U.S./China Trade: Imports and Exports

Jarrett Rennie, Hannah Goldstein, Nicolas Renaud, Brendan Hennessey

Agenda

1. Introduction
2. Exploratory Data Analysis
3. ETS & SARIMA
4. Nonlinearity & Neural Networks
5. Retrospective & Comparison of All Models
6. Conclusions & Future Work
7. Questions?

Introduction

Background

Subject: bilateral trade volume between the world's (current) largest economies

Source of data: U.S. Bureau of Economic Analysis (FRED)
https://fred.stlouisfed.org/source?soid=18

Two time series analyzed:

1. Chinese **imports** to U.S. in millions of USD, by month (Jan. 1985-Sept. 2019)
2. U.S. **exports** to China in millions of USD, by month (Jan. 1985-Sept. 2019)

bea | Bureau of Economic Analysis
U.S. DEPARTMENT OF COMMERCE

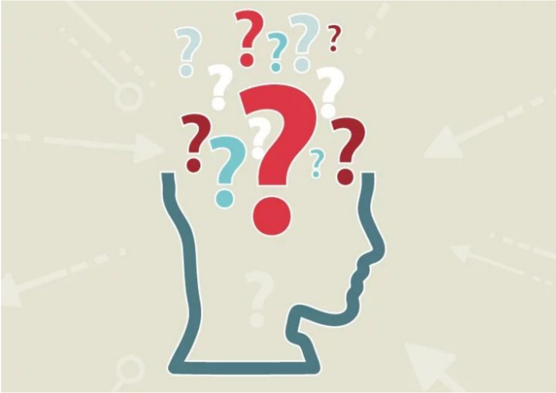
Questions to guide investigation

1. What do imports and exports look like over time?

2. Is there any sort of noticeable trend, seasonality?

3. How about linearity; do imports and exports need to be modeled via nonlinear methods?

4. Can a reasonably good model be fit to each series?
    - Is that model as good at forecasting (test) as it is at simulating (train)?



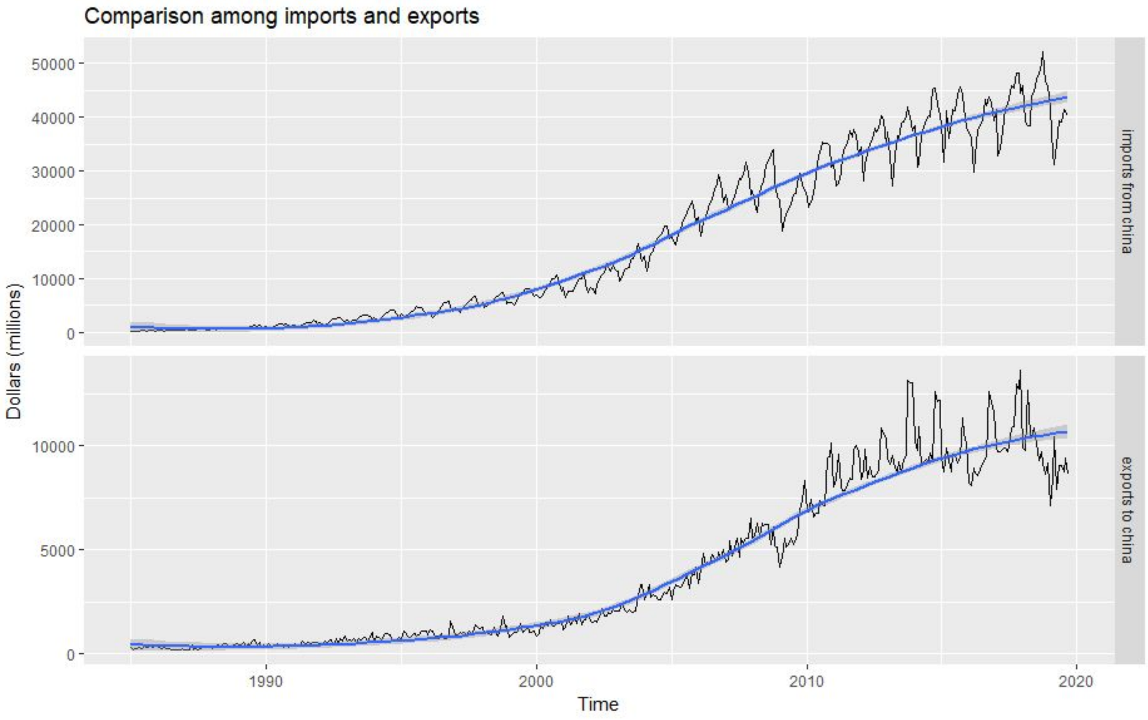
Key trade relations dates

- **2000:** U.S. and China normalize trade relations
- **2001:** PRC joins the World Trade Organization
- **2006:** China overtakes Mexico as U.S.'s second largest trading partner
- **2010:** China becomes world's second largest economy
- **March, 2018:** First tariffs totalling at least $50 billion are placed on respective imports
- **July, 2018:** $34 billion in additional tariffs are enacted by each side
- **May, 2019:** tariffs on Chinese goods increased by 15% affecting $200 billion; China responds with $60 billion in tariffs on U.S.

Source: https://www.cfr.org/timeline/us-relations-china

Exploratory Data Analysis

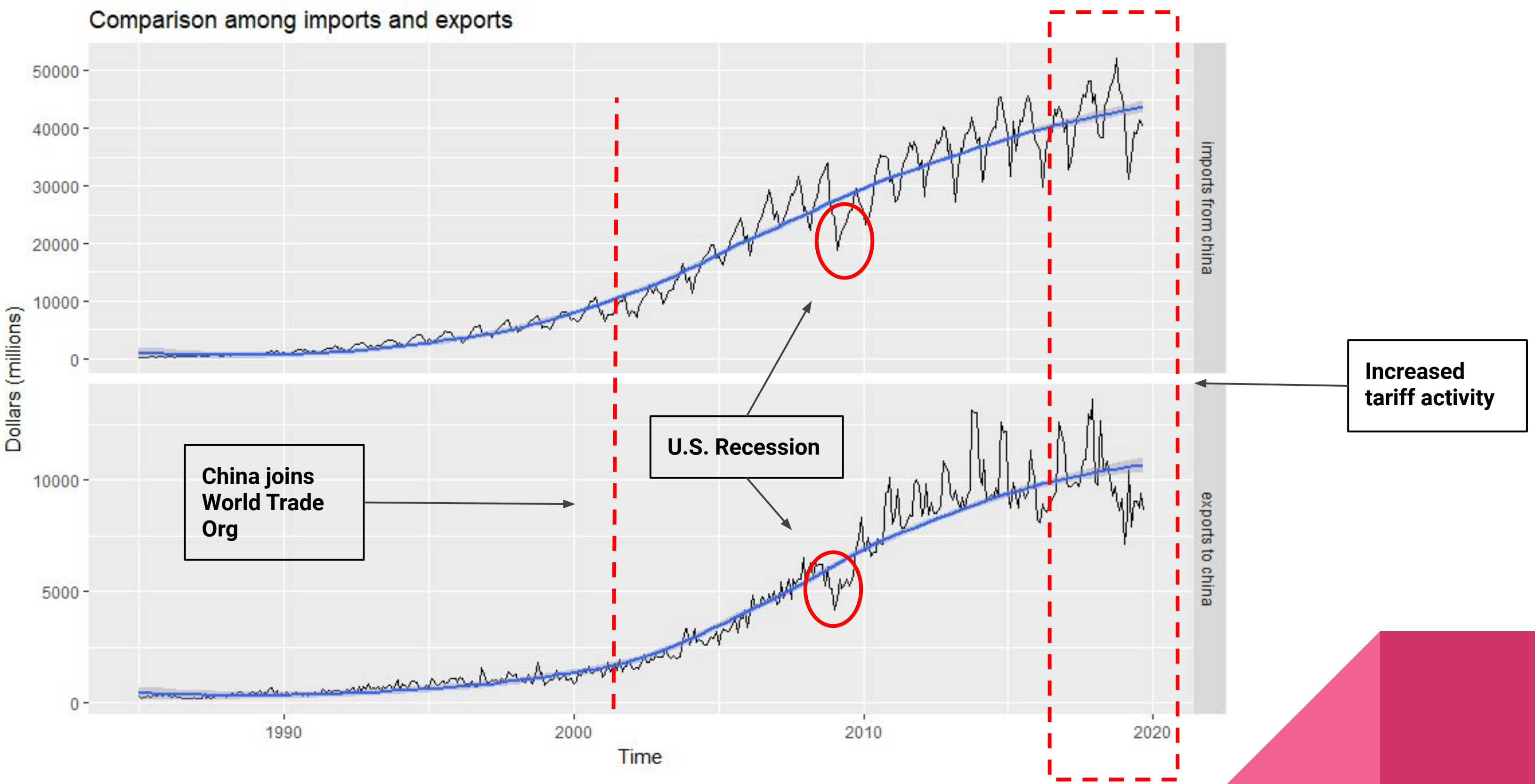
Shape of each series



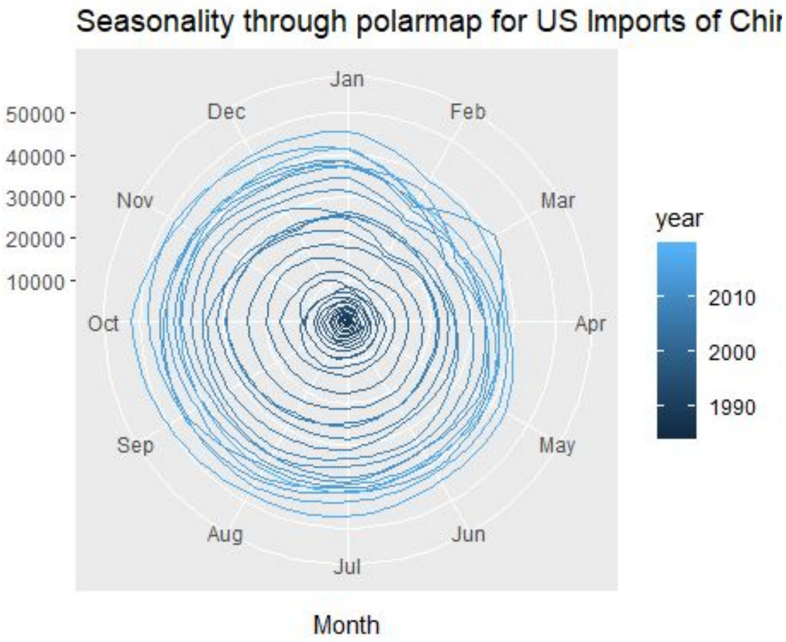
	Imports	Exports
F_T	0.988	0.982
F_S	0.509	0.267

```
#check entropy
SampEn(imp.ts)

## [1] 0.1134533

SampEn(exp.ts)

## [1] 0.1184296
```

Imports & Exports with Current Events



Polar plots


Seasonality through polarmap for US Imports of Chir
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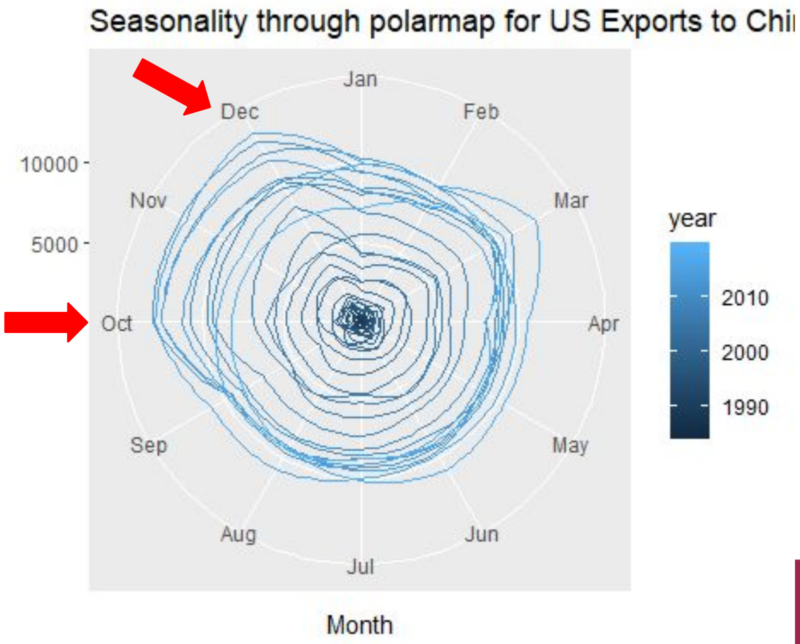
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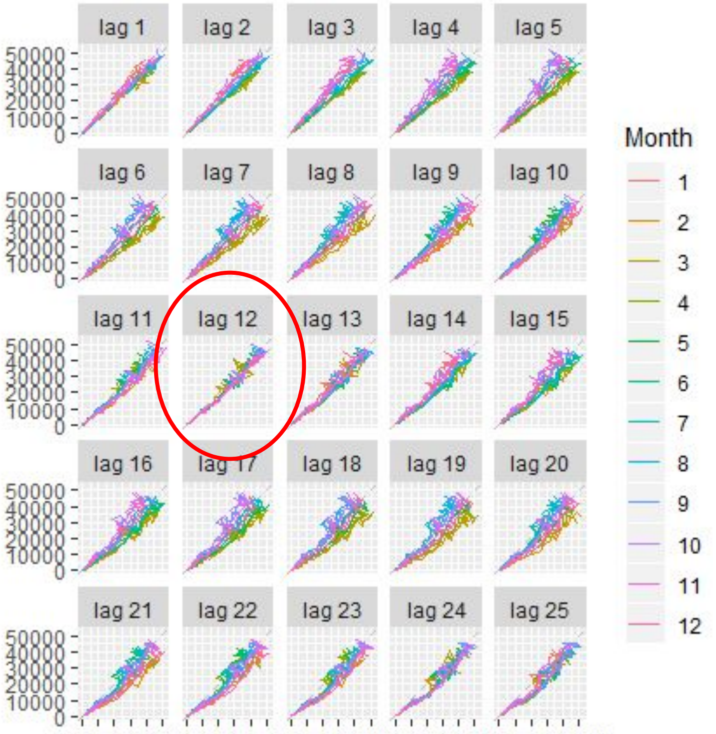
Lag plots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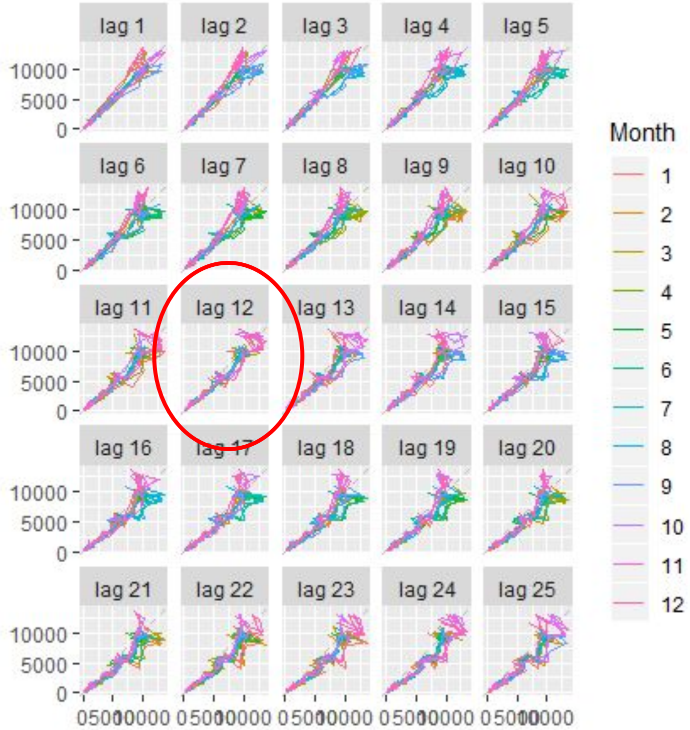
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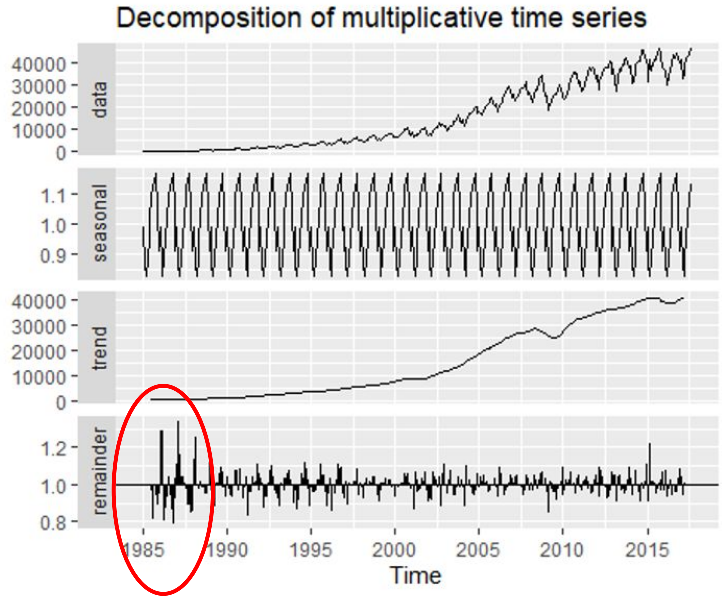
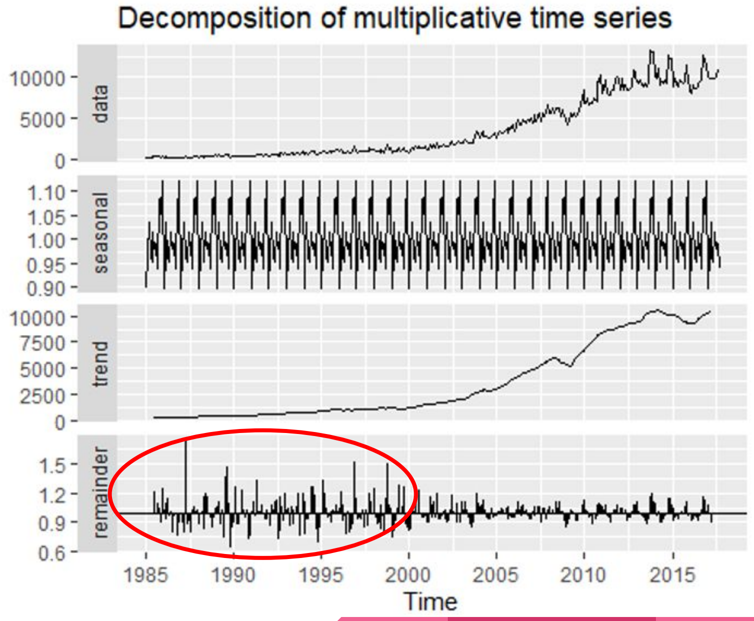
Series decomposition

```
autoplot(decomp.imp.mult)
```



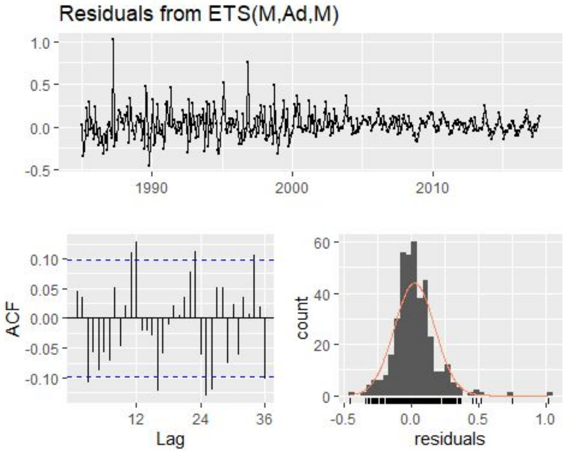

```
autoplot(decomp.exp.mult)
```

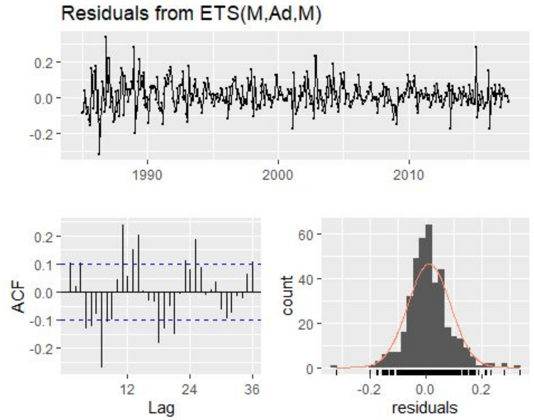


ETS & ARIMA

ETS

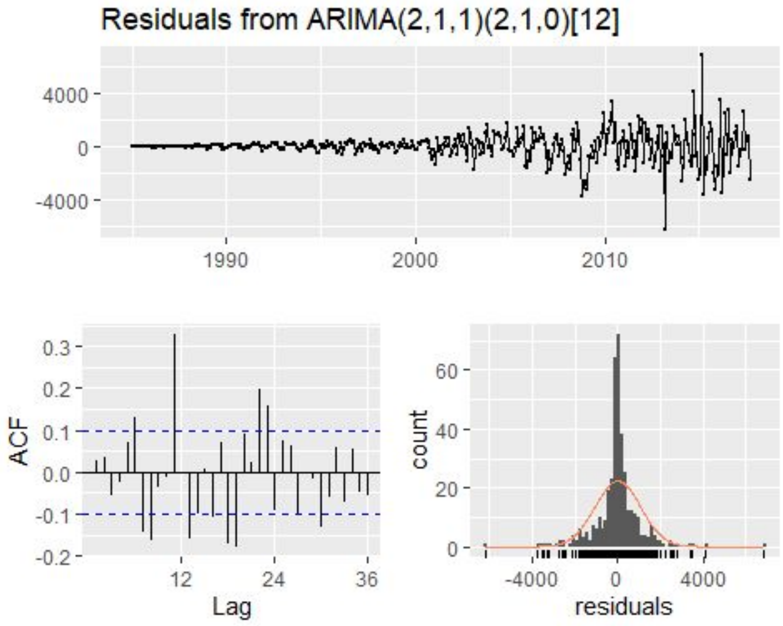
data	method	model	lambda	sigma**2	subset	mape	mase	residuals
import	ets	M,Ad,M	N/A	0.0763	train	5.494712	0.3703234	dependent
					test	7.537235	1.763118	
export	ets	M,Ad,M	N/A	0.1551	train	10.37534	0.5103051	dependent
					test	15.89129	2.8818206	



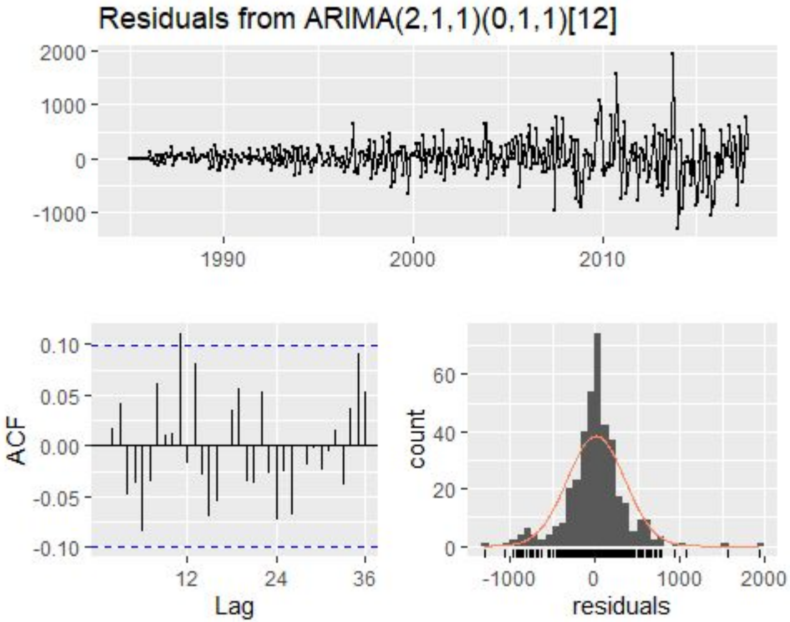


ARIMA/SARIMA

Imports, no lambda:



Exports, no lambda:



Checking ARIMA/SARIMA

data	method	model	lambda	sigma**2	significant parameters	subset	mape	mase	residuals
import	sarima	ARIMA(2,1,1)(2,1,0)[12]	N/A	1180427	YES	train	5.356059	0.3627931	dependent
						test	6.900162	1.6583602	
import	sarima	ARIMA(2,1,1)(2,1,0)[12]	0.1637399	0.07768	YES	train	4.977908	0.3433272	dependent
						test	7.287937	1.7651253	
export	sarima	ARIMA(2,1,1)(0,1,1)[12]	N/A	119334	YES	train	11.35756	0.4513094	independent
						test	19.70742	3.5138966	
export	sarima	ARIMA(2,1,1)(2,0,0)[12] with drift	0.220129	0.4778	YES	train	10.81068	0.4775985	independent
						test	22.87962	4.1109044	

Nonlinearity & Neural Networks

Nonlinearity - Imports

```
#non-linear testing
nonlinearityTest(train.imp.ts)

##       ** Teraesvirta's neural network test  **
##       Null hypothesis: Linearity in "mean"
##       X-squared =  14.54697  df =  2  p-value =  0.0006936909
##
##       ** White neural network test  **
##       Null hypothesis: Linearity in "mean"
##       X-squared =  14.67384  df =  2  p-value =  0.0006510522
##
##       ** Keenan's one-degree test for nonlinearity  **
##       Null hypothesis: The time series follows some AR process
##       F-stat =  20.80022  p-value =  7.11869e-06
##
##       ** McLeod-Li test  **
##       Null hypothesis: The time series follows some ARIMA process
##       Maximum p-value =  0
##
##       ** Tsay's Test for nonlinearity **
##       Null hypothesis: The time series follows some AR process
##       F-stat =  110.6  p-value =  3.2e-15
##
##       ** Likelihood ratio test for threshold nonlinearity **
##       Null hypothesis: The time series follows some AR process
##       Alternativce hypothesis: The time series follows some TAR process
##       X-squared =  111.4864  p-value =  1.121134e-10
```

Nonlinearity - Exports

```
nonlinearityTest(train.exp.ts)

##       ** Teraesvirta's neural network test  **
##       Null hypothesis: Linearity in "mean"
##       X-squared =  39.29675  df =  2  p-value =  2.929673e-09
##
##       ** White neural network test  **
##       Null hypothesis: Linearity in "mean"
##       X-squared =  42.37493  df =  2  p-value =  6.286389e-10
##
##       ** Keenan's one-degree test for nonlinearity  **
##       Null hypothesis: The time series follows some AR process
##       F-stat =  6.013017  p-value =  0.01470146
##
##       ** McLeod-Li test  **
##       Null hypothesis: The time series follows some ARIMA process
##       Maximum p-value =  0
##
##       ** Tsay's Test for nonlinearity **
##       Null hypothesis: The time series follows some AR process
##       F-stat =  9.493  p-value =  1.722e-06
##
##       ** Likelihood ratio test for threshold nonlinearity **
##       Null hypothesis: The time series follows some AR process
##       Alternativce hypothesis: The time series follows some TAR process
##       X-squared =  62.49455  p-value =  0.002001879
```

Neural Network

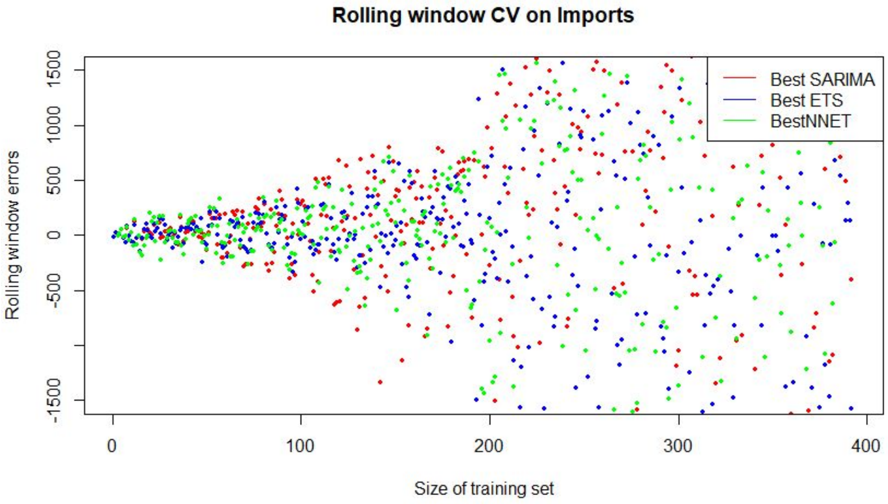
data	method	model	lambda	sigma**2	subset	mape	mase
import	neural	NNAR(4,1,3)[12]	N/A	1618448	train	7.23142	0.4292306
					test	8.17489	2.02708
import	neural	NNAR(1,1,2)[12]	0.1637399	0.1308	train	6.597035	0.5082465
					test	8.48026	2.0782421
export	neural	NNAR(1,1,2)[12]	N/A	195589	train	12.53733	0.5520151
					test	19.45795	3.5122214
export	neural	NNAR(2,1,2)[12]	0.220129	0.5041	train	11.04153	0.5366247
					test	16.06305	2.9532921

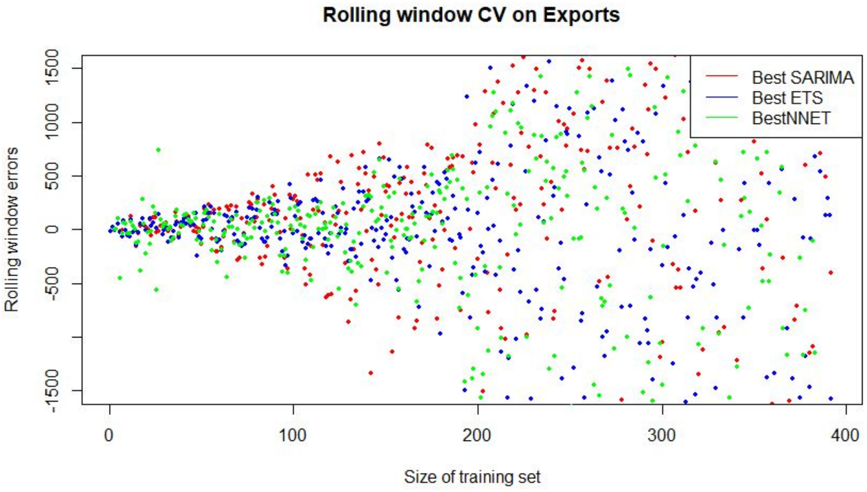
Bagged model

data	method	lambda	subset	mape	mase
import	bagged	N/A	train	5.215448	0.3438924
			test	8.673755	2.0504201
import	bagged	0.1637399	train	60220.0962	22417.894
			test	147209.9	62004.77
export	bagged	N/A	train	9.4366	0.4757732
			test	15.04068	2.7782196
export	bagged	0.220129	train	13916.27189	3543.666
			test	35757.59	10691.656

Rolling CV & Comparison of All Models

Rolling Window CV





Not our most important accuracy consideration - not focused too much on “tomorrow” in our time series.

Comparison of all models

data	method	model	lambda	sigma**2	subset	mape	mase	residuals
import	ets	M,Ad,M	N/A	0.0763	train	5.494712	0.3703234	dependent
					test	7.537235	1.763118	
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export	sarima	ARIMA(2,1,1)(2,0,0)[12] with drift	0.220129	0.4778	YES	train	10.81068	0.4775985	independent
						test	22.87962	4.1109044	

	data	method	model	lambda	sigma**2	subset	mape	mase
imports best nonlinear model->	import	neural	NNAR(4,1,3)[12]	N/A	1618448	train	7.23142	0.4292306
						test	8.17489	2.02708
	import	neural	NNAR(1,1,2)[12]	0.1637399	0.1308	train	6.597035	0.5082465
						test	8.48026	2.0782421
	export	neural	NNAR(1,1,2)[12]	N/A	195589	train	12.53733	0.5520151
						test	19.45795	3.5122214
	export	neural	NNAR(2,1,2)[12]	0.220129	0.5041	train	11.04153	0.5366247
						test	16.06305	2.9532921

	data	method	lambda	subset	mape	mase
	import	bagged	N/A	train	5.215448	0.3438924
				test	8.673755	2.0504201
	import	bagged	0.1637399	train	60220.0962	22417.894
				test	147209.9	62004.77
exports best nonlinear model->	export	bagged	N/A	train	9.4366	0.4757732
				test	15.04068	2.7782196
	export	bagged	0.220129	train	13916.27189	3543.666
				test	35757.59	10691.656

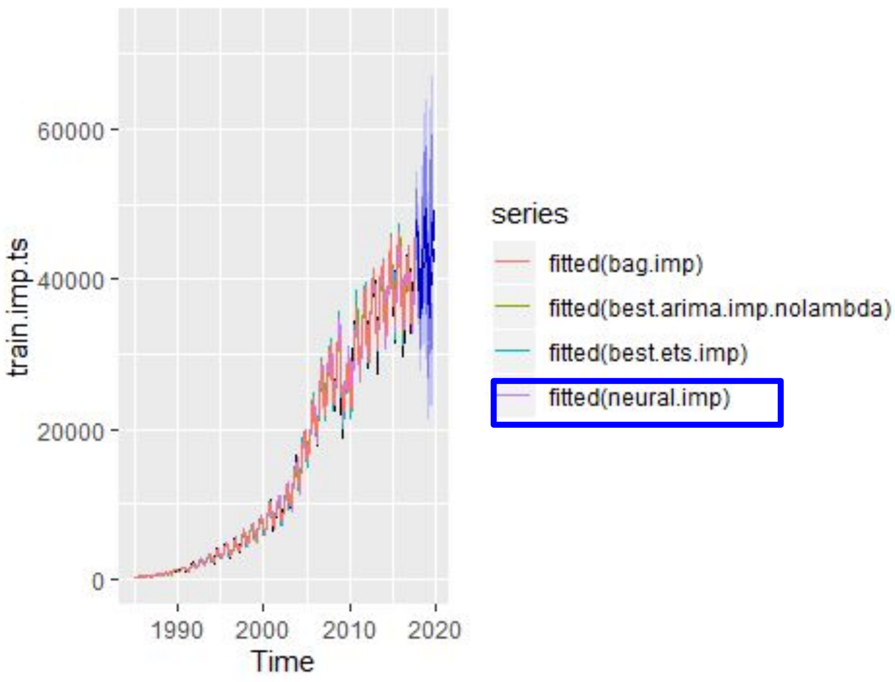
Linear models rules out with NL tests

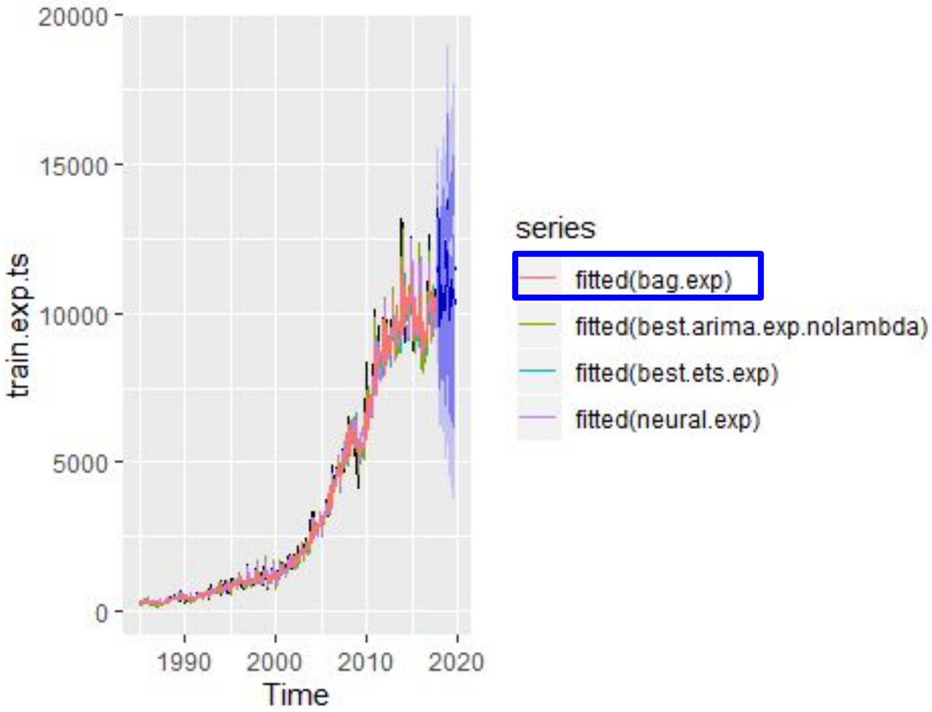
Imports:
NNAR(4,1,3)[12]
Sigma: 1,272.18

95% PI width = 4,986.95 million USD

Exports: Bagged (see MAPE and MASE)

Visual comparison



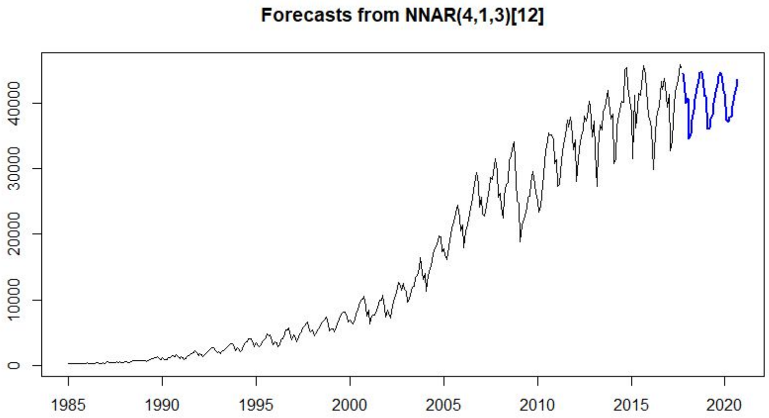


Prediction Patterns for winners

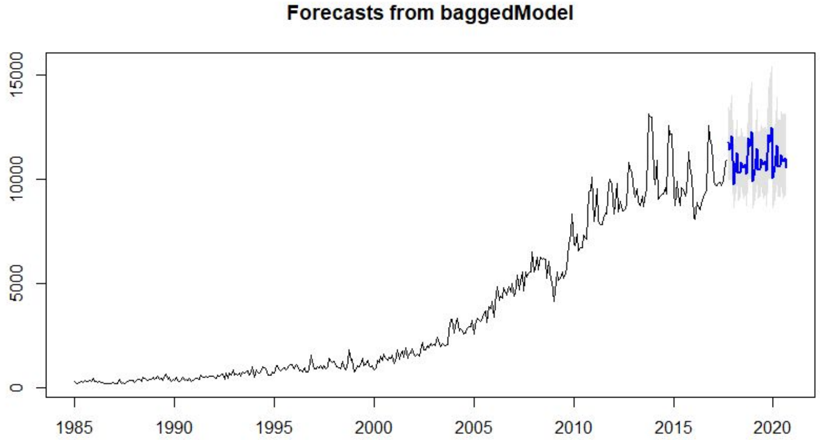
	Point Forecast	Lo 100	Hi 100
Sep 2020	10575.346	8713.885	12998.14

Forecasts:

Imports: NNET(4,1,3)[12]



Exports: Bagged Model



Export Bagging predictions: “Intervals are calculated as min and max values over the point forecasts from the models in the ensemble. I.e., the intervals are not prediction intervals, but give an indication of how different the forecasts within the ensemble are.” - https://rdrr.io/cran/forecast/man/forecast.baggedModel.html

Conclusions & Future Work

Conclusion

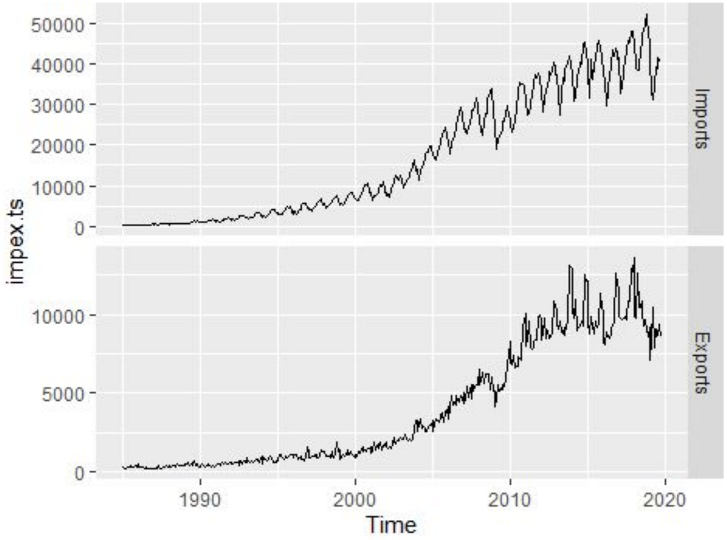
- Nonlinearity of data was a prime factor for us to select a neural network model for Chinese imports, and a bagged model for U.S. exports to China

- Changing relationship - non-stationary data. Relatively low entropy, though.

- Seasonality is consistent - Peaks late in each year.

Future Work

- Trade balance
- Looking at similar countries to see if model works for other bilateral relationships
- Adding in regressors - population, GDP, Median Income
- Check back in once the new tariffs have been in place for longer, see how it changes the models and overall trend strength.
- Seasonality - causes?



Questions?