Analysis of Meat Production in the United States

Group 1 – Jocelyn Hunyadi, Elizabeth Schneider, Jack Kramer, Karleshia Dorsey, & Ken Marciel

Project Objectives

Primary Goal – Investigate time series data of meat production in the US

- Have significant epidemiological events (i.e. pandemics, epidemics) influenced trends in meat production?
- Have historical and economic events (i.e. recession) influenced trends in meat production?

Secondary Goal – Analyze and compare trends in production between total red meat and total poultry production (federally inspected)

Data Overview

Time: Monthly data from January 1983 - April 2021.

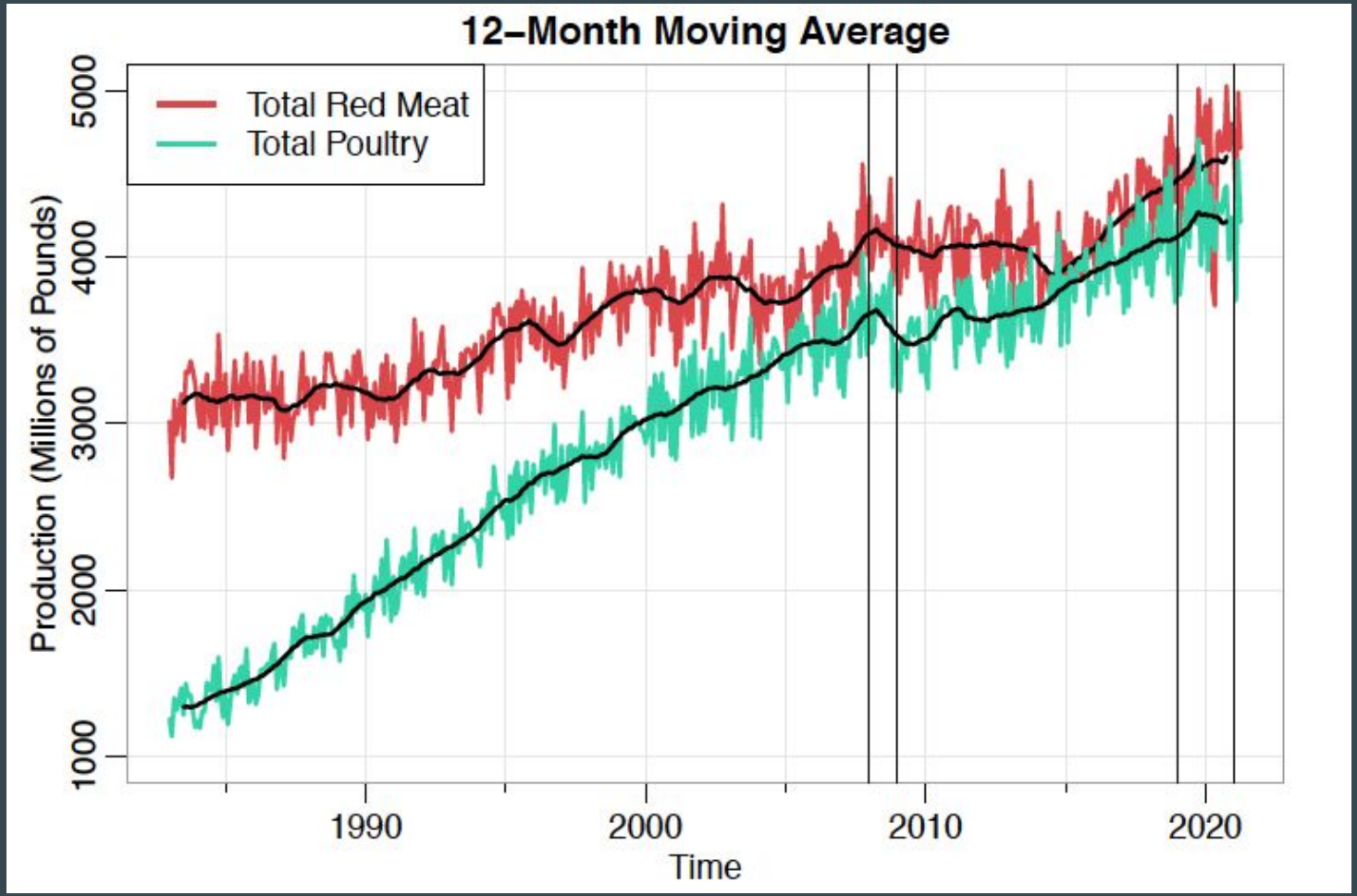
Meat Types:

1. Red Meat – Beef, Veal, Lamb & Mutton, and Pork
2. Poultry – Broilers, Other Chicken, and Turkey

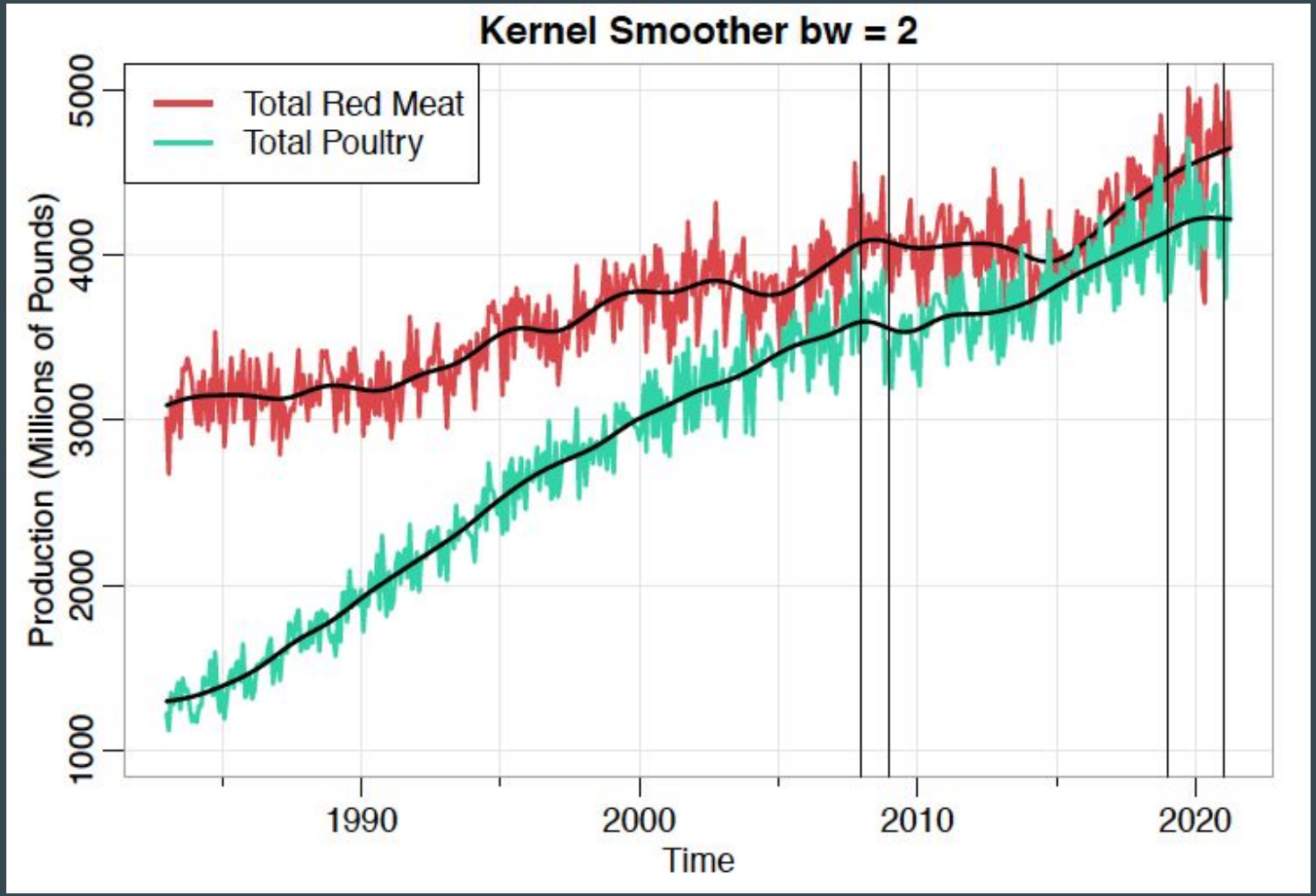
Production: Response variable - units: millions of pounds

Additional Variables: Time (months), Population (thousands), Median Income (monthly)

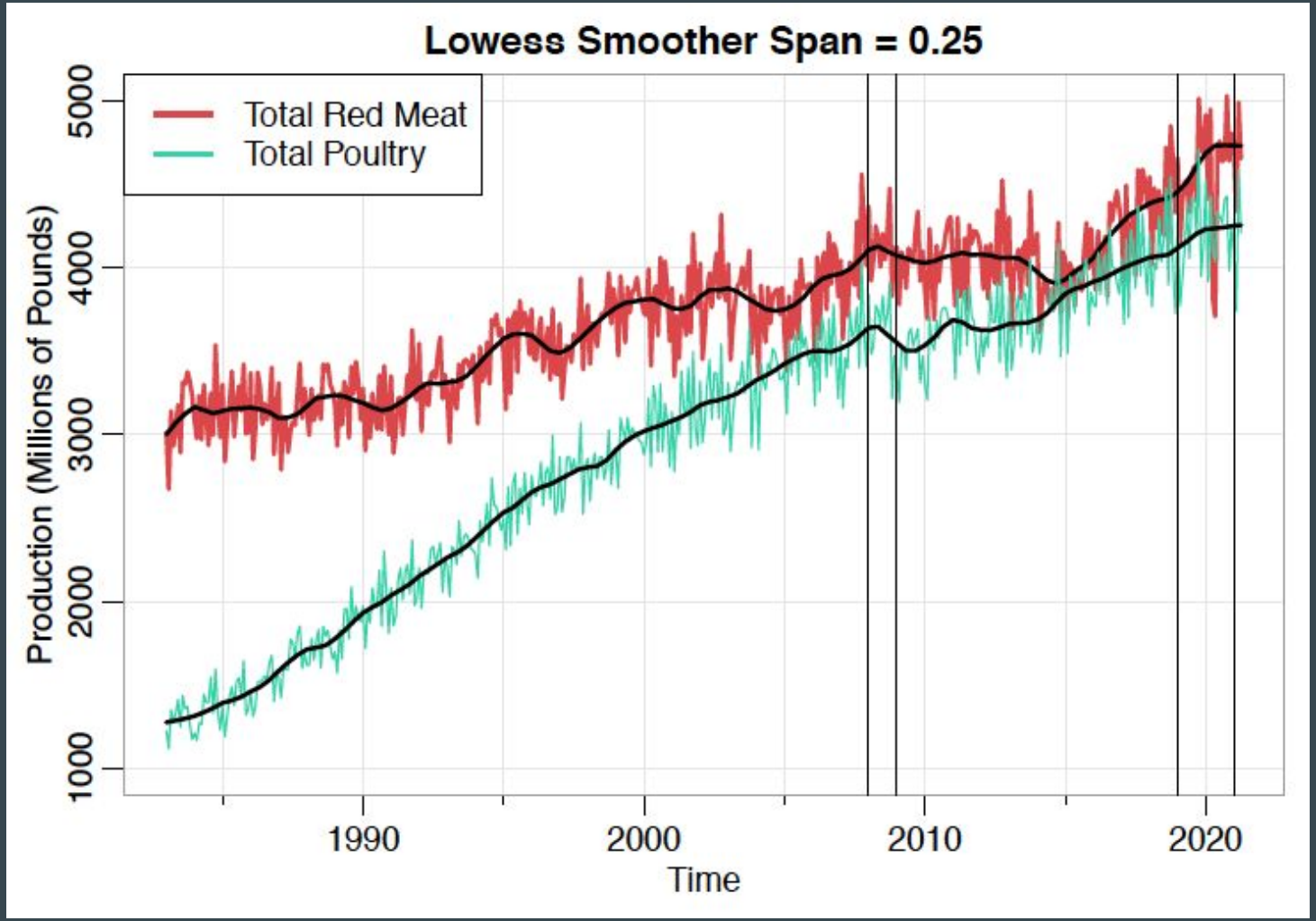
Red Meat & Poultry: 12-month moving average



Red Meat & Poultry: Kernel Smoother



Red Meat & Poultry: Lowess Smoother

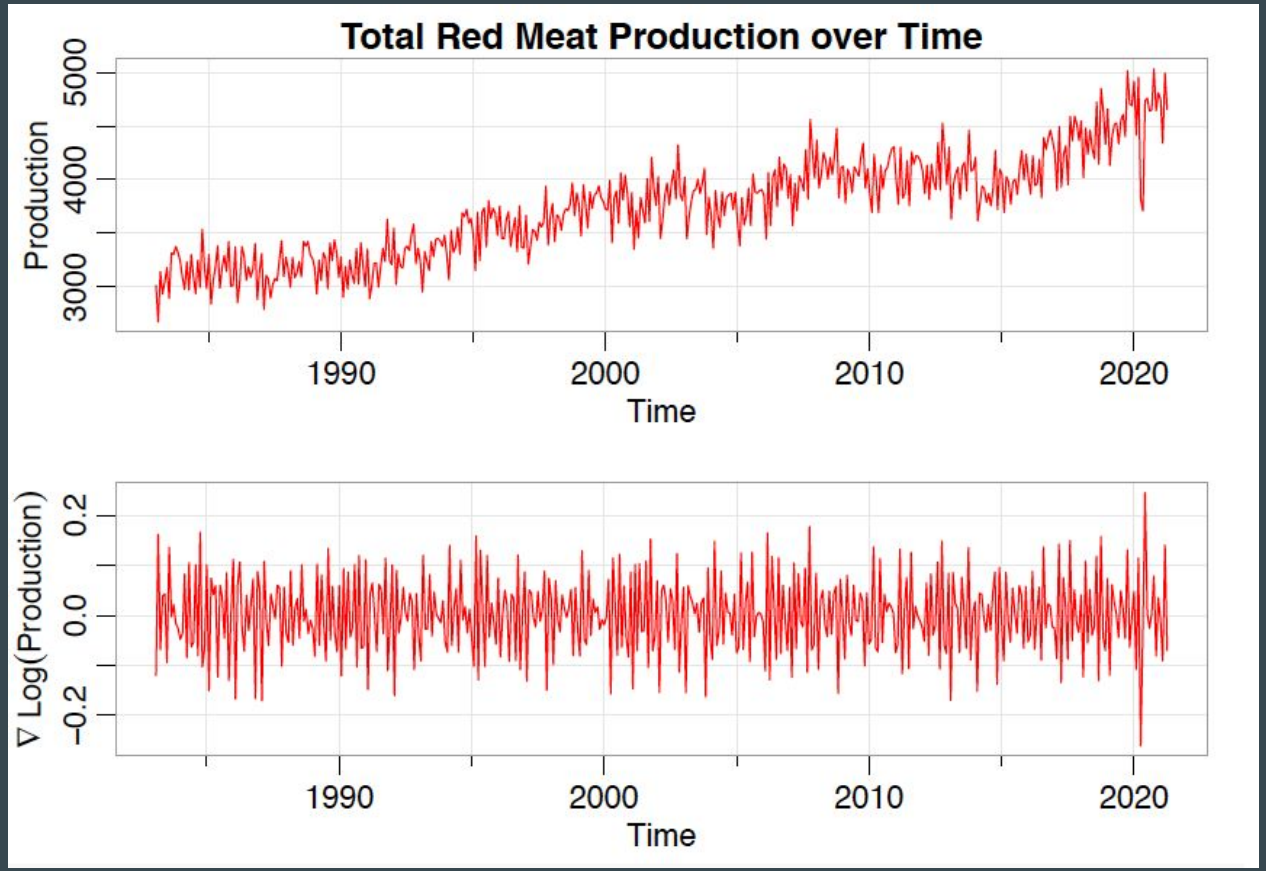


Analysis of Red Meat Production – ARIMA Model

Transformation to Stationarity

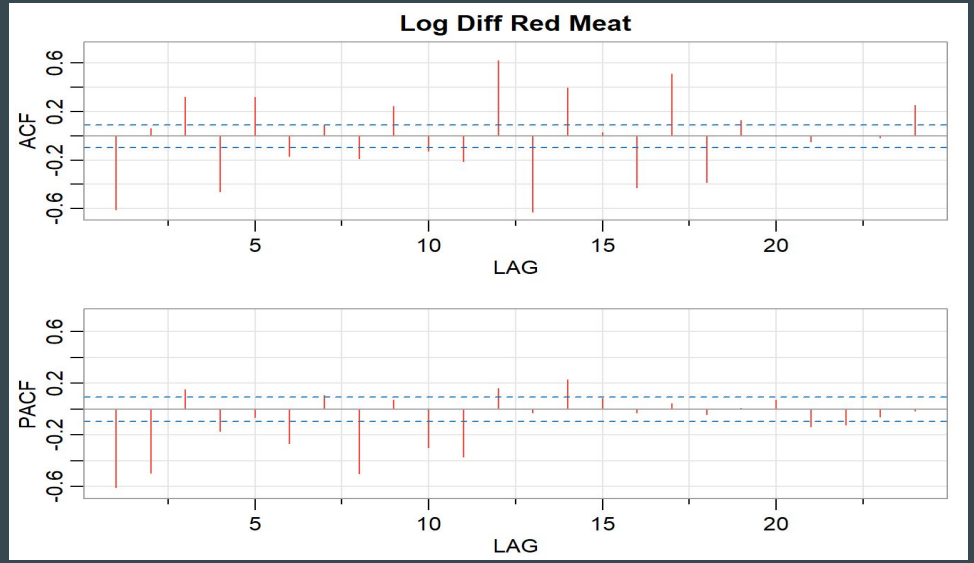
Differencing the log production appears to improve the time series to stationarity.

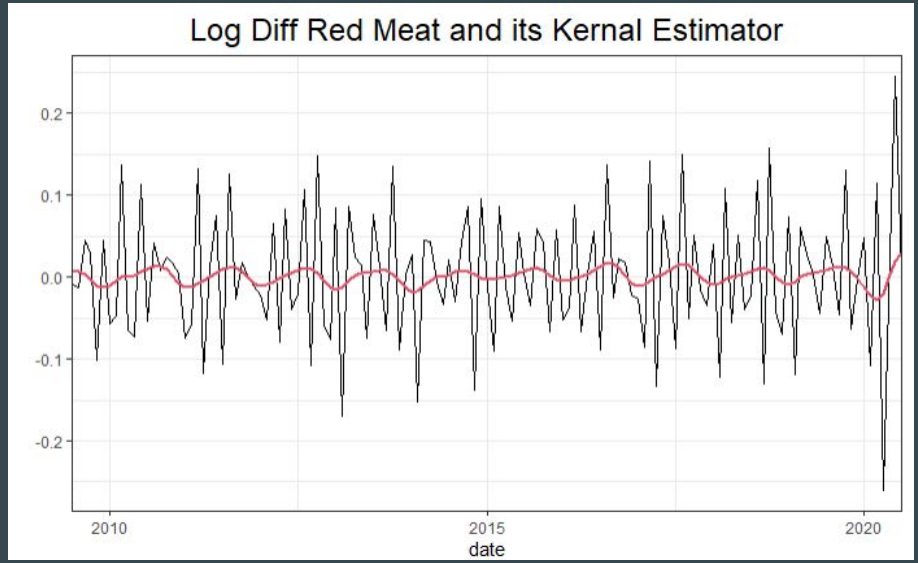
DF, ADF, and PP test all had p-value < 0.01



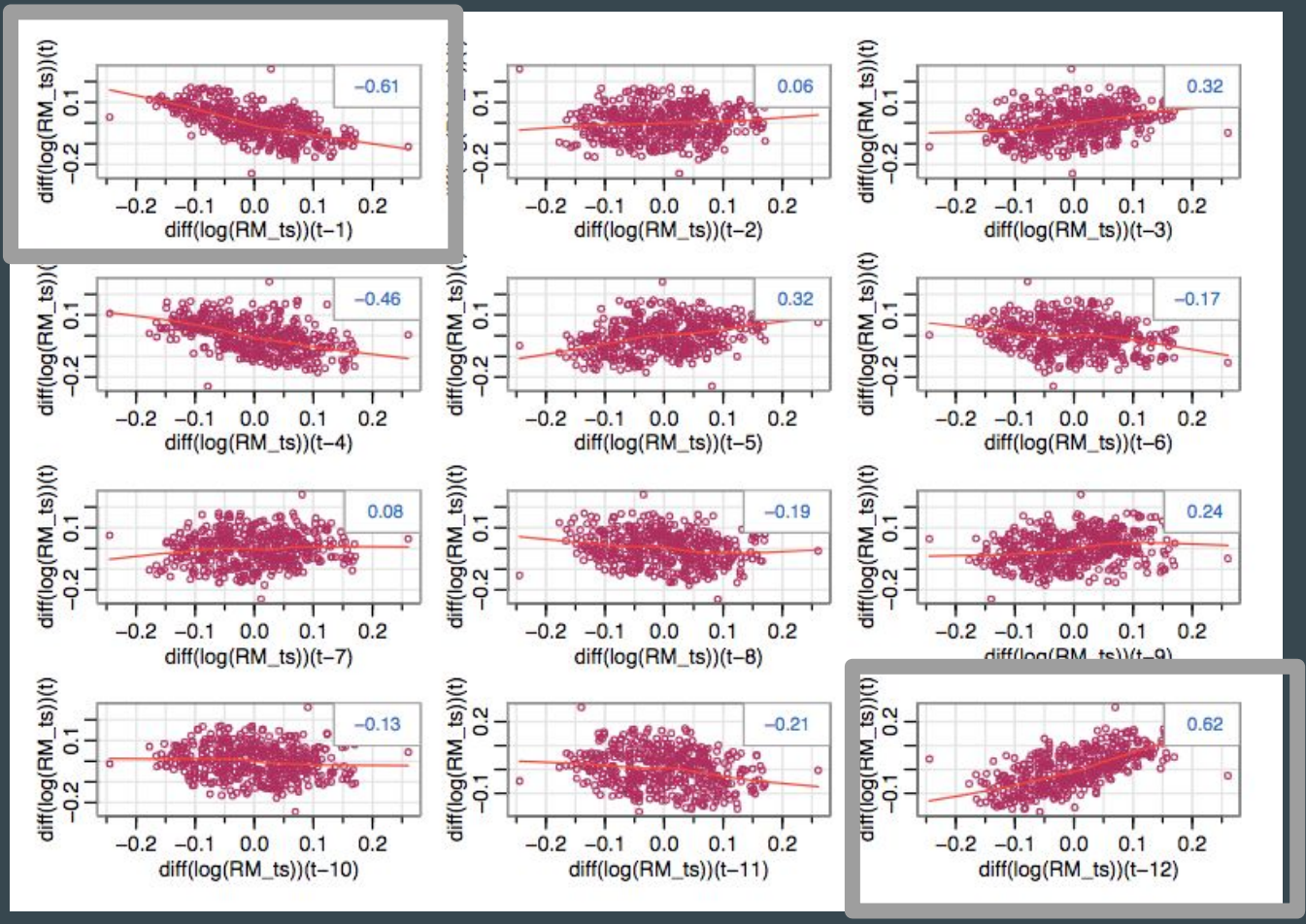
Transformation to Stationarity

Some seasonal pattern still exists after differencing, thus a SARIMA model should be considered

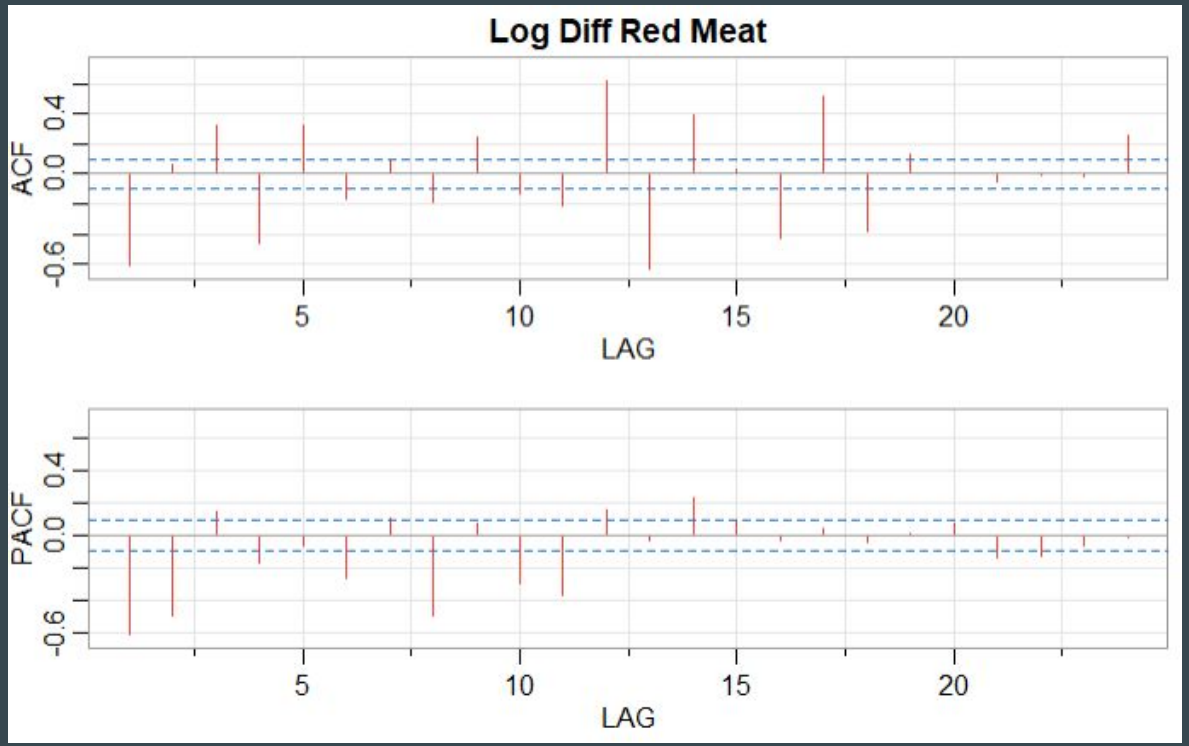




Red Meat: Transformed



Preliminary TS Model Selection



ARIMA(12,1,0) model (though complex) may be appropriate for red meat based on the PACF.

Model 1 - ARIMA(12,1,0)

Parameter estimates for Yule-Walker and OLS were approximately equivalent.

$\mathbf{M_t} = -0.75_{(0.047)}M_{t-1} - 0.61_{(0.058)}M_{t-2} - \ldots + 0.16_{(0.047)}M_{t-12}$

...where M_t is total red meat production.

AIC: -3.695

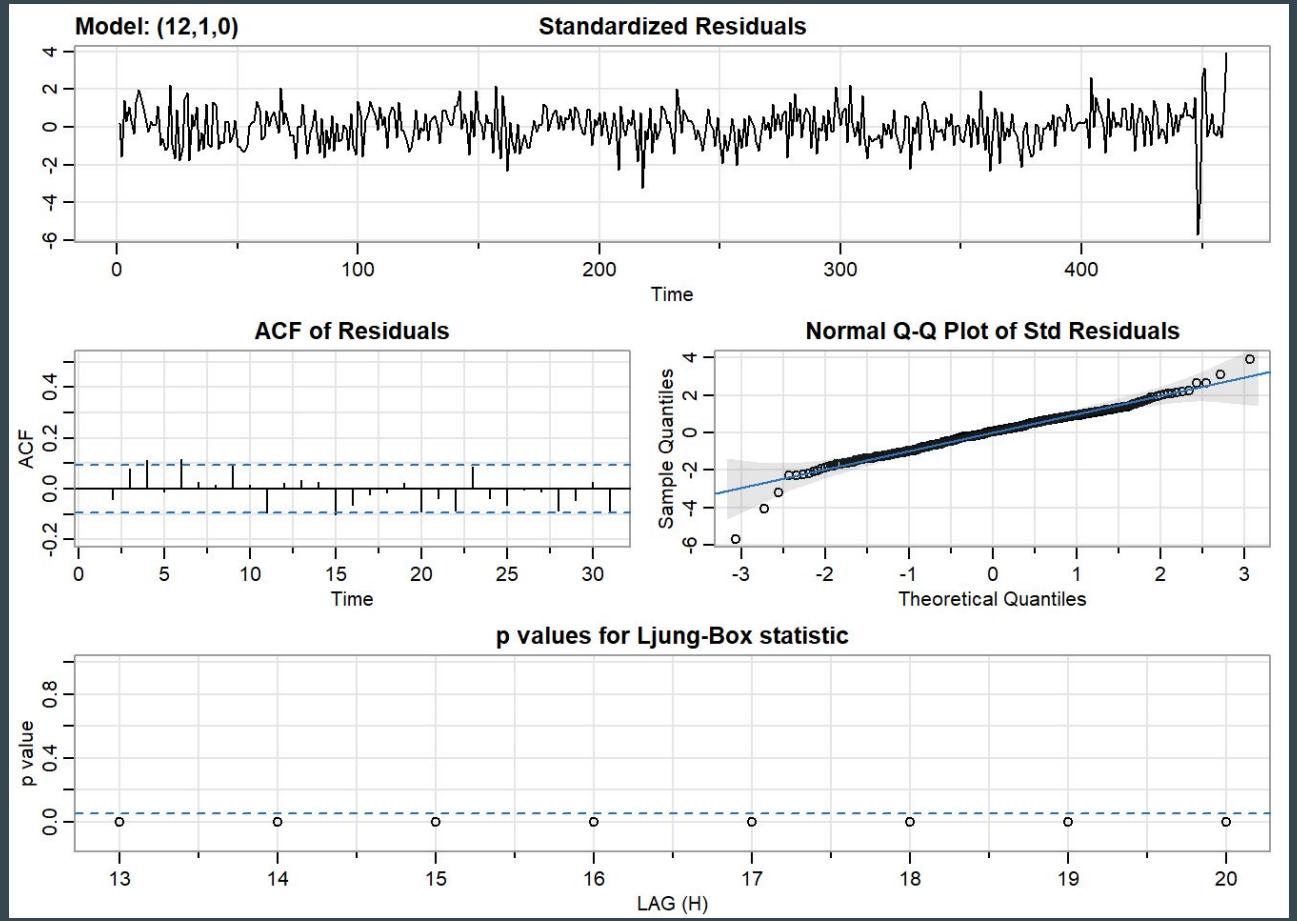
AICc:-3.694

BIC:-3.569

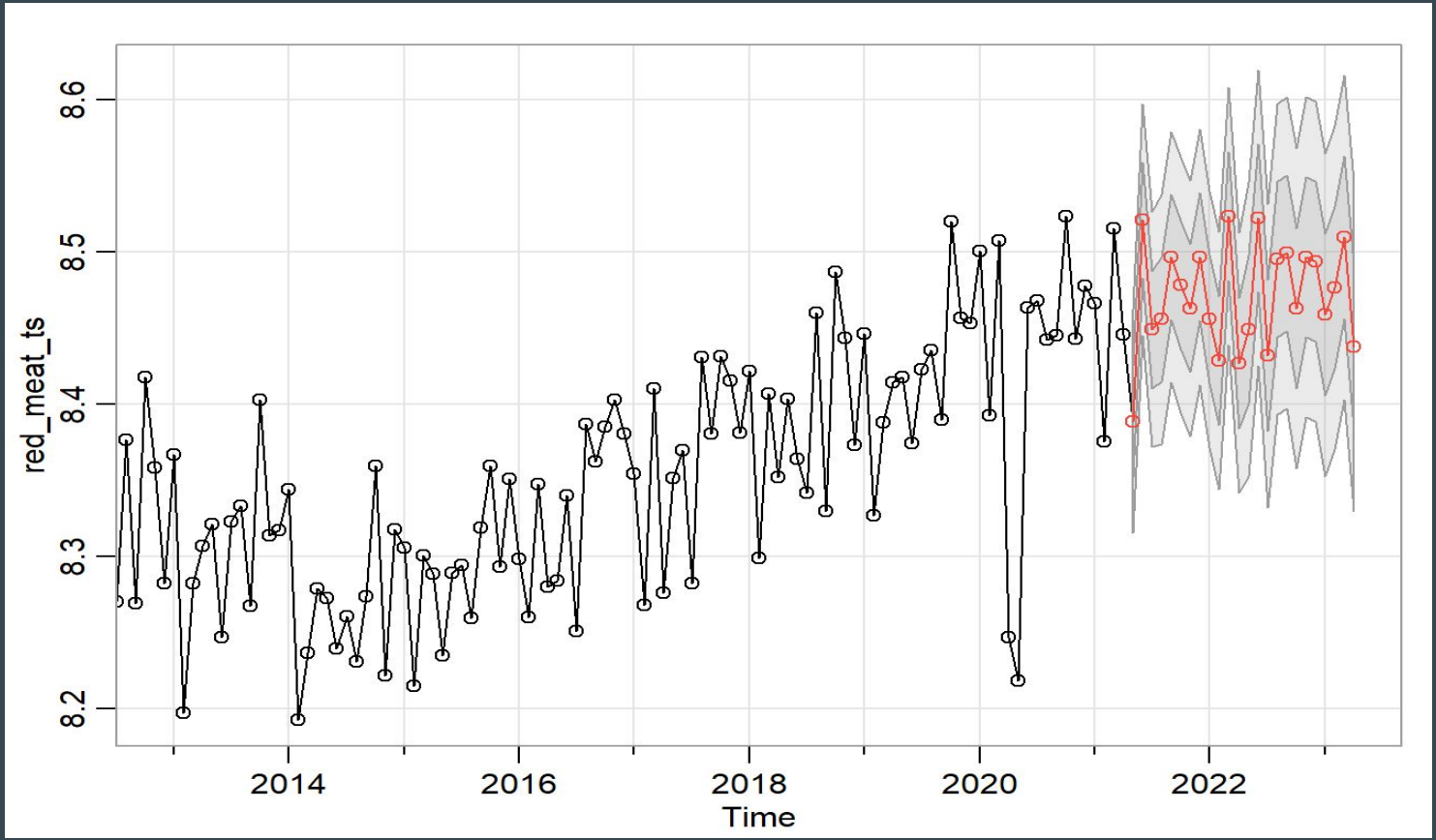
AR(12) Model for Red Meat Production	
YWE	**OLS**
$\hat{\varphi}_1 = -0.7526_{(0.0467)}$,	$\hat{\varphi}_1 = -0.7501_{(0.0473)}$,
$\hat{\varphi}_2 = -0.6148_{(0.0577)}$,	$\hat{\varphi}_2 = -0.6282_{(0.0585)}$,
$\hat{\varphi}_3 = -0.3196_{(0.0611)}$,	$\hat{\varphi}_3 = -0.3297_{(0.0619)}$,
$\hat{\varphi}_4 = -0.6084_{(0.0610)}$,	$\hat{\varphi}_4 = -0.6168_{(0.0615)}$,
$\hat{\varphi}_5 = -0.3738_{(0.0624)}$,	$\hat{\varphi}_5 = -0.3856_{(0.0626)}$,
$\hat{\varphi}_6 = -0.5343_{(0.0614)}$,	$\hat{\varphi}_6 = -0.5511_{(0.0616)}$,
$\hat{\varphi}_7 = -0.4375_{(0.0614)}$,	$\hat{\varphi}_7 = -0.4463_{(0.0622)}$,
$\hat{\varphi}_8 = -0.5449_{(0.0624)}$,	$\hat{\varphi}_8 = -0.5388_{(0.0632)}$,
$\hat{\varphi}_9 = -0.3238_{(0.0610)}$,	$\hat{\varphi}_9 = -0.3244_{(0.0610)}$,
$\hat{\varphi}_{10} = -0.4440_{(0.0611)}$,	$\hat{\varphi}_{10} = -0.4552_{(0.0620)}$,
$\hat{\varphi}_{11} = -0.2403_{(0.0577)}$,	$\hat{\varphi}_{11} = -0.2477_{(0.0604)}$,
$\hat{\varphi}_{12} = 0.1599_{(0.0467)}$	$\hat{\varphi}_{12} = 0.1738_{(0.0489)}$

Model 1 – Diagnostics

- Spike in the residuals plot in 2020 (COVID-19)
- Significant p-values for Q-stat



Model 1 – Forecast

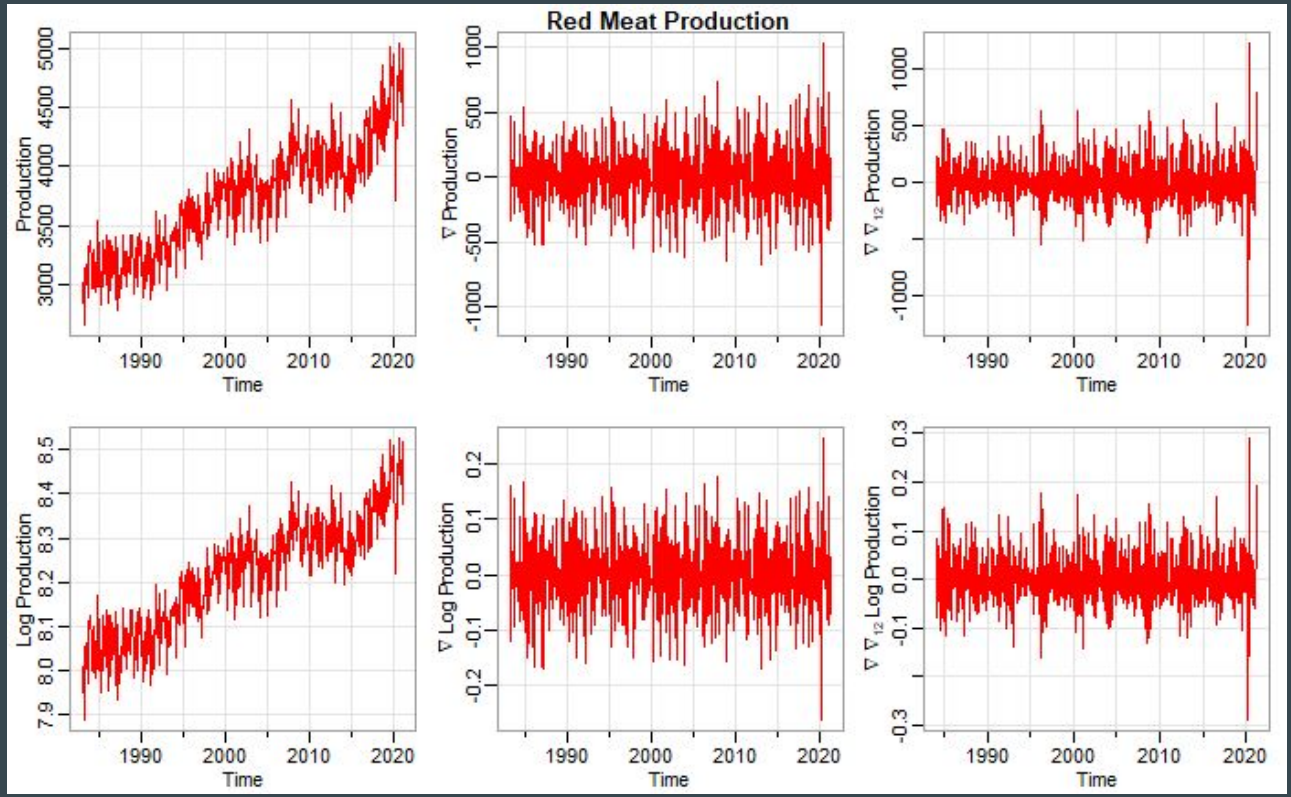


Analysis of Red Meat Production – SARIMA Model

Model 2 - SARIMA

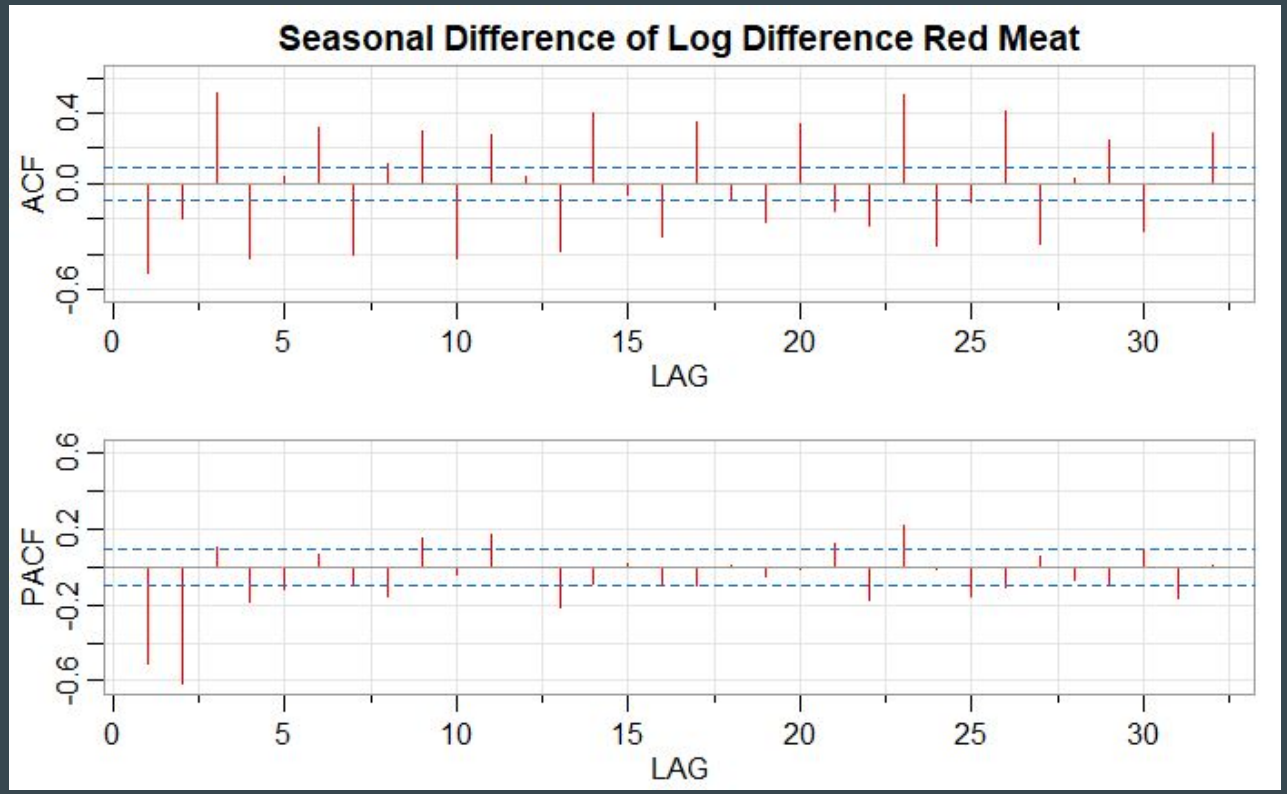
The trend is removed by differencing, but the transformations do not remove the spike in variance in 2020

Possible indication of COVID impact on meat production?



Model 2 - SARIMA

The PACF appears to cut off after lag 2.



Model 2 - Model Selection Process

Based on AIC, AICc, and BIC values, the SARIMA$(3,1,3)x(1,1,1)_{12}$ is the best seasonal model choice.

p	d	q	P	D	Q	S	DOF	AIC	AICc	BIC
0	1	0	1	1	0	12	446	-2.53752	-2.5375	-2.5196
1	1	0	1	1	0	12	445	-2.82721	-2.82715	-2.80034
2	1	0	1	1	0	12	444	-3.36642	-3.36631	-3.33059
3	1	0	1	1	0	12	443	-3.36577	-3.36557	-3.32098
4	1	0	1	1	0	12	442	-3.4008	-3.40051	-3.34706
0	1	0	1	1	0	12	446	-2.53752	-2.5375	-2.5196
0	1	1	0	0	0	12	445	-3.1483	-3.14824	-3.12143
0	1	2	1	0	0	12	444	-3.19585	-3.19574	-3.16002
0	1	3	1	0	0	12	443	-3.21393	-3.21374	-3.16914
0	1	4	1	0	0	12	442	-3.34901	-3.34872	-3.29526
0	1	0	1	0	0	12	446	-2.53752	-2.5375	-2.5196
1	1	1	1	0	0	12	444	-3.17419	-3.17408	-3.13836
2	1	2	1	0	0	12	442	-3.39004	-3.38975	-3.33629
3	1	3	1	0	0	12	440	-3.43341	-3.43287	-3.36175
0	1	0	1	0	1	12	436	-3.61918	-3.61789	-3.51169
1	1	1	1	0	1	12	436	-3.61918	-3.61789	-3.51169
2	1	2	1	0	1	12	436	-3.61918	-3.61789	-3.51169
3	1	3	1	1	1	12	439	-3.91218	-3.91148	-3.83156

Model 2 - SARIMA(3,1,3)x(1,1,1)12

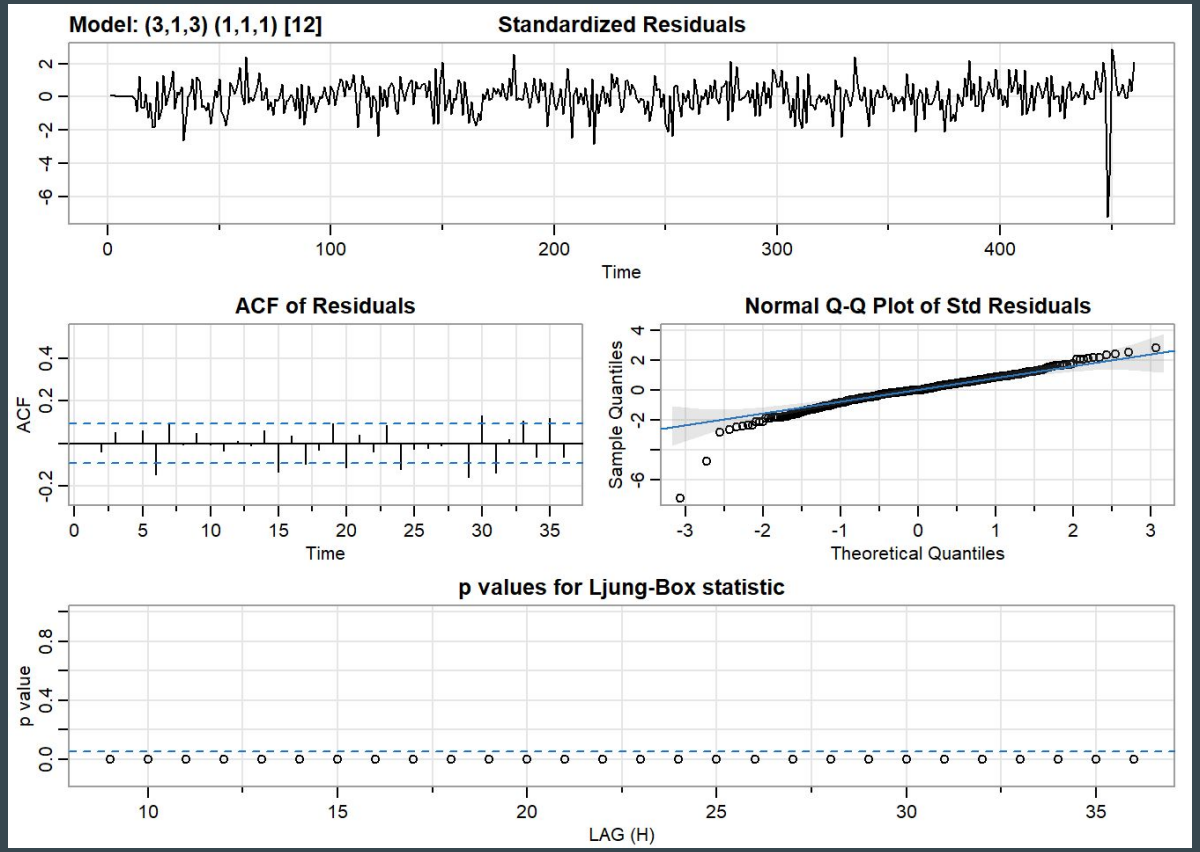
```
Parameters for SARMA(3,1,3)(1,1,1)[12] model

##       Estimate     SE  t.value p.value
## ar1    -1.0951 0.0675 -16.2301  0.0000
## ar2    -0.9267 0.0782 -11.8578  0.0000
## ar3     0.0632 0.0674   0.9371  0.3492
## ma1     0.3788 0.0468   8.0900  0.0000
## ma2     0.1141 0.0519   2.1999  0.0283
## ma3    -0.7707 0.0438 -17.5921  0.0000
## sar1    0.1366 0.0550   2.4847  0.0133
## sma1   -0.9225 0.0278 -33.2408  0.0000
```

Note that the AR3 parameter is **not** significant.

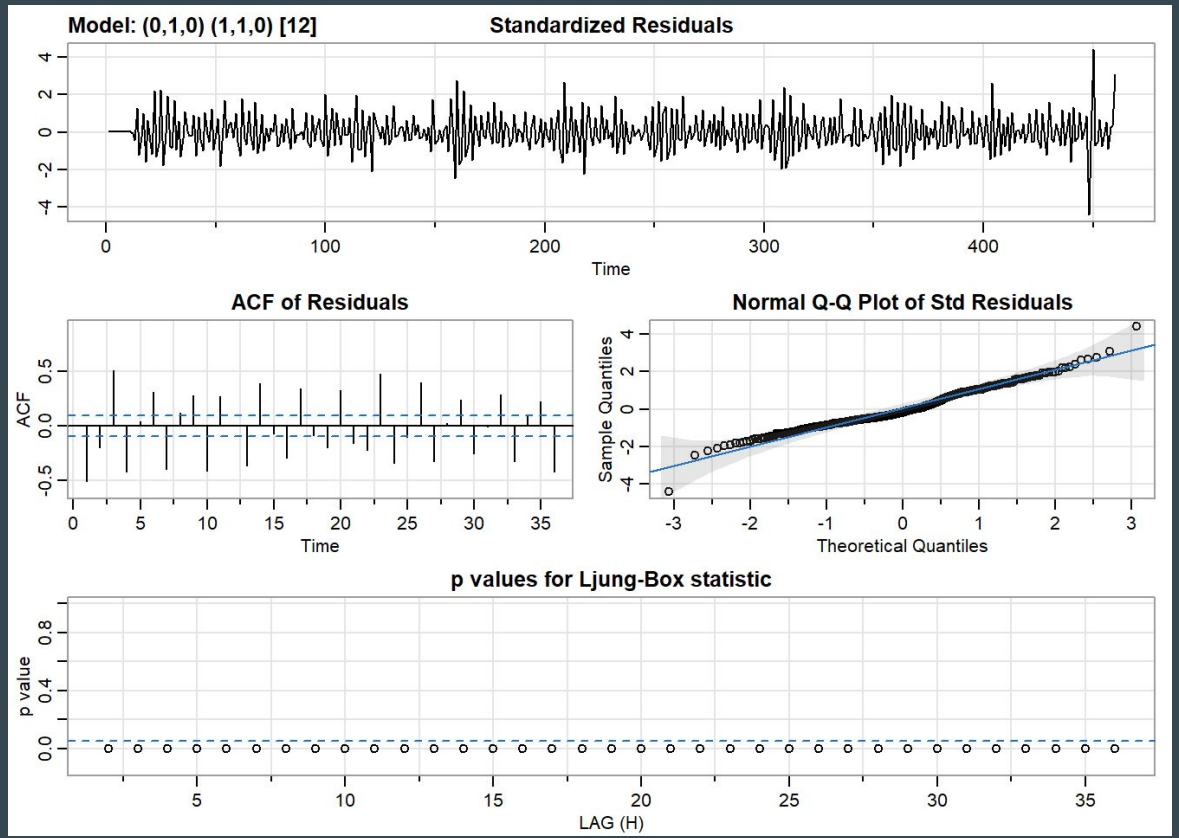
Model 2 - Diagnostics

- Note large spike in residual plot.
- ACF of residuals mostly not significant
- Q-stats, however, are all significant indicating that the residuals are not white noise.



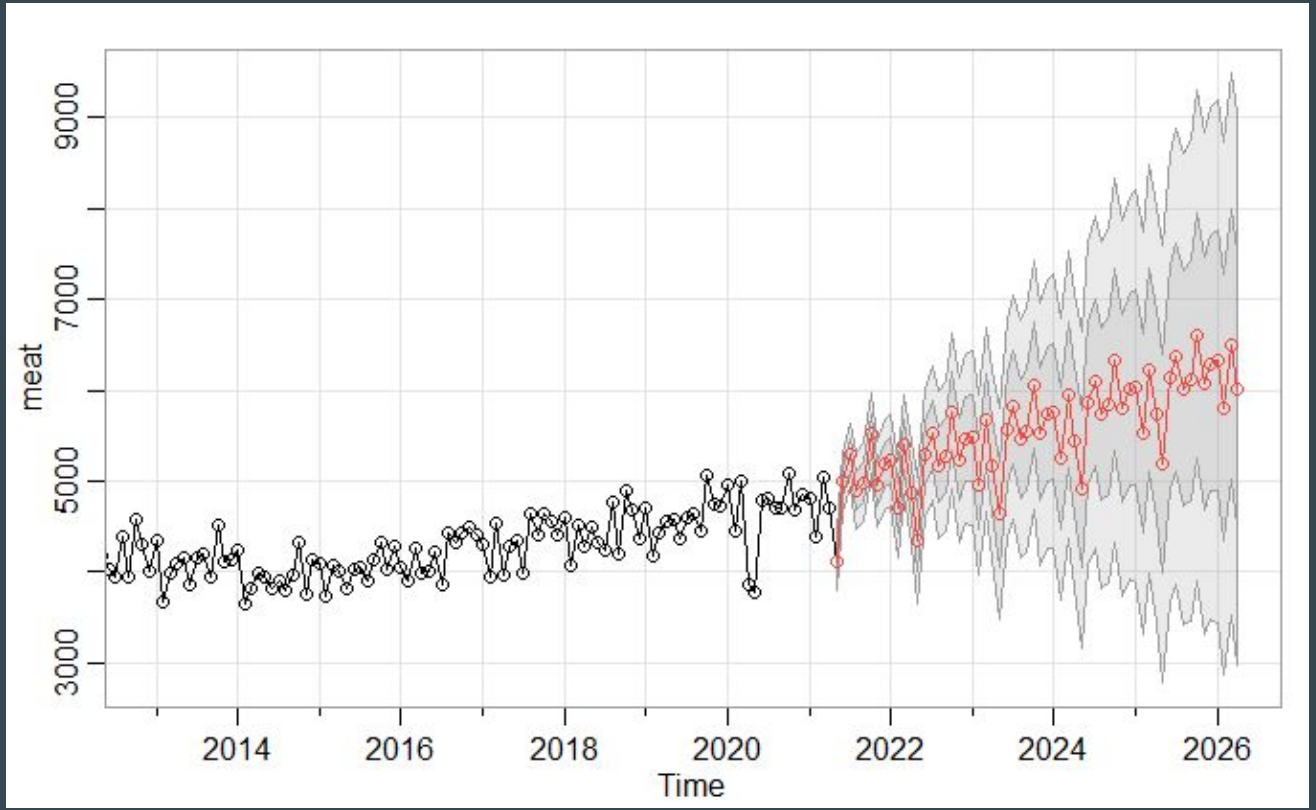
Model 2 - Comparison

- SARIMA$(0,1,0)x(1,1,0)_{12}$
- Notice multiple large and significant correlations in the ACF
- Q-stat values are all significant.



Model 2 - Forecasts

Forecasts predict a slight increase in red meat total production (on average) over the next 2 years.



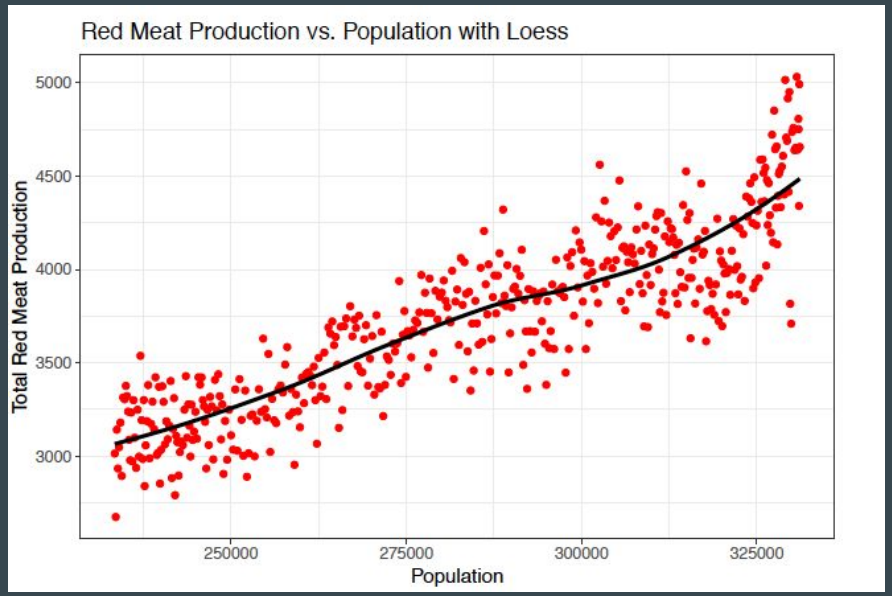
May, June and July Actual vs Forecast

Total Red Meat in Millions of Pounds

	Actual	ARIMA(12,1,0)	SARIMA(3,1,3)(1,1,1)12
May	**4246.3**	**4397.2**	**4448.9**
June	**4617.8**	**5019.5**	**4941.2**

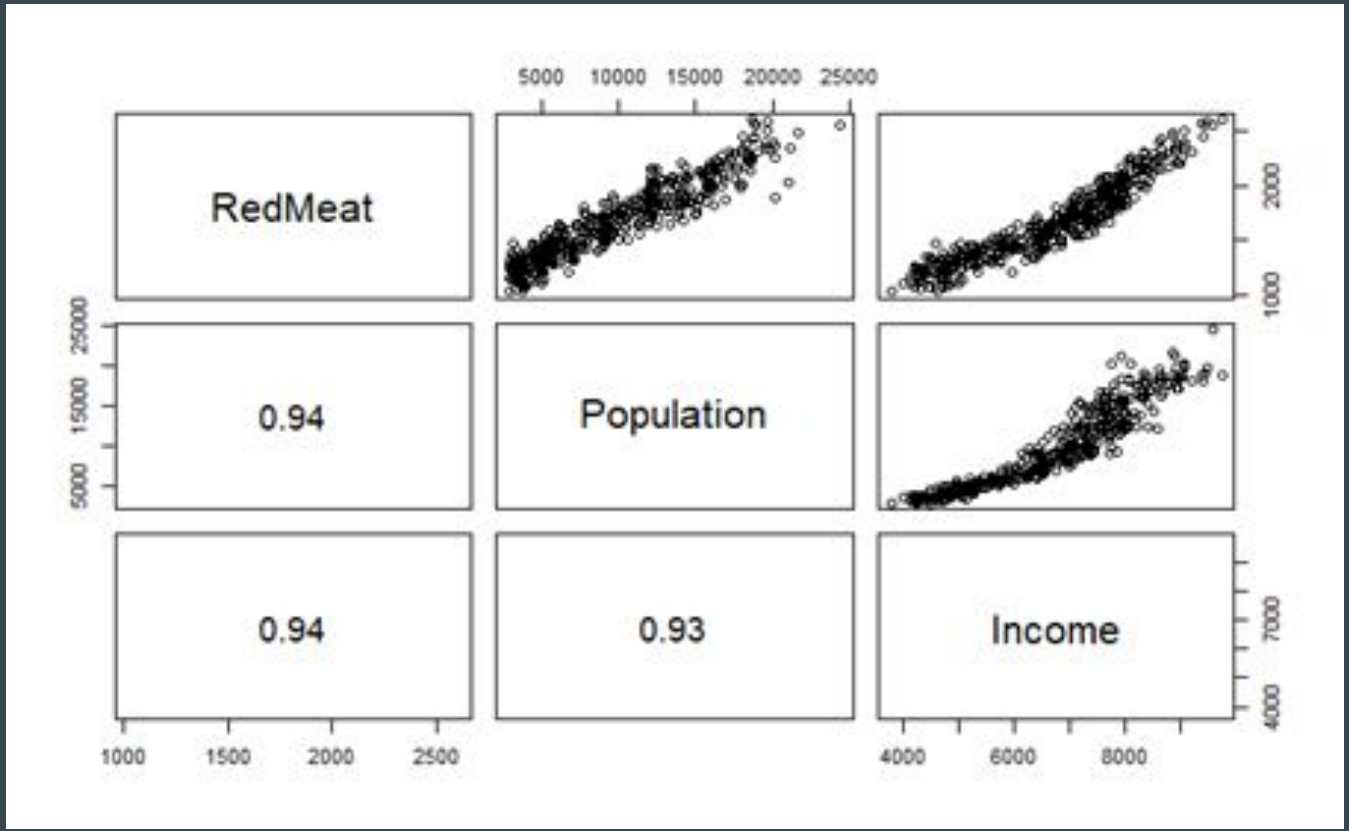
Analysis of Red Meat Production – Regression with AutoCorrelated Errors

Covariates – Population & Personal Income



Covariates generally have a linear relationship with Red Meat Production with slight underlying curvature as indicated by the Loess smoother.

Covariates – Population & Personal Income



Model 3 - Initial Linear Regression

Model	k	SSE	df	MSE	R2	AIC	BIC
M1	2	23268197	458	50804	0.7572	11.8444	13.7092
M2	3	23265587	457	50909	0.7572	11.8487	13.7225
M3	4	23223123	456	50928	0.7577	11.8512	13.734

M1: $M_t = \beta_0 + \beta_1 t + w_t$

M2: $M_t = \beta_0 + \beta_1 t + \beta_2 (L_t - L.) + w_t$

M3: $M_t = \beta_0 + \beta_1 t + \beta_2 (L_t - L.) + \beta_3 (L_t - L.)^2 + w_t$

Where L_t = Population & $L.$ = Mean population

Concerns

- **Model 1, 2** – Q-stats indicate that even transformed red meat is not white noise; a better model is needed.
  - Alternative modeling techniques?
  - Alternative transformations of total red meat production?
- **Model 3** – Personal Income had collinearity issues; Population was not significant in the model.
  - Alternative covariates that may be related to meat production
  - Environmental variables, retail value of red meat, etc.

Discussion & Conclusion

- Despite our best efforts and fitting over 50 models, we could not achieve whiteness (even after considering more complex models) in ARIMA or SARIMA models
- Our covariates were not significant predictors of red meat production, which made investigating regression with autocorrelated errors difficult.
- Even after models were fit to account for autocorrelated variables, population did not become significant.

Questions?

Appendix

1. *USDA ERS - Livestock & Meat Domestic Data*. https://www.ers.usda.gov/data-products/livestock-meat-domestic-data/. Accessed 13 June 2021.
2. Shumway, Robert, and David Stoffer. *Time Series: A Data Analysis Approach Using R (Chapman & Hall/CRC Texts in Statistical Science)*. 1st ed., Chapman and Hall/CRC, 2019.
3. Thornton, Philip K. "Livestock production: recent trends, future prospects." *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* vol. 365,1554 (2010): 2853-67. doi:10.1098/rstb.2010.0134
4. US Bureau of Economic Analysis, Personal Income [PI], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/PI, July 4, 2021.
5. US Bureau of Economic Analysis, Population [POPTHM], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/POPTHM, July 4, 2021