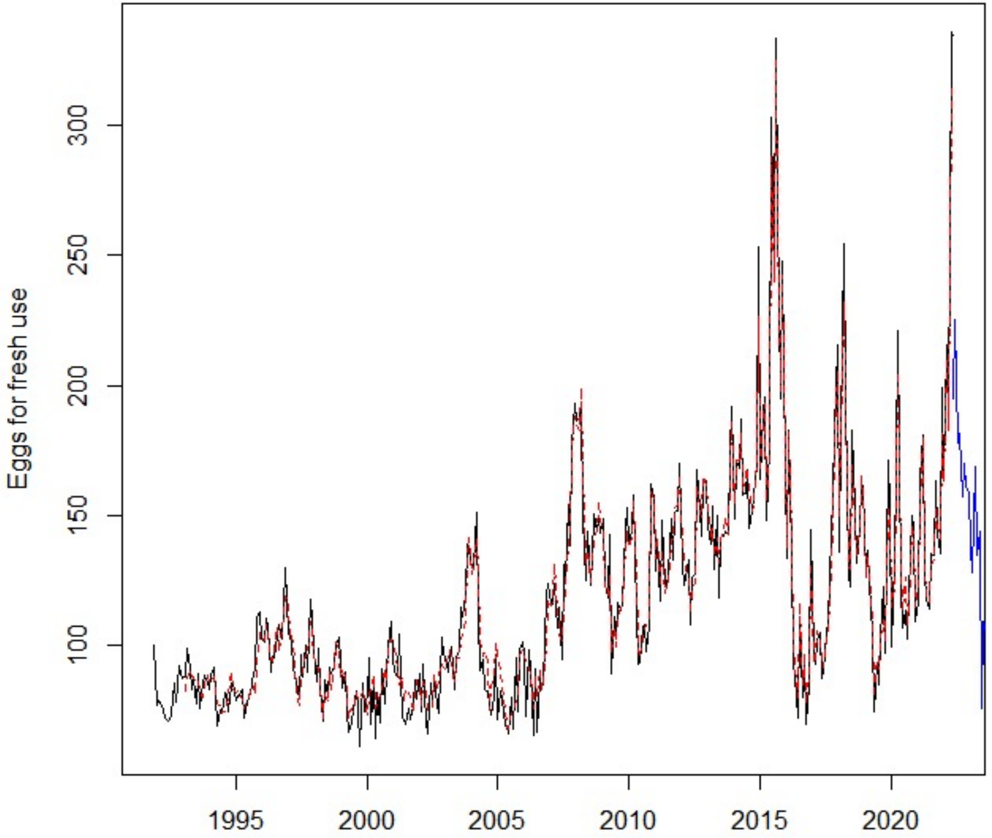
# NNETAR

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# Step 1: time series models

- Train 3 models on data through April
  - Holt-Winters, ARIMA, NNETAR
- Project models by one month to forecast a value for May
- Result: 3 predictions of index value for May
- Eggs for fresh use
  - Holt-Winters: 250.08
  - ARIMA: 274.80
  - NNETAR: 211.08

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# Step 2: weighted average

- As a form of validation, rerun models to predict the prior month, April.
- Use previous month's error to compute weight placed on each model in current month
    - Less accurate prediction in April → lower weight for May prediction
- Overall prediction is weighted average of three model predictions

# Step 2: weighted average

- Eggs for fresh use
  - Holt-Winters weight: 31.9%
  - ARIMA weight: 38.5%
  - NNETAR weight: 29.5%
- Overall prediction $= (0.319 \times 250.08) + (0.385 \times 274.80) + (0.295 \times 211.08) = 248.09$

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# Step 3: percent error

- Compute percent error between overall prediction and actual index value in current month.
- Calculated as a percent error to account for differences in sizes of indexes.
- Eggs for fresh use
  - Actual index value in May 2022 was 334.65
  - Overall prediction was 248.09
  - $\% \text{ error} = \frac{|334.65 - 248.09|}{334.65} = 25.9\%$

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# Note on accuracy

- Time series models: terrible at long-term forecasting, but surprisingly good in short-term
- Mean percent error: 2.10%
- Median percent error: 0.73%

# Step 4: relative importance

- Some indexes are more important to the economy at large than others
- Significance of each index is quantified as its “relative importance to final demand”
  - Higher relative importance value → more important index
- Calculate an index’s “error score” by multiplying its relative importance and percent error

- Eggs for fresh use
  - Relative importance = $0.069$
  - Error score = $\%\ error \times relative\ important = 25.9 \times 0.069 = 1.78$

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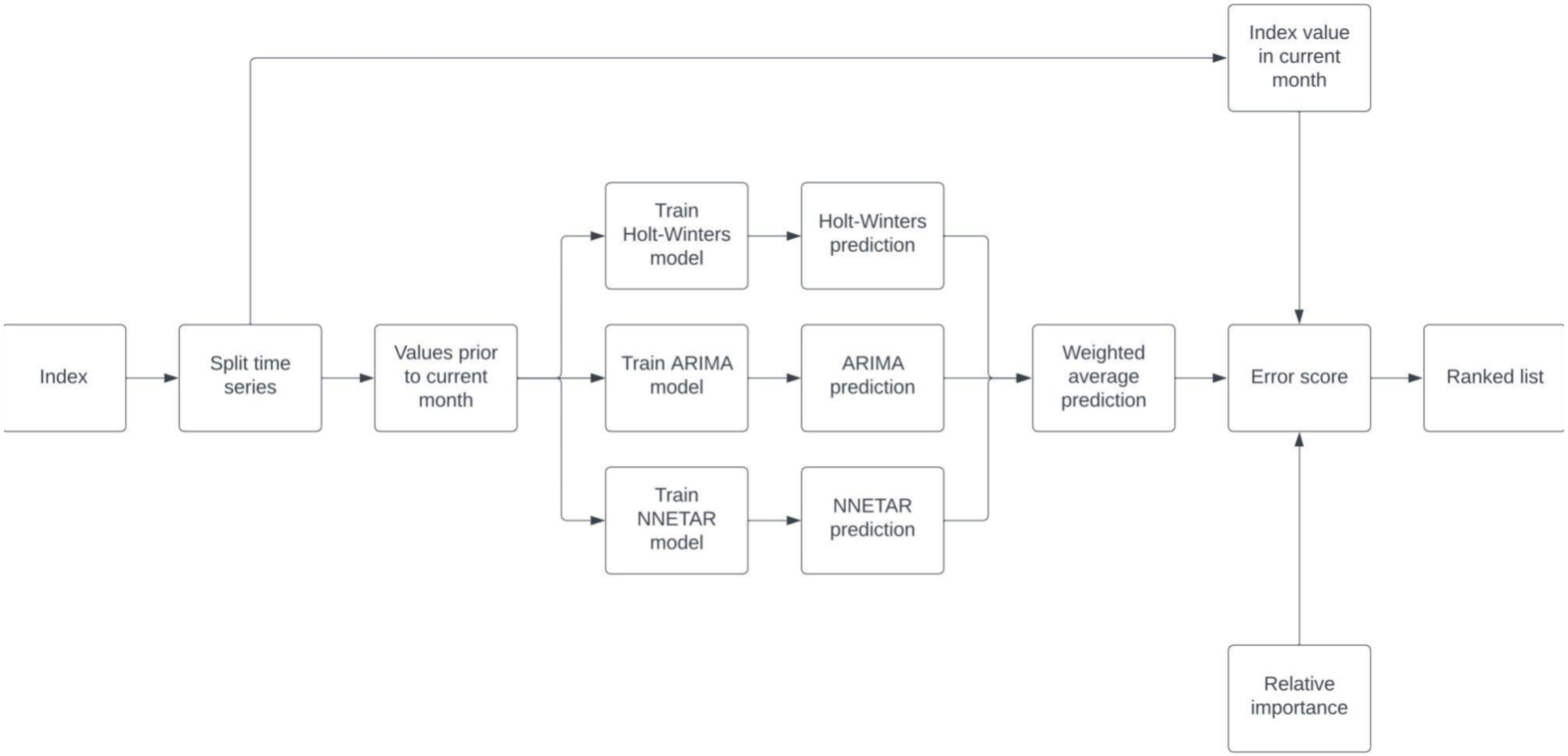
# Step 5: rank

- 374 indexes are "in scope" of Price Notes Algorithm
  - 359 are useable for Differential Error Algorithm
- Sort indexes by decreasing error score and assign a ranking
- Smaller index rank # → higher priority for a price note
- Eggs for fresh use
  - Ranked #28

# Flowchart recap



# May results

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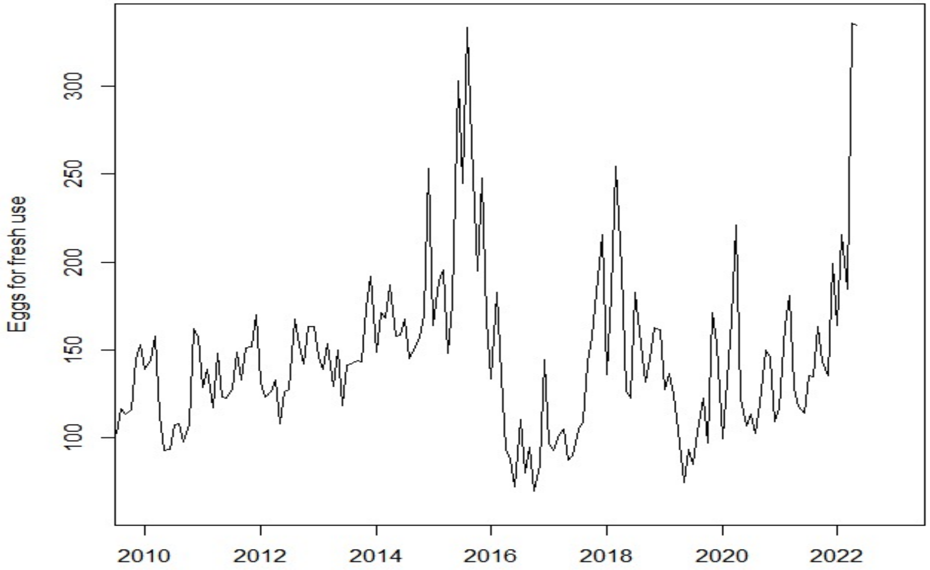
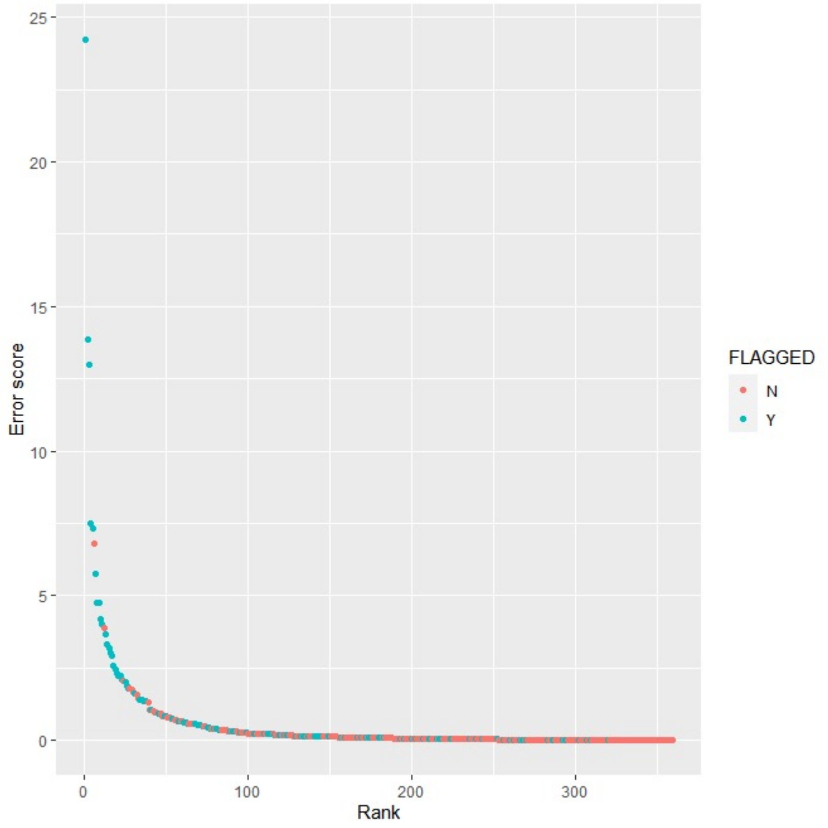
# Validation: eggs for fresh use

- Differential Error Algorithm results are difficult to validate
- However, it is catching notable cases that the Price Notes Algorithm **misses**
- Eggs for fresh use
  - Was not flagged by PNA
  - Still had a price note written



# Interpreting results

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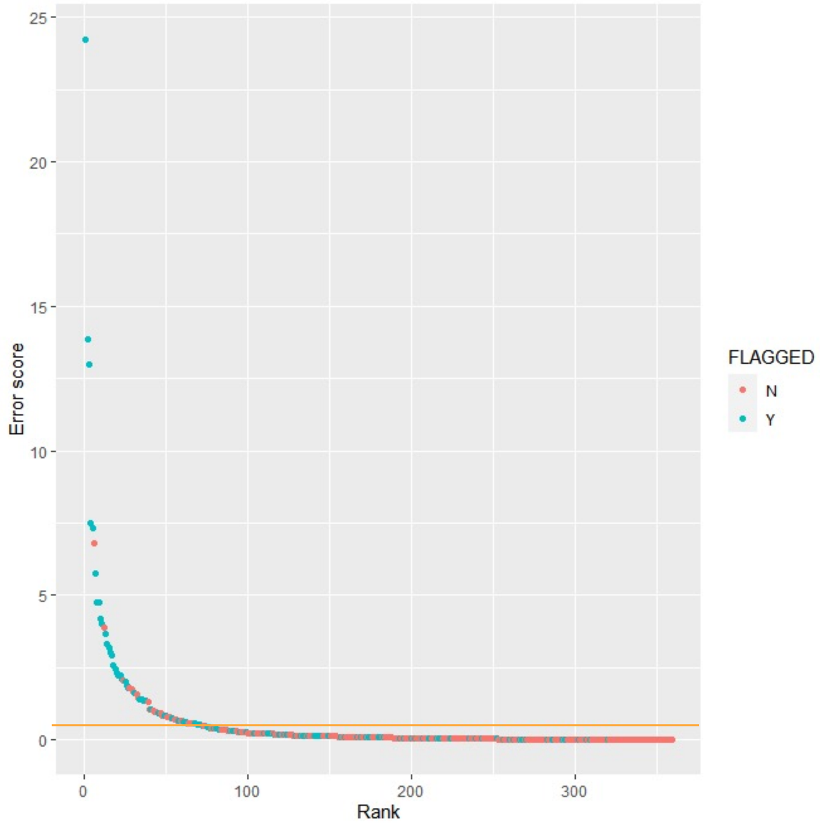
# Interpreting results: horizontal line

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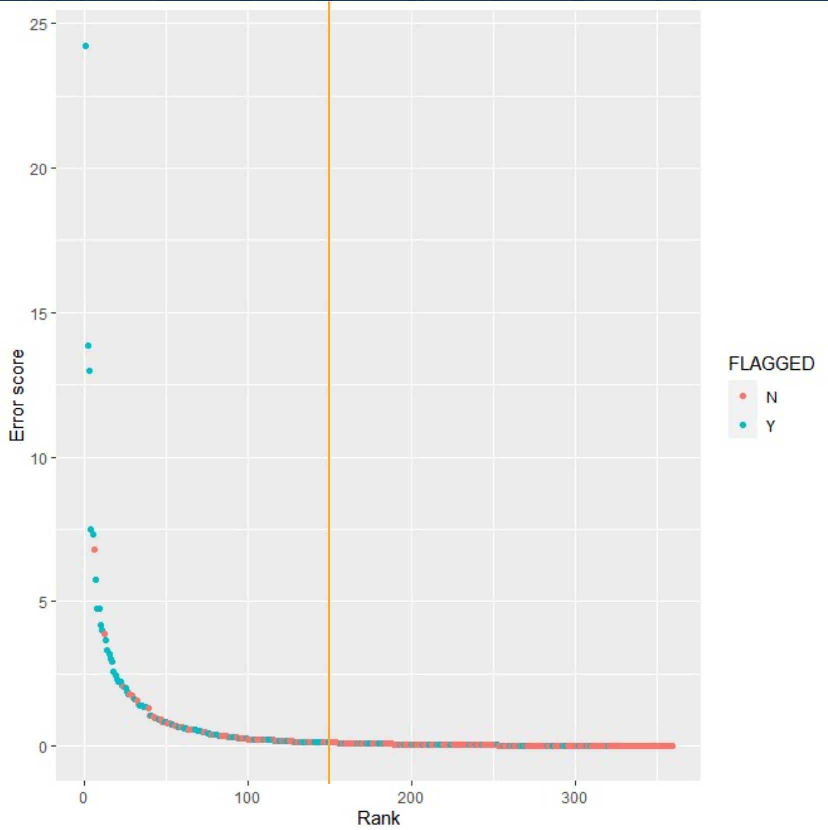
# Interpreting results: vertical line

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# Added value in practice

- Providing a ranking gives a way to more efficiently direct resources
- Catching indexes which the PNA might miss
- Automation

# Contact

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