AS.440.617.51.FA25

Unemployment in Pennsylvania (1995–2025): A Time-Series Study of Economic Trends and the Steel Industry's Role

Date | 10/02/2025 Speaker | Tracy Wang

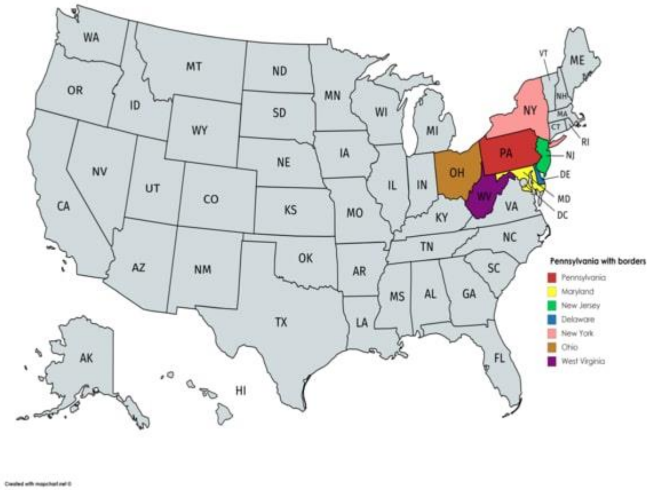
Outline

PART 01

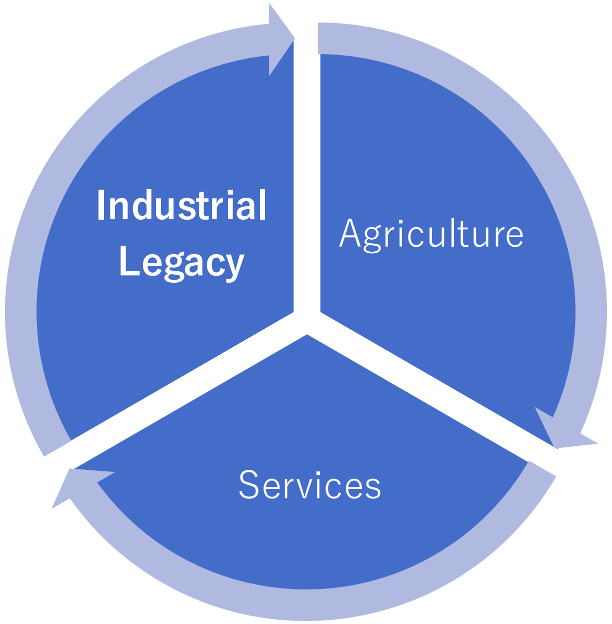
Introduction

Background research on the PA's economy

1. Makeup of different employment sectors
2. Significant events that affected the PA's labor market
3. Demographics of the state



Makeup of different employment sectors



- Pittsburgh was once the center of U.S. steel production
- Deindustrialization in the late 20th century caused large, lasting job losses
- Coal mining - anthracite in the northeast, bituminous in the west, also major historically
- Manufacturing today is ~ up to 10% of state employment, still important but smaller than before

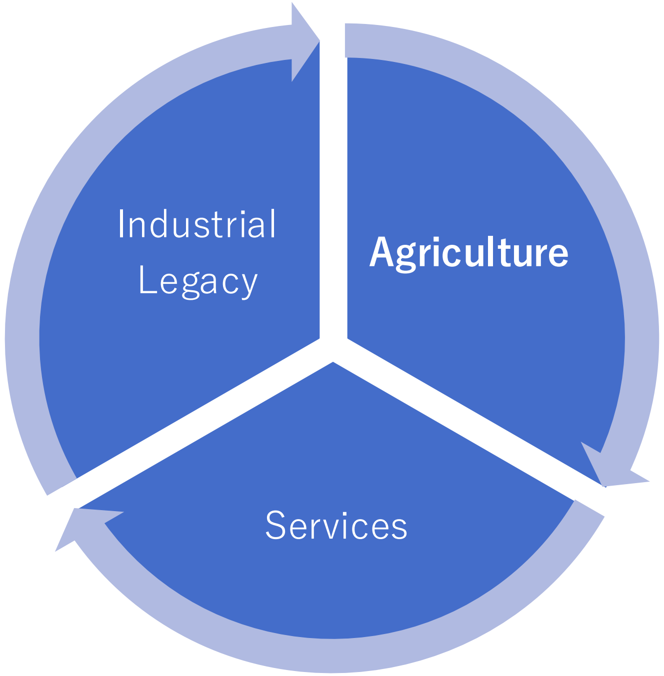
Pennsylvania Center for the Book. *Steel Industry in Pennsylvania.* Penn State University Libraries. Accessed September 29, 2025. https://pabook.libraries.psu.edu/literary-cultural-heritage/steel-industry.
Federal Reserve Bank of Philadelphia. *State Economic Overview.* Accessed September 29, 2025. https://www.philadelphiafed.org/regional-economy.
Pennsylvania Department of Agriculture. *Pennsylvania Agriculture: A Keystone of Our Economy.* Accessed September 29, 2025. https://www.agriculture.pa.gov/Pages/default.aspx

Steel City Pittsburgh

The Golden Triangle in 1930

A view above Allegheny River recently

Makeup of different employment sectors



- A smaller share compared to services and manufacturing, but an important stabilizing force
- Top five milk-producing states and is the nation's leading producer of mushrooms (Kennett Square is called the "Mushroom Capital of the World")
- The state also produces apples, corn, soybeans, and poultry.
- Agricultural employment tends to **be more stable and less cyclical**, making it an important counterbalance to the volatility of steel and manufacturing.

Pennsylvania Center for the Book. *Steel Industry in Pennsylvania.* Penn State University Libraries. Accessed September 29, 2025. https://pabook.libraries.psu.edu/literary-cultural-heritage/steel-industry.
Federal Reserve Bank of Philadelphia. *State Economic Overview.* Accessed September 29, 2025. https://www.philadelphiafed.org/regional-economy.
Pennsylvania Department of Agriculture. *Pennsylvania Agriculture: A Keystone of Our Economy.* Accessed September 29, 2025. https://www.agriculture.pa.gov/Pages/default.aspx

Pennsylvania is home to the world's mushroom capital

Over 500 million pounds of mushrooms are produced by Chester County farmers every year.

April 10, 2024 | By Rebekah Sager

In this photo taken Aug. 23, 2011, workers at Phillips Mushrooms harvest one of the beds of button mushrooms at the Kennett Township, Pennsylvania, facility. (AP Photo/Daily Local News, Tom Kelly IV)

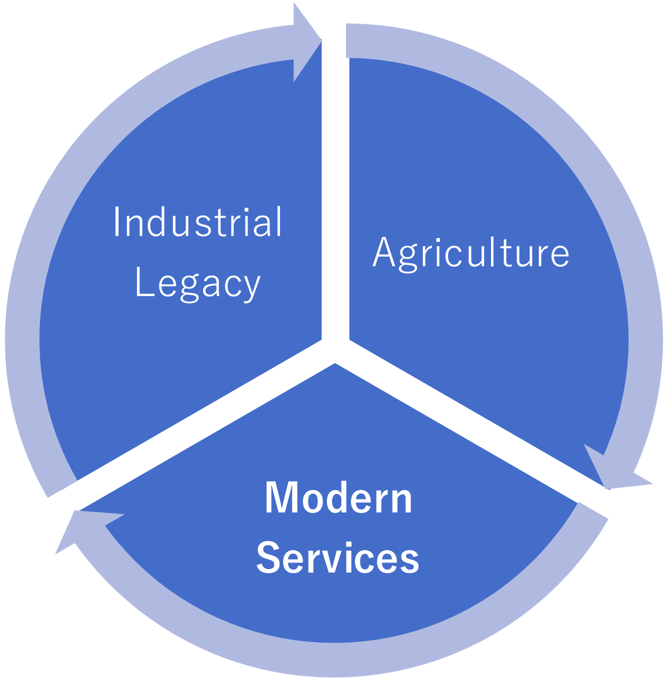
Chester's Mushroom Farm

Eco-Friendly & Sustainable Micro-Mooery

With only one dairy to operate, we can do it right! Carefully controlling diet and living accommodations keeps our pampered cows happy and healthy.

Lancaster's Milk Farm

Makeup of different employment sectors



- Healthcare and education: now the largest employers. University of Pennsylvania Health System, UPMC in Pittsburgh, Penn State University are among the state's biggest job providers.
- Finance and insurance also have a strong presence, particularly in Philadelphia.
- Technology and research sectors have grown around universities such as Carnegie Mellon (known for robotics and computer science) and Penn State.
- These jobs tend to be less cyclical than manufacturing, providing more resilience during recessions.

Pennsylvania Center for the Book. *Steel Industry in Pennsylvania.* Penn State University Libraries. Accessed September 29, 2025. https://pabook.libraries.psu.edu/literary-cultural-heritage/steel-industry.
Federal Reserve Bank of Philadelphia. *State Economic Overview.* Accessed September 29, 2025. https://www.philadelphiafed.org/regional-economy.
Pennsylvania Department of Agriculture. *Pennsylvania Agriculture: A Keystone of Our Economy.* Accessed September 29, 2025. https://www.agriculture.pa.gov/Pages/default.aspx

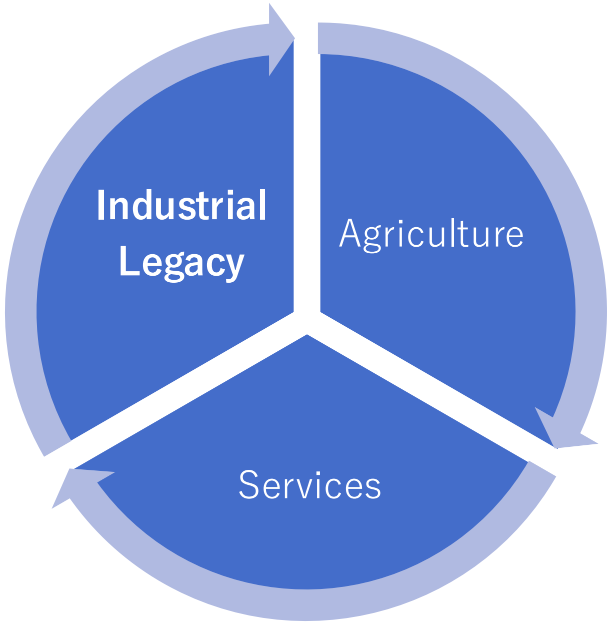
UPMC: Committed to Life Changing Medicine

Headquartered in Pittsburgh, UPMC is a world-renowned health care provider and insurer. We are an international health care leader — pioneering groundbreaking research, treatments, and clinical care. UPMC operates 40 hospitals and more than 700 doctors' offices and outpatient centers. We serve people throughout western and central Pennsylvania, Maryland, New York, and around the globe.

UPMC health care center in Pittsburgh

Penn's Medicine

Makeup of different employment sectors



- Pittsburgh was once the center of U.S. steel production
- Deindustrialization in the late 20th century caused large, lasting job losses
- Coal mining - anthracite in the northeast, bituminous in the west, also major historically
- Manufacturing today is ~ up to 10% of state employment, still important but smaller than before

Pennsylvania Center for the Book. *Steel Industry in Pennsylvania.* Penn State University Libraries. Accessed September 29, 2025. https://pabook.libraries.psu.edu/literary-cultural-heritage/steel-industry.
Federal Reserve Bank of Philadelphia. *State Economic Overview.* Accessed September 29, 2025. https://www.philadelphiafed.org/regional-economy.
Pennsylvania Department of Agriculture. *Pennsylvania Agriculture: A Keystone of Our Economy.* Accessed September 29, 2025. https://www.agriculture.pa.gov/Pages/default.aspx

PA's Top 3 Industries by Real GDP: 1995 vs. 2025

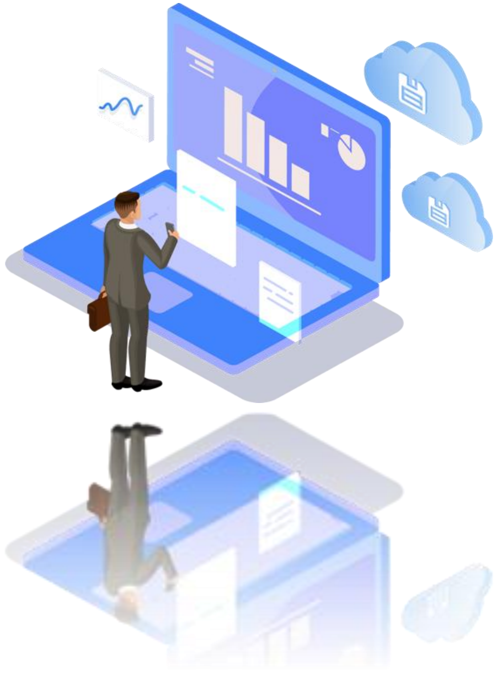
Rank	Industry Sector (1995 Est.)	Est. Real GDP (1995) (Chained 2017 $ Billions)	Industry Sector (2025 Est.)	Real GDP (2024 Est.) (Chained 2017 $ Billions)
1	**Manufacturing**	$\approx 95 - 110$	**Real Estate and Rental and Leasing**	**$103.2**
2	**Finance, Insurance, Real Estate (FIRE)**	$\approx 85 - 95$	**Educational Services, Health Care, & Social Assistance**	**$106.5**
3	**Retail Trade/Services**	$\approx 75 - 85$	**Professional & Business Services**	**$131.3**

Pennsylvania Center for the Book. *Steel Industry in Pennsylvania.* Penn State University Libraries. Accessed September 29, 2025. https://pabook.libraries.psu.edu/literary-cultural-heritage/steel-industry.
Federal Reserve Bank of Philadelphia. *State Economic Overview.* Accessed September 29, 2025. https://www.philadelphiafed.org/regional-economy.
Pennsylvania Department of Agriculture. *Pennsylvania Agriculture: A Keystone of Our Economy.* Accessed September 29, 2025. https://www.agriculture.pa.gov/Pages/default.aspx

Significant events & Demographics

Deindustrialization
higher baseline unemployment in the late 1990s–2000s

Urban vs. Rural
Industrial counties recover slowly; service-based cities bounce back faster



2008 Crisis
A large shock: a spike in later data

Aging Population
Fewer workers re-entering labor force; slower declines in unemployment after shocks

2020 COVID19
A sharp, short-term surge (nearly 16%)

Education hubs
Tech and research jobs create resilience: why long-term trend isn't purely upward

- Events: why the data is non-stationary and why differencing/ARIMA is appropriate.
- Demographic factors: why Pennsylvania's unemployment does not just follow the U.S. average one-to-one and worthy of research on a state basis.

PART 02

Data

Explain data information

1. Data source
2. Data type with reason for the choice

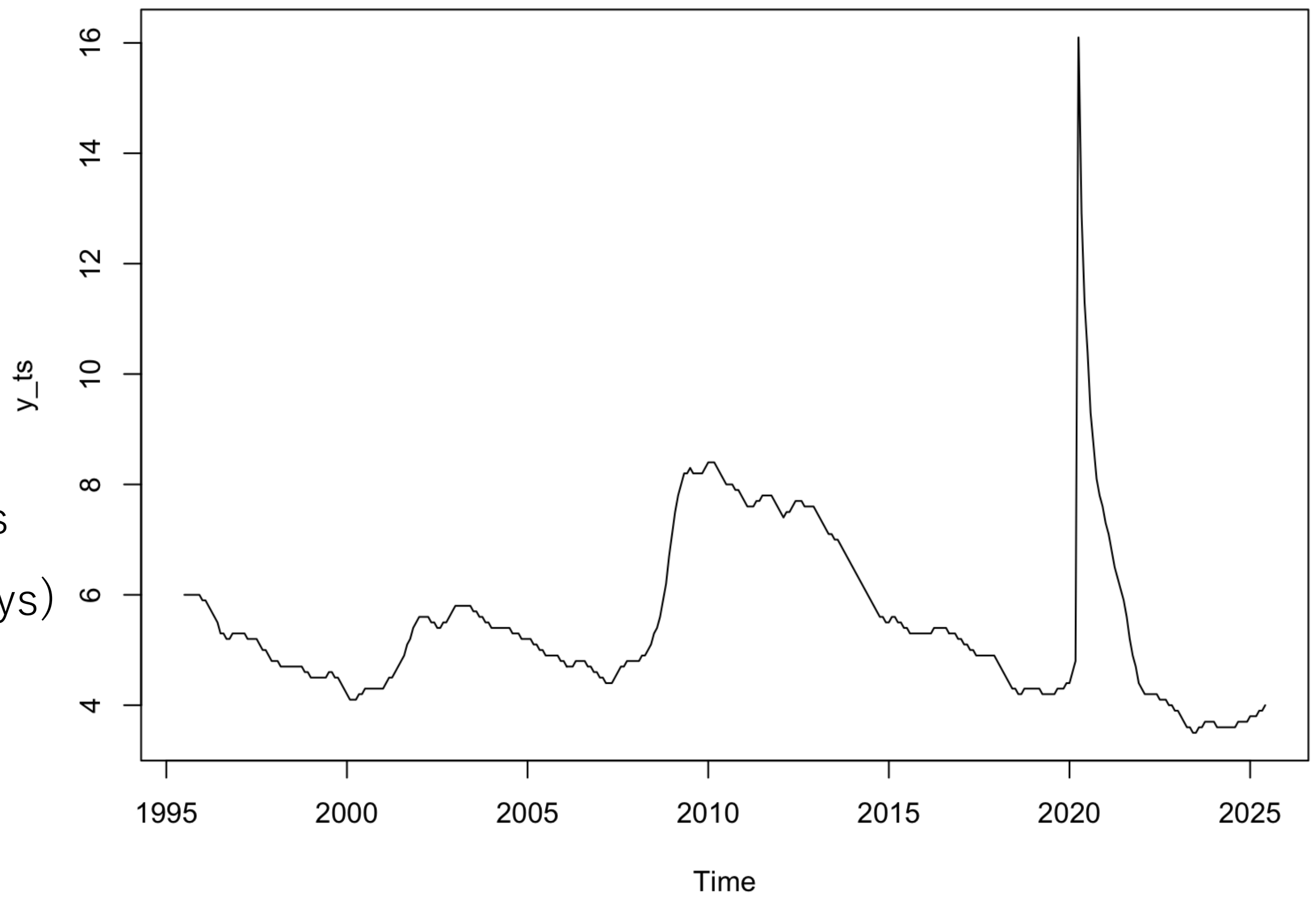
Seasonally-Adjusted Unemployment Rate in Pennsylvania (1995–2025)

Data information

- Federal Reserve Bank of St. Louis (FRED)
- PAUR for Pennsylvania
- July 1995 to June 2025

Why use SA not NSA?

- Highlights steel decline and recession cycles
- Removes seasonal noise (agriculture, holidays)
- Clearer view of true economic shocks
- Cleaner input for accurate ARIMA forecasts



PART 03

Methods

Different types of analysis performed

1. Application in R studio framework
2. Methods Flow with the results

Methodological Framework

Box-Jenkins 1

Identification

- Exploratory Analysis - Seasonal STL
- Stationarity Testing - ADF&KPSS
- Determine (p, d, q)

Box-Jenkins 2

Estimation

- Fit ARIMA models using orders
- Compare by information criteria (AICc/BIC)
- Select a final model

Box-Jenkins 3

Diagnostics

- Residual Analysis
- Ljung–Box test

Forecasting

ARIMA Forecasting-Post Box–Jenkins

- Forecasts & Prediction Intervals
- Holdout Backtesting

STL decomposition

T_t: long-run movement

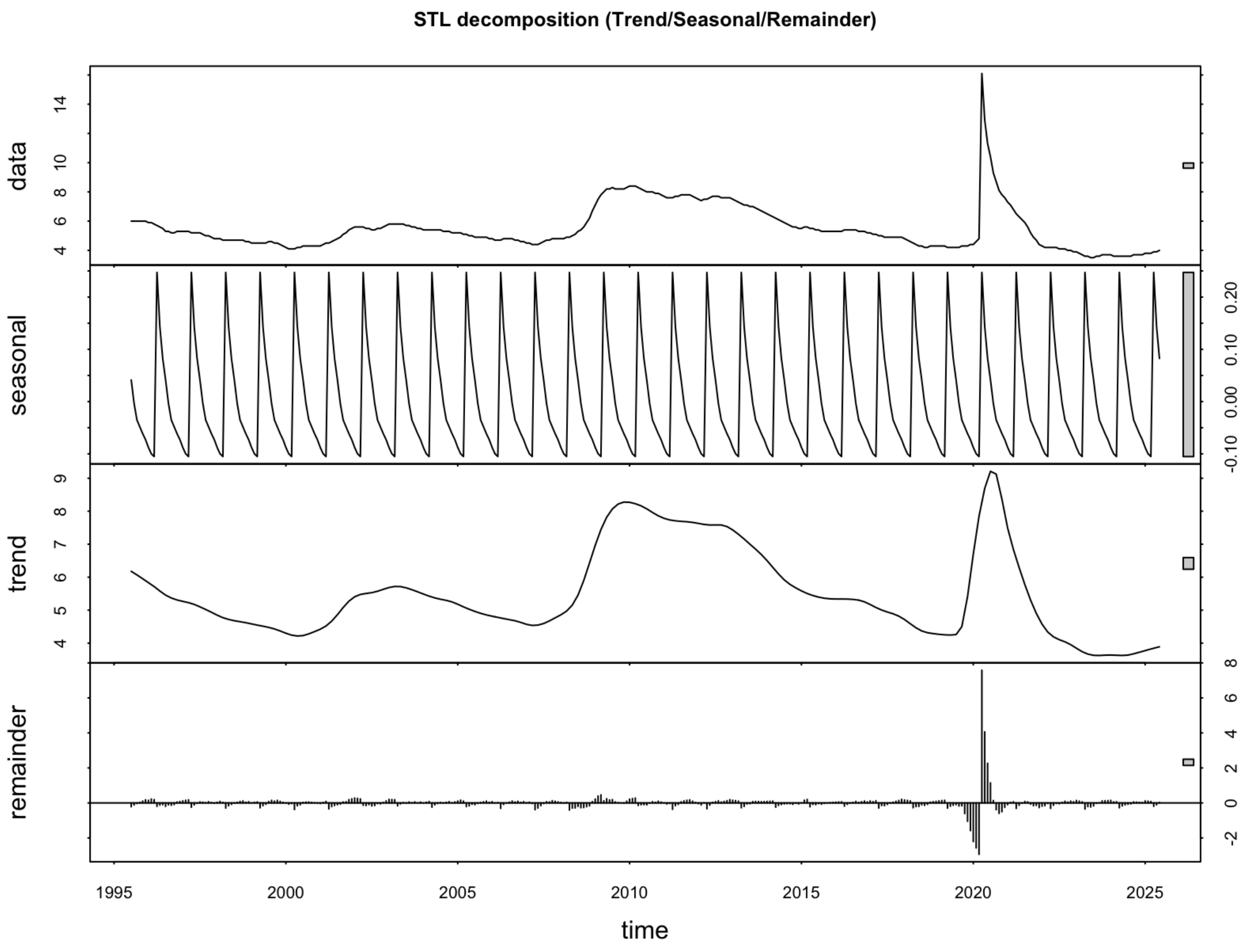
- steel decline in PA

S_t: negligible in SA data

- very small (±0.2)
- no seasonal differencing

R_t: irregular shocks

- 2008 crisis
- COVID-19



Stationarity Testing - ADF&KPSS

- KPSS:
  KPSS Level = 0.5119, Truncation lag parameter = 5, p-value = 0.03899

- ADF:
  Dickey-Fuller = -2.7191, Lag order = 7, p-value = 0.2734; alternative hypothesis: stationary

Non-stationary

- KPSS test
  - rejects the null hypothesis of level stationarity
  - Indicating: presence of a unit root

- ADF test
  - fails to reject the null hypothesis of non-stationarity
- Include difference

Differencing (d=1) applied to achieve stationarity

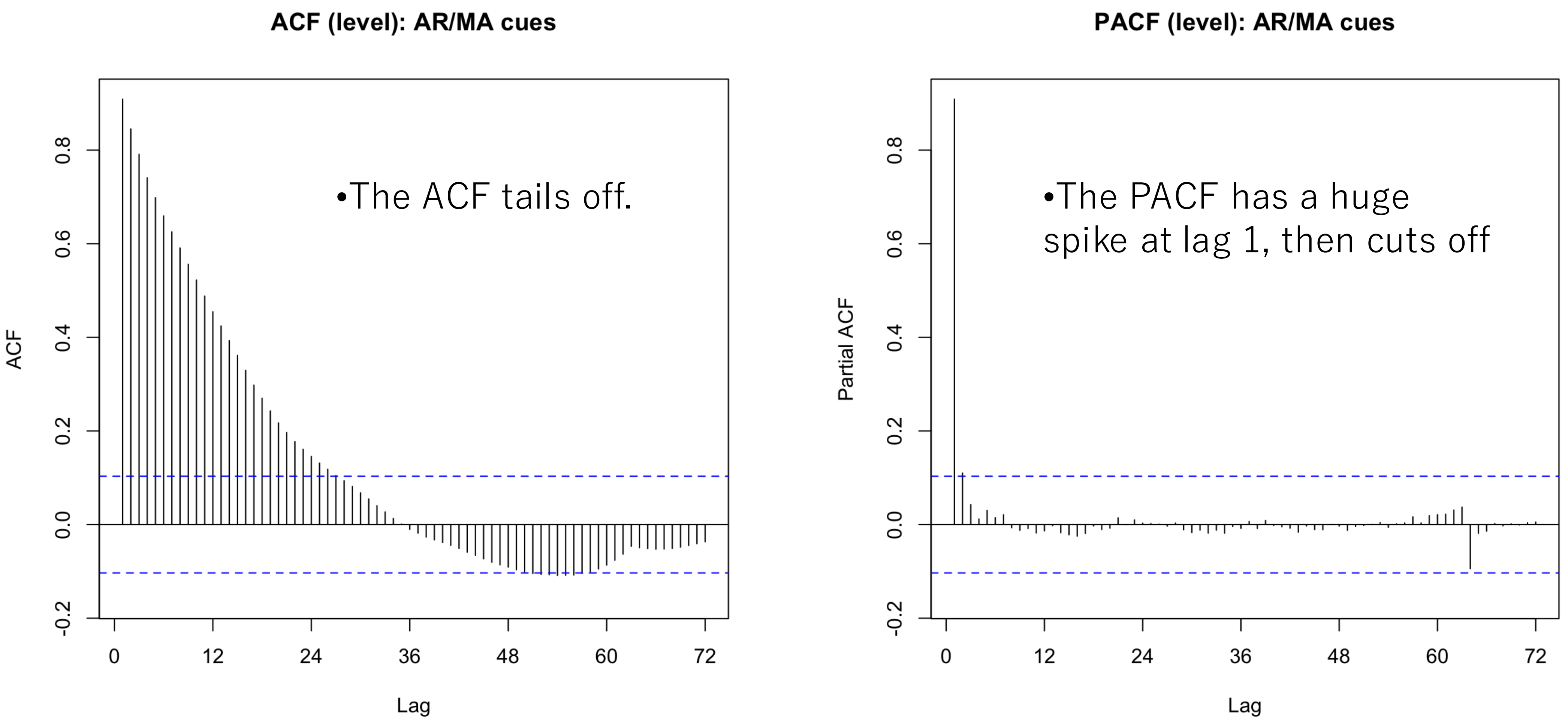
- KPSS:
  KPSS Level = 0.031539, Truncation lag parameter = 5, p-value = 0.1

- ADF:
  Dickey-Fuller = -7.6778, Lag order = 7, p-value = 0.01; alternative hypothesis: stationary

Stationarity with d=1

- Recheck stationary tests with d = 1
- Becomes stationary
- This confirms that ARIMA with d=1 is an appropriate model choice

MA/AR cues from ACF/PACF plots



ACF/PACF plots used to identify AR vs. MA terms

This is consistent with AR(1)-type behavior (PACF cutoff at lag 1, ACF tailing off).

Choose ARIMA value based on ACF/PACF

- **Nonseasonal ARIMA** (SA data → P=Q=D=0)
- **Stationarity**: 1 regular difference → d=1
- **Focus on AR** → fix q=0
- **Candidate orders**: p=0–3 (PACF suggests low lags)
- **Final class**: ARIMA(p,1,0)
- **Goal**: parsimonious, interpretable, avoids overfitting

Identification summary

- Period m = 12 | D = 0 | d = 1
- Use ACF/PACF of w_t to bound:
- **Nonseasonal: p in {0,1,2,3}, q in {0,1,2,3}**
- Seasonal: P in {0,1,2}, Q in {0,1,2}
- Proceed to ESTIMATION with a small grid using these bounds.

```
List of 9
 $ frequency   : num 12
 $ d: num 1
 $ D: num 0
 $ w_ts: Time-Series [1:359] from
1996 to 2025: 0 0 0 0 0 ...
 $ y_seas: Time-Series [1:360]
from 1996 to 2025: 6 6 6 6 6 6 5.9
5.9 5.8 5.7 ...
 $ p_candidates: int [1:4] 0 1 2 3
 $ q_candidates: num 0
 $ P_candidates: num 0
 $ Q_candidates: num 0
```

Model Selection by AICc

Table of top candidates (p,d,q)

idx	p	d	q	P	D	Q	m	AICc	BIC
3	3	2	1	0	0	0	12	695.2163	710.6366
2	2	1	1	0	0	0	12	695.3782	706.9605
4	4	3	1	0	0	0	12	696.5329	715.7795
1	1	0	1	0	0	0	12	701.9637	709.6967

Chosen model (AICc)

idx	p	d	q	P	D	Q	m	AICc	BIC
3	3	2	1	0	0	0	12	695.2163	710.6366

ARIMA(2,1,0) with drift gave the lowest **AICc (695.22).**

Reasons choosing AICc:

1. N = 360 , medium size
2. AICc is the most common criterion for ARIMA selection in practice
3. AICc balances fit and complexity, reducing overfitting but still capturing necessary dynamics.

Parameter Estimation

Coefficient table (ar1, ar2, drift) with t-stats / p-values

<table>
<tr><th></th><th>Estimate</th><th>Std.Error</th><th>t</th><th>Pr(>|t|)</th></tr>
<tr><td>ar1</td><td>-0.1659</td><td>0.0526</td><td>-3.1562</td><td>0.0017</td></tr>
<tr><td>ar2</td><td>-0.0781</td><td>0.0525</td><td>-1.4880</td><td>0.1376</td></tr>
<tr><td>drift</td><td>-0.0056</td><td>0.0267</td><td>-0.2106</td><td>0.8333</td></tr>
</table>

Results shows that

- AR1 significant ($p \approx 0.0017$) → confirms short-run persistence.
- AR2 marginal ($p \approx 0.138$) → weaker second-lag effect.
- drift not significant ($p \approx 0.83$) → no long-run deterministic trend.

Model Summary

Series: y_ts
ARIMA(2,1,0) with drift

Coefficients:

	ar1	ar2	drift
	-0.1659	-0.0781	-0.0056
s.e.	0.0526	0.0525	0.0267

sigma^2 = 0.4003: log likelihood = -343.55

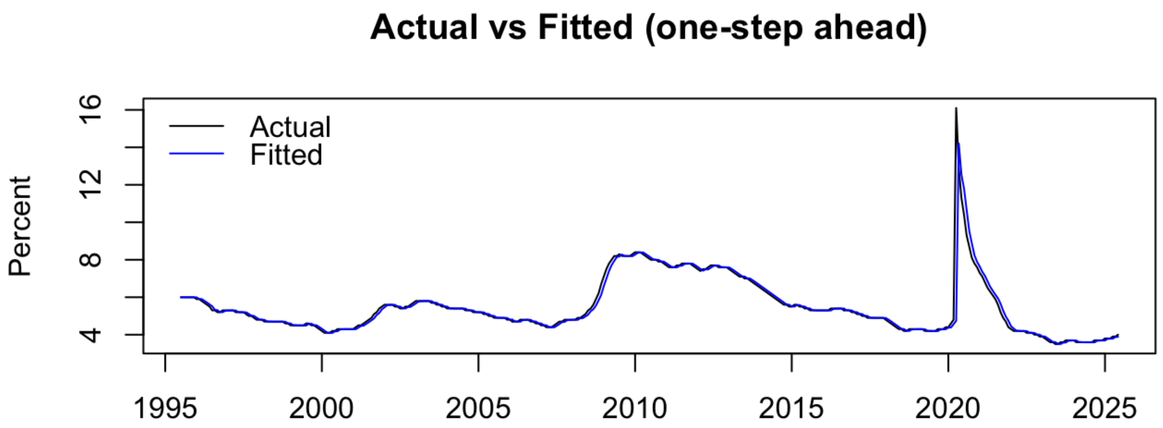
Information criteria for the chosen model
AIC=695.1 AICc=695.22 BIC=710.64

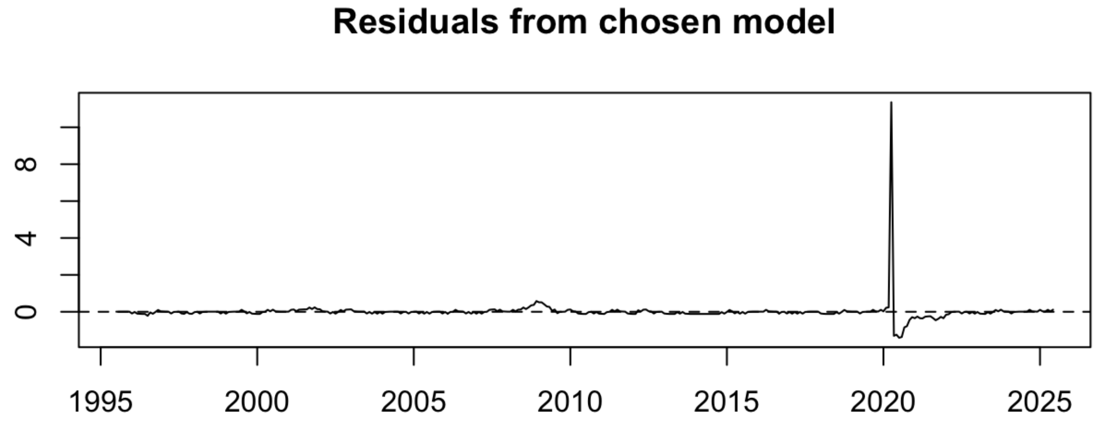
- AR(2) terms: weak negative autocorrelation at 1–2 lags
- Drift term: slight long-run downward trend in unemployment changes.
- σ^2=0.40 is small: model explains most variation.
- AIC and BIC are reasonably close: the model is relatively parsimonious.

Model Fitting: In-sample Accuracy

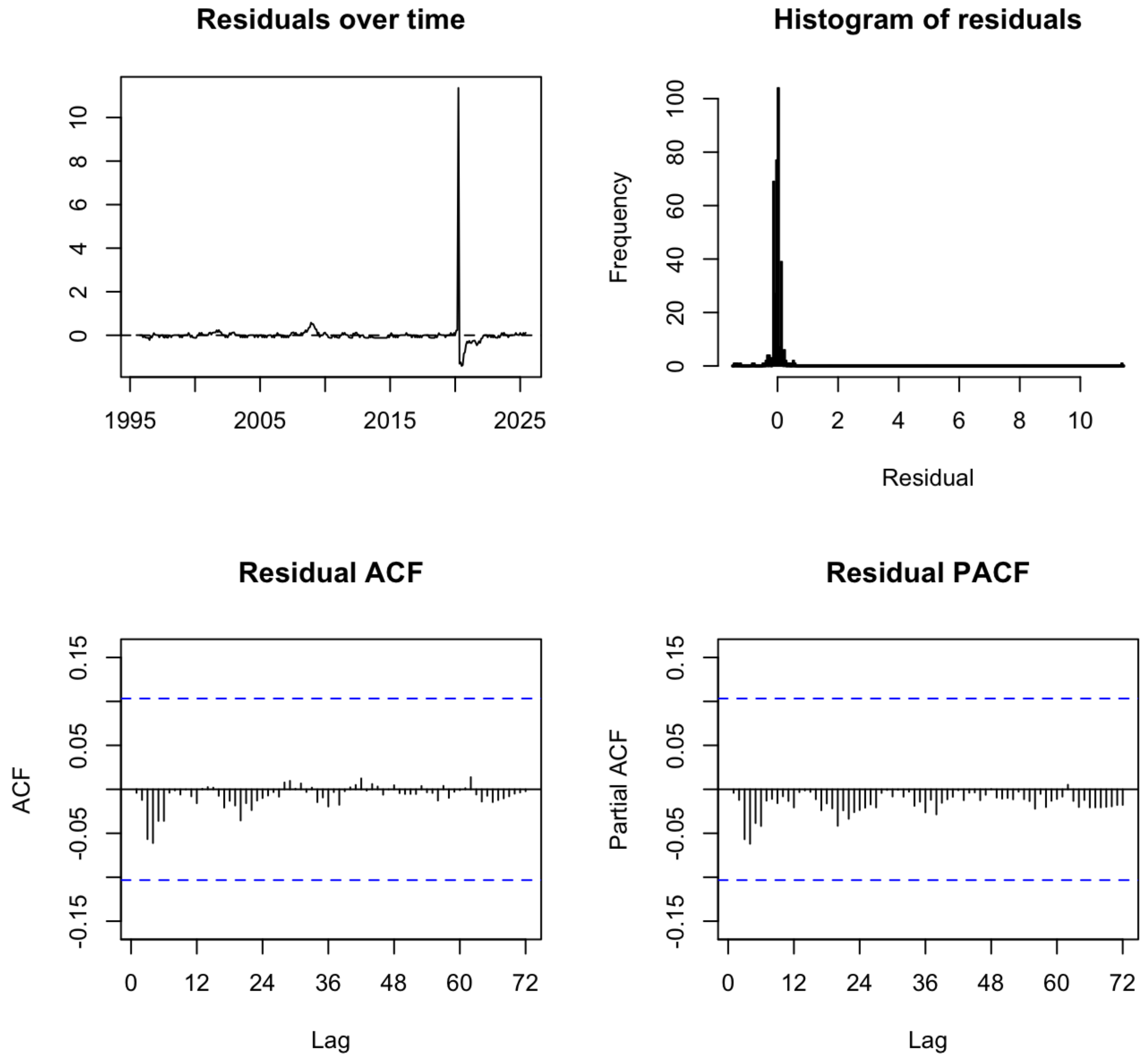
RMSE = 0.6291, MAE = 0.1257, MAPE = 1.75%

- MAE (0.1257) and MAPE (1.75%) are very small: the model is highly accurate on average.
- RMSE (0.6291) is significantly larger than the MAE:
  - Presence of a few large errors or outliers(the 2020 COVID-19 spike)
  - Remainder component
- Adequate forecasting model:
  - Fitted closely catch up with actual data
  - Residuals resembles white noise





Residuals Analysis



- Residuals fluctuate around zero with no long-term trend, aside from a spike during COVID
- Histogram shows most residuals are tightly clustered near zero, consistent with white noise.
- Residual ACF: no significant autocorrelations beyond the 95% confidence bounds.
- Residual PACF: no clear pattern, supporting model adequacy.
- Overall, ARIMA captures the main unemployment dynamics; residuals behave like white noise.

Ljung–Box Tests

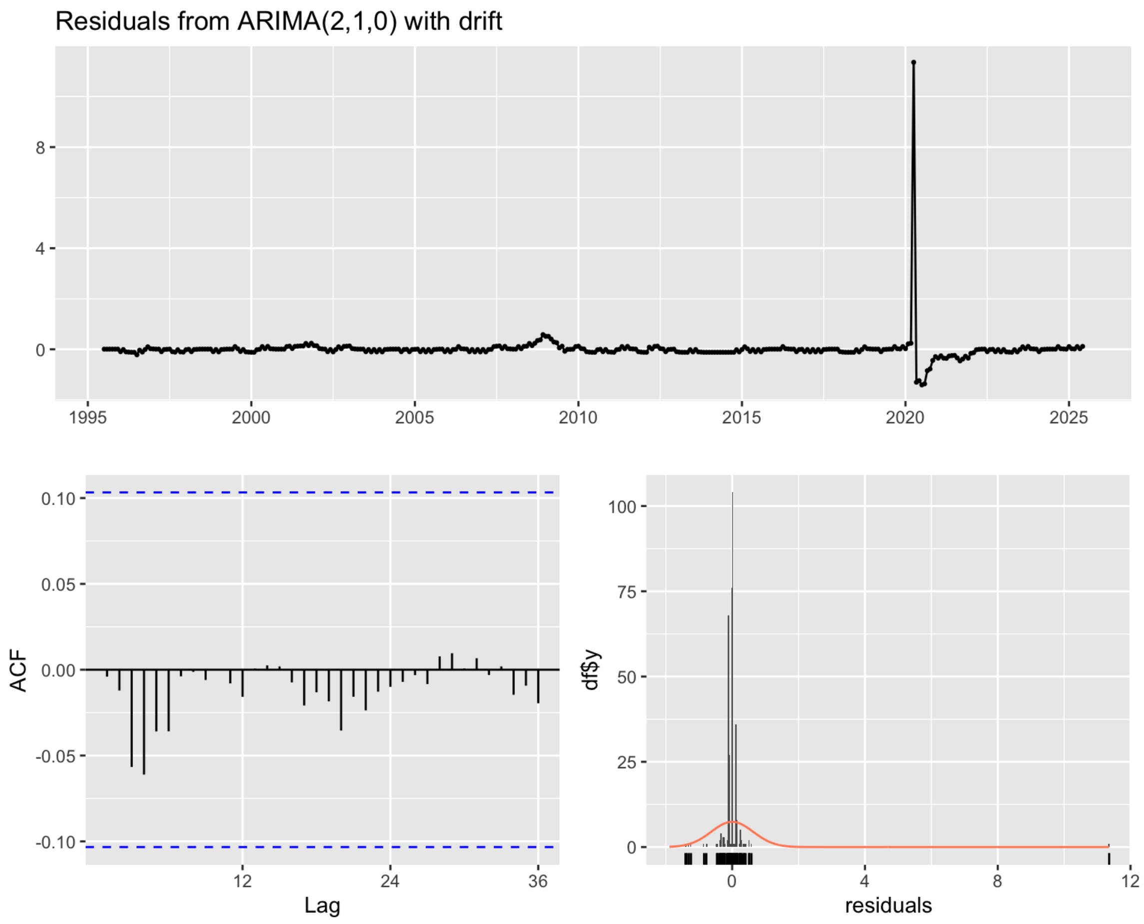
- Ljung–Box test (H_0: no autocorrelation):
  - Lag 12: $\chi^2 = 3.68$, $p = 0.96$
  - Lag 24: $\chi^2 = 4.96$, $p = 0.9999$
  - Lag 36: $\chi^2 = 5.37$, $p = 1.0000$
- All p-values > 0.95 → **fail to reject H_0.**
- Residuals behave like white noise → model is adequate

Ljung–Box Tests-Combined Check

data: Residuals from ARIMA(2,1,0) with drift

Q* = 4.9579, df = 22, p-value = 0.9999

- H_0: Residuals = white noise
- Q* = 4.96, df = 22, p = 0.9999
- Fail to reject H_0 → no evidence of autocorrelation
- Residuals behave like white noise
- Confirms ARIMA(2,1,0) with drift is an appropriate model



ARIMA Forecast for PA Unemployment SA

	date	mean	lo80	hi80	lo95	hi95
1	2025-07-01	3.971186	3.160104	4.782268	2.730744	5.211629
2	2025-08-01	3.960160	2.905819	5.014501	2.347685	5.572635
3	2025-09-01	3.952628	2.725695	5.179561	2.076196	5.829060
4	2025-10-01	3.948805	2.578419	5.319190	1.852981	6.044628
5	2025-11-01	3.943249	2.437705	5.448793	1.640719	6.245780
6	2025-12-01	3.937512	2.307470	5.567553	1.444579	6.430444

Economic interpretation

- PA's unemployment is expected to stay **low and steady**, close to pre-COVID lows.
- The narrow drift downwards: structural stability
- Consistent with slow recovery pattern in PA's industrial economy

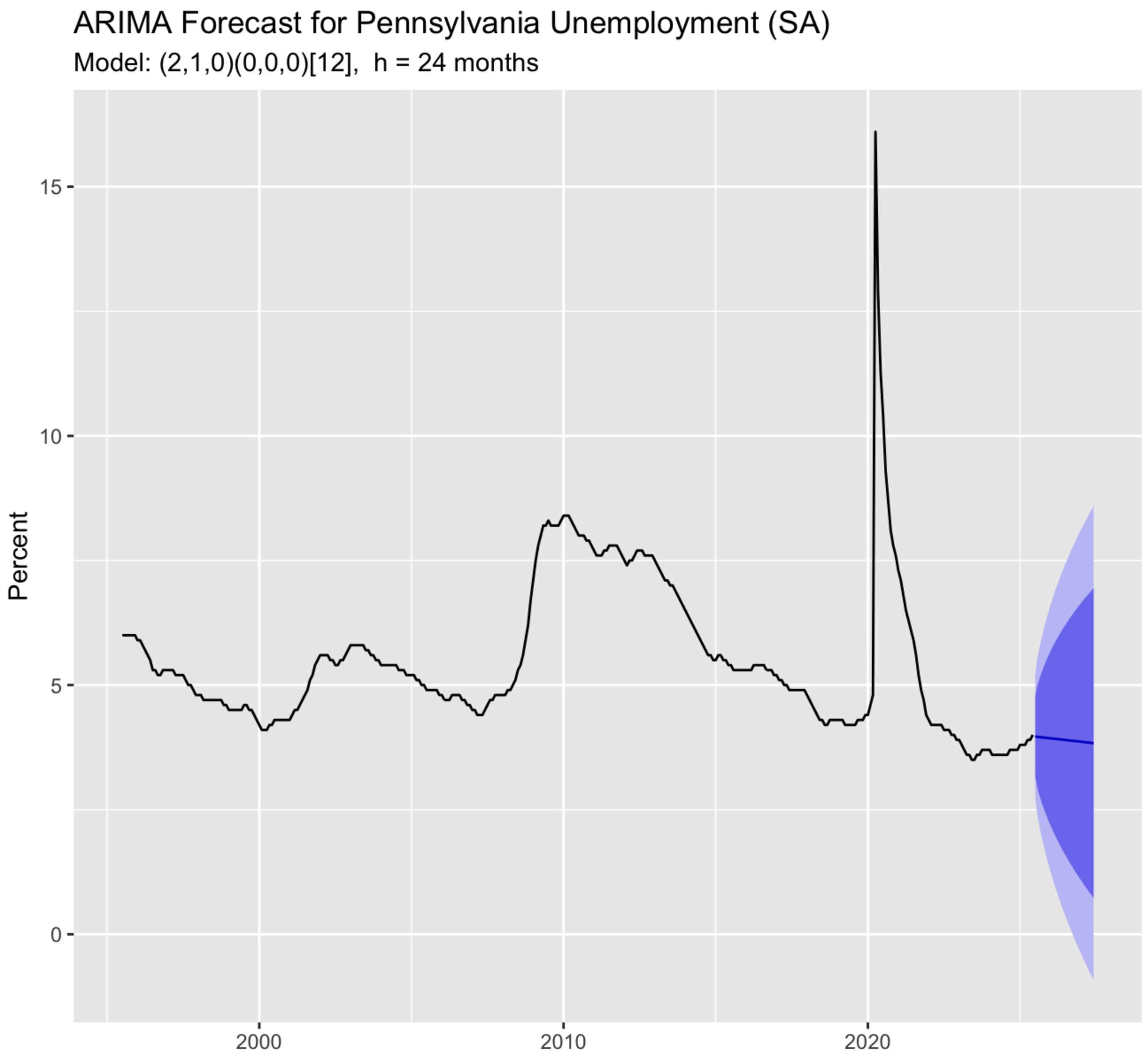
Point forecasts (mean):

- July 2025 → ~3.97%
- December 2025 → ~3.94%
- Unemployment will remain stable, just under 4%.

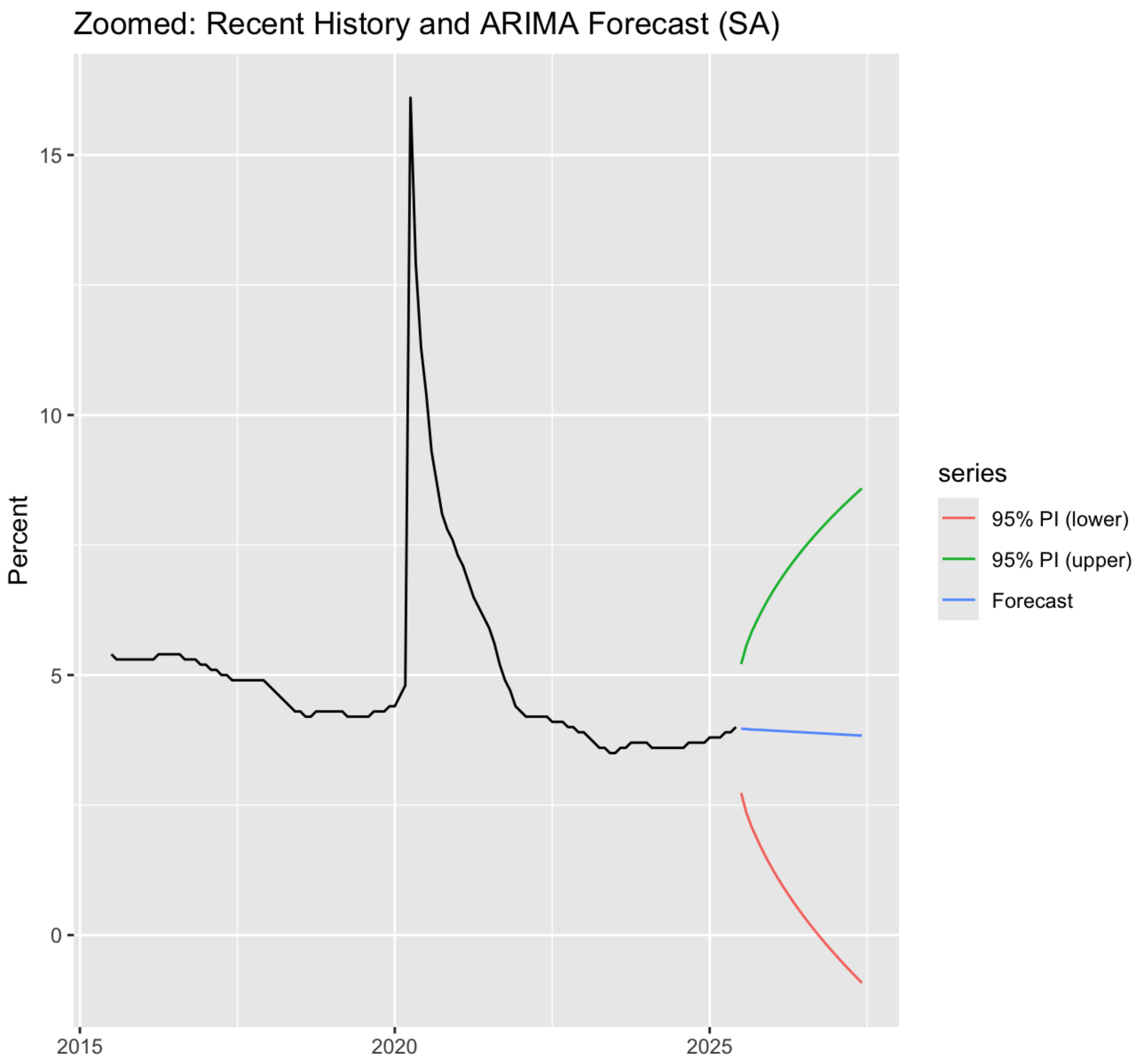
Confidence intervals:

- 80% CI: ~2.3% to ~5.6%
- 95% CI: wider, ~1.4% to ~6.4%
- Increasing uncertainty the further out this forecast

ARIMA Forecast for PA Unemployment SA



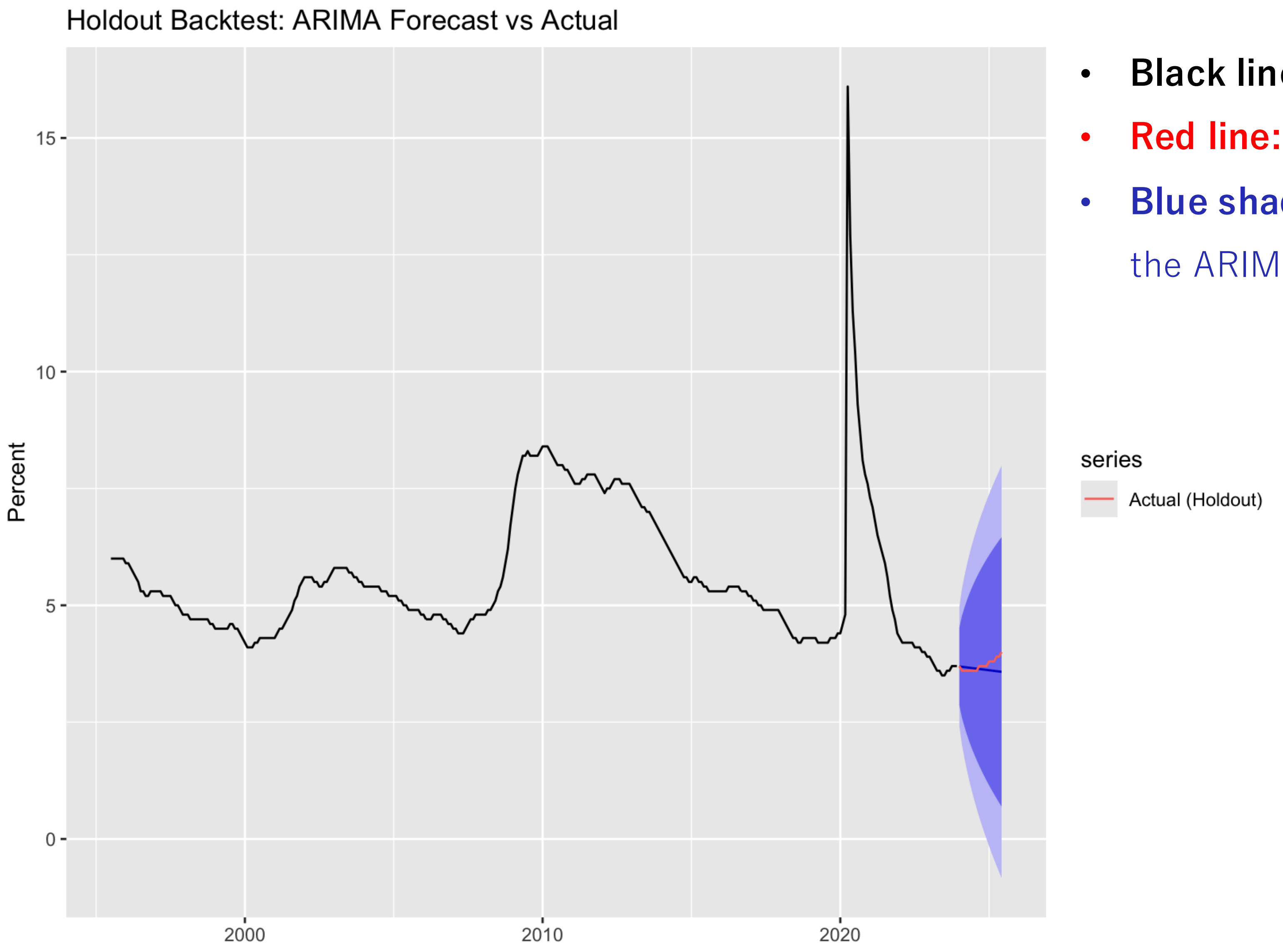
Forecasting- Recent History




```
ME       RMSE       MAE
Training set 2.227008e-05 0.6453432
0.1302104
Test set     8.258384e-02 0.1736688 0.1327195
                    MPE      MAPE      MASE
Training set -0.2420419 1.787542 0.1551804
Test set      2.0940015 3.486659 0.1581706
                     ACF1 Theil's U
Training set -0.004061638        NA
Test set      0.790081851  3.216152
```

- Training set:
  - low error (RMSE = 0.65, MAPE = 1.8%) model fits well
- Test set:
  - modest errors (RMSE = 0.17, MAPE = 3.5%) forecasts stable out-of-sample
- Model slightly overpredicts unemployment (MPE = 2.1%)
- COVID spike explains higher error ,Theil's U > 1
- Overall, ARIMA(2,1,0) with drift is adequate for short-term forecasting

Holdout Backtest: Forecast vs Actual



- **Black line:** the full historical unemployment rate
- **Red line:** the actual values from the holdout period
- **Blue shaded area:** the prediction intervals generated by the ARIMA(2,1,0) model estimated on the training set.

Interpretation

Validation approach: hold out the last 18 months and compare forecasts with actuals.

Result: the actual series (red) falls well inside the forecast intervals (blue).

Conclusion: forecast errors are small (MAPE ≈ 3.5%), confirming the ARIMA(2,1,0) with drift model generalizes well.

PART 04

Conclusion

Data’s report relativeness to PA’s feature

1. Key Findings
2. Broader Economic Interpretation
3. Limitations and Future Research

Key Findings

- ARIMA(2,1,0) with drift best fits Pennsylvania unemployment (1995–2025).
- Stationarity confirmed after differencing → validates ARIMA choice.
- Model diagnostics (residuals ≈ white noise, Ljung–Box $p \approx 1$) confirm adequacy.
- Forecasts (2025–2027): unemployment stabilizes around ~4%, but wide CIs reflect uncertainty.
- Economic link: Unemployment patterns to some extent reflects steel industry decline, cyclical sensitivity, and COVID-19 shock.

Broader Interpretation

- Steel legacy: Deindustrialization left long-term scars on the labor market.
- Cyclical shocks: 2008 crisis & COVID amplified unemployment, showing sensitivity to industrial demand.
- Diversification: Transition toward services, healthcare, and education helps stabilize unemployment.
- Forecast message: Structural improvements, but still vulnerable to external shocks.

Limitations & Future Research

Limitations:

- Model excludes exogenous variables (e.g., steel production, energy prices)
- COVID spike remains an extreme outlier, harder to capture

Future Research:

- VAR to compare PA vs. U.S. unemployment or neighboring states
- ARIMAX including steel output or policy shocks as predictors
- Explore sector-specific unemployment (manufacturing vs. agriculture vs. services)

Reference

Moore, E. E. "PITTSBURGH AND THE STEEL INDUSTRY." Pennsylvania History: Journal of Mid-Atlantic Studies 26, no. 1 (1959): 54–68. http://www.jstor.org/stable/27769859.

Haller, William. "Industrial Restructuring and Urban Change in the Pittsburgh Region: Developmental, Ecological, and Socioeconomic Tradeoffs." Ecology and Society 10, no. 1 (2005). http://www.jstor.org/stable/26267706.

Sisson, William. "A Revolution in Steel: Mass Production in Pennsylvania, 1867-1901." IA. The Journal of the Society for Industrial Archeology 18, no. 1/2 (1992): 79–93. http://www.jstor.org/stable/40968251.

Pennsylvania Center for the Book. Steel Industry in Pennsylvania. Penn State University Libraries. Accessed September 29, 2025. https://pabook.libraries.psu.edu/literary-cultural-heritage/steel-industry.

Federal Reserve Bank of Philadelphia. State Economic Overview. Accessed September 29, 2025. https://www.philadelphiafed.org/regional-economy.

Pennsylvania Department of Agriculture. Pennsylvania Agriculture: A Keystone of Our Economy. Accessed September 29, 2025. https://www.agriculture.pa.gov/Pages/default.aspx

AS.440.617.51.FA25

Thanks
Q&A

Date | 10/02/2025 **Speaker** | Tracy Wang